High Speed Spinning of Polyester and Its Blends with Viscose

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A Practical Guide

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About the Author

Mr. Sharachchandra Yeshavant Nanal was born in Pune on 16th December 1932. His father, Y.M. Nanal, was the Principal of Maratha High School in Karachi. Therefore, Mr. S.Y. Nanal's schooling was in Karachi. After partition, the Nanal family shifted to Thane, near Mumbai. Mr. Nanal completed his B. Text, in First Class in 1955 from the Bombay University. He did his M. Text also from Bombay University in 1958. The subject of his Master's thesis was fibre friction.

His career has been in four areas in textiles: teaching and research, quality control and management in mills, technical services for polyester fibres, and consultation.

He spent first 11 years in the academic field as a Lecturer and Assistant Professor at the V.J. Technical Institute, and in BTRA (Bombay Textile Research Association).

The next 11 years saw him in textile mills. He worked as Head (Central Quality Control) in Mafatlal Group doing inter mill comparisons on technical subjects. Here, he developed a Point Rating System to quantify all fabric defects jointly with Mr. S. Maruthi. He presented a paper on this subject at the world's first international conference on Quality Control (ICQC 1969) in Tokyo in October 1969. Thereafter, he worked as a Mill Manager at Afprint Nigeria Ltd in Lagos, Nigeria.

The next 22 years were spent in Polyester Staple Fibre Industry as Technical Service Manager at Indian Organic Chemicals Ltd, Chennai; Swadeshi Polytex

Ltd at Ghaziabad; Reliance Industries Ltd, Mumbai and P.T. Polysindo Eka Perksa in Jakarta, Indonesia.

At the age of 67—in 1999—Mr. Nanal started to work as a free lance consultant in polyester fibre and blend spinning. He also marketed speciality polyester staple fibres from Saehan Industries Inc, Seoul, Korea. During these consultancies, he worked with Priyadarshini Spinning Mills to run their ring frames on 60s grey PV at 24 500 rpm and with Raymond Ltd, Chhindwara to run 33s and 50s fibre dyed PV at 22 000 rpm.

Mr. Nanal was awarded the fellowship of the Textile Institute, Manchester (FTI) in 1973; and in 1983, The Textile Association India honored him with an Honorary Fellowship of the Textile Association India. Mr. Nanal had written several technical articles and had presented numerous papers at conferences and seminars.

S.Y. Nanal died 17 days before the book release function and he couldn't see his book in print. He expired due to severe heart attack on 3rd December, 2008, just 13 days before his 76th birth day.

Foreword

India has always been known for its high productivity in spinning. When synthetic fibre spinning started a few decades back, the spindle speeds used to be low when compared with spindle speeds in cotton spinning. But the productivity of ring frames on synthetics was much higher than those of ring frames working on cotton on any count due to the lower twist multiplier used for synthetic spinning.

Of course, there were apprehensions that high spindle speeds could spoil the yarn quality. We cannot say that these fears were totally baseless. At the same time, just because the twist multiplier is low with synthetic spinning, it does not mean that these ring frames have to be run at low speeds.

When the ring frame is run at high spindle speed, there are certain factors which play an important role and help in determining the optimum speed. Machine condition, quality of spindles, rings and travelers; and breakage rate, increase in power consumption, etc are important factors. Of course, these factors vary from mill to mill and so whatever speed is achieved in one mill, may not be possible in other mills.

We at Priyadarshini believe in high speed spinning of polyester blends. So in the year 2000, we went in for 14 Lakshmi's LR 6 ring frames which are designed to run at a maximum spindle speed of 25 000 rpm. After we placed the order with LMW, I told my people that we are buying these high speed ring frames and I want them to be run as near to 25 000 rpm as is practically possible. I knew they had problems and I agreed with them to invite Mr. Nanal, the author of this book for help. I was happy when in 2001, all the 14 LR 6 ring frames ran at a maximum speed of 24 500 on 60s and

76s PV blends. I was really thrilled when Mr. Nanal told me that we were running these ring frames at the highest spindle speed in the whole world. And at that time — in 2001 — most blend spinning mills could not imagine spindle speeds higher than 18 000 rpm even in the wildest of their dreams.

We are convinced that high speed spinning of polyester blends is technically feasible and commercially viable. This will enable the managements of spinning mills to reduce the conversion cost to the lowest level and to be able to survive the worst market conditions — as they happen to be at present. The LR 6 ring frames are quite sturdy and we have had no breakdowns with them in the last 7 years, even when running them continuously at 24 500 rpm. I compliment my people for running these ring frames at these super high speeds with steady working for the last 7 years. I am aware of the daily checks and observations they carry out religiously day in and day out. We are running not only the LR 6 ring frames at high speeds, we are also running Chinese and other local ring frames at 22 000–23 000 rpm. We have achieved high values of grammes per spindle shift. In 30s 100% polyester, we get 300 g/ss; in 40s PV we obtain 200 g/ss. We have established since several years a culture of high speed spinning in our mills.

The author of this book was associated with synthetic fibres and synthetic yarn spinning industry for several decades and had extensively toured many countries. He was quite conversant with the intricacies of synthetic fibre spinning. The author, with his long experience, had dealt with many issues in high speed spinning technology. I am quite sure that the information and the recommendations given in this book will help the synthetic yarn manufacturers in a big way to achieve the best productivity in their mills. This book will go a long way to make the synthetic spinning mills in our country more competitive in the international market. I wish that all the synthetic spinning mills in India take full advantage of this book.

C. K. Rao
Priyadarshini Spinning Mills,
Hyderabad
November 2008

Preface

Early in 2000 AD, the two major manufacturers of ring frames in India—viz. Lakshmi Machine Works and Kirloskar Toyota Textile Machinery Manufacturers Ltd—offered their latest ring frames—LR6 and RXI 240 respectively to the Indian spinning industry. Both these ring frames are designed to run at spindle speeds of 25 000 rpm.

It was in 2001, that I got involved with high speed spinning of polyester blends when I worked with the technical team of Priyadarshini Spinning Mills, Hyderabad to run their 14 Lakshmi's LR 6 ring frames at a maximum speed of 24 500 rpm. Since then, I have worked with other mills to speed up their LR 6 ring frames.

Since then, several spinning mills have installed these ring frames. But currently most of them run these ring frames at the speed of 16 000–18 000 rpm under utilising them. Spinners, who use these ring frames, have several fears—that at speeds above 18 000 rpm, the traveler temperature could reach 290 °C—well above the melting point of polyester which is 260 °C; and could lead to fusion of protruding fibres creating dark spots in fabric on dyeing; that hairiness will be so high that it will be difficult to weave these yarns especially on an air jet loom; and that power cost will go up too high which will make spinning uneconomic.

However, some of the adventurous spinners, whose number may be about 8 or 10, are running these ring frames at spindle speeds ranging from 20 500 to 24 500 rpm on both grey and dyed fibre spinning. They have found—to their relief—that the fears expressed by other spinners were not true. No fusing of fibres was found while hairiness increased only marginally. The power cost did go up, but not as high as they feared. Making a success of high speed spinning involves several factors—right from selecting bales to be fed to the blow room to controlling U% and CV% of wrapping at finisher drawing, to ensuring almost zero breaks at roving. I have been personally involved in helping a few mills to run their ring frames at 22000–24500 rpm and so have built up a knowledge base on how to go about making a success of high speed spinning. This practical knowledge has a strong theoretical basis, Hence it can be applied successfully under varying industrial conditions. Therefore, I felt the urge to write this book as a practical guide to the spinners, not only of polyester viscose blends, but also of other fibres at the mechanically designed maximum spindle speed at ring frames.

This book includes four live case studies of spinning mills in India (Chapter 7) that are running their ring frames successfully on both grey and dyed fibre spinning at speeds varying from 20500 rpm to 24500 rpm. The book concludes by saluting the pioneers (Chapter 8) of 'High Speed Spinning of Polyester Blends', who had vision and took great risks to run their ring frames at real high speeds.

Since high speed spinning of polyester blends (Chapter1) is mostly an Indian phenomenon (Chapter 2), it is apposite that this book is written by an Indian and is produced in India. However, it charts out a path that a spinning mill any where in the world could take to run their ring frames at super high speeds. Right from blowroom till winding, one needs to ensure quality in such a way that at high ring frame speeds, end breaks at ring frame, vital yarn properties, and winding cuts remain more or less at the same level (Chapters 3 and 4) as obtained at slower ring frame speeds. The book examines economics of high-speed spinning (Chapter 5) and ends up predicting the future of high speed spinning technology (Chapter 6). The book would prove eminently useful to spinning mills, which buy modern high-speed ring frames, to run them successfully at speeds 20 500–24 500 rpm depending upon the count spun. By doing so, the spinning mill will ensure that their conversion cost is lowered substantially and the 'bottom line' is improved considerably.

It must be clarified here that this book could also be useful to all those mills that run their ring frames at speeds lower than the designed highest mechanical spindle speed, irrespective of the fibre material they process. To give an example: a spinning mill with Laksmi's G 5/1 ring frames runs them at say 16000 rpm for a PC blend or for 100% cotton in the range of 30–40s. This machine is designed to run at a maximum speed of 20000 rpm. If this spinning mill wants to speed up their G 5/1 frame to 20000 rpm, it will find ways to do so in this book. Of course, the norms of quality given in this book, which apply only to polyester and its blends with viscose, would need to be adapted to the material being processed. In fact, the financial returns from high speed spinning are so high that it is worth replacing the spindles, rings and the drive motors by high speed versions to raise the mechanically achievable upper limit of spindle speed. (Appendix 1)

The ideas given in this book can definitely be applied to high speed spinning of other fibre/blends such as polyester/cotton, viscose, cotton and others.

This book should prove eminently useful to:

- The top management of spinning mills who should compare the highest spindle speed at their ring frames with those employed by high speed spinners, look closely at the economics given and then check if their ring frames can be speeded up so as to increase substantially their mill's profits. Also if the mill does not posses high speed ring frames, then top management should take inspiration from RSWM Ltd. which runs their Lakshmi's G 5/1 ring frames at 22000 rpm against the designed speed of 20000 rpm in a very cost effective way as given in Chapter 7, and supported in Appendix 1.
- Senior spinning technologists can check if they can speed up their ring frames and make a success of high speed spinning as suggested in this book, so as to add to their unit's profits.
- Quality control heads who would need to help the production personnel in taking trials to finally reach the goal of high speed spinning
- Maintenance personnel will know what mechanical conditions of the machines are expected to make a success of high speed spinning and could plan their activities accordingly.
- Teachers in textile institutes would find this book useful to explain to their students the inter relations of various actions starting from fibre properties to breakage rates in ring spinning and winding. The way in which knowledge gained as different subjects gets used in controlling the processes will become clear to the students. A good study of the ides in this book will prepare them to become better technicians when they join the industry.

I hope that my efforts of putting the ideas used in consultation in a book form become fruitful, and all these groups use this book on a large scale and benefit from it.

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S. Y. Nanal

1

Concept of High Speed Spinning of Polyester Blends

The highest spindle speed at which a modern ring frame can work is 25 000 rpm. This high value of the mechanical limit to spindle speed was achieved by machinery makers about 15 years ago; and several manufacturers have delivered such machines in several countries including India. The limiting cause for this stagnation in the highest achievable speed could be that the ring/traveler friction becomes excessive at higher speeds, or the ring frame tenter finds it extremely difficult to manage a satisfactory piecing. Several other factors which, a mill technologist would not be expected to know or to understand, may also be responsible for this upper limit not increasing continuously over the years. But is this upper limit really restricting the Indian spinners at present in their efforts to increase productivity to the maximum? Not really.

Is high speed spinning of polyester blends practicable?

Many spinners have expressed several fears for running ring frames at higher than 18 000 rpm. Important among them are as follows:

(a) Possible fusing of protruding ends of the polyester staple fibre (PSF) due to coming in contact with traveler. The temperature at the traveler can go as high as 290 °C at very high spindle speeds, and the melting point of polyester is 260 °C. So, the protruding ends would fuse. On dyeing the fabric, the fused portions will take deeper colour leading to several dark spots in the fabric.

(b) The speed of yarn delivery from the front rollers would become so high that good piecing of ends after a break would become difficult; and the proportions of bad piecings will become too high for good working of the yarn in further processes like winding and weaving.

(c) The other worry is about the end breakage rate increasing steeply. At high levels of end breaks, the tenter would not be able to manage the higher workload and the frames under his care would get 'jammed' i.e. too many un-pieced ends leading to roller lapping and increase in suction clearer waste and consequent loss in productivity.

(d) Yarn hairiness would increase so much that weaving, particularly on air jet looms, would then be uneconomical due to very poor running efficiency of the looms.

(e) The traveler life would become as short as a few hours; apart from the increased costs, very frequent traveler changes would increase workload and would reduce the machine running time substantially.

(f) And finally, the power cost would go so high that spinning as a commercial operation would become uneconomic.

The combined effect of all these fears has been that no one wants to try out high speed spinning of polyester blends. But, are these fears real? Are they supported by technological logic or experiments?

Before we answer this question, we need to define 'high speed'. The Indian textile mills have grown gradually in the use of polyester fibres over the years starting from early 1960s, and the speeds have been gradually increasing from about 10000–18000 rpm by 2000 AD. Any number above which the spindle speed (in revolutions per minute) is to be considered as 'high speed' would, of necessity, be an arbitrary number. However, knowing that the maximum permissible speed is 25000 rpm, that the spindle speed is kept somewhat lower at the beginning of a doff than at the middle of the doff, and that most mills in India run their frames at not more than 18000 rpm as the maximum speed during the doff. We can consider any spindle speed above 20000 rpm used for regular yarn production on ring frames as high speed.

Only when the maximum speed of a ring frame spinning polyester blended yarns is 20000 rpm and above, only then should that spinning operation be termed as "*High Speed Spinning of Polyester Blends*". The average speed over the doff could be lower than 20000 rpm in some cases of high speed spinning.

Fortunately, India manufactures two models of modern ring frames—LR6 made by Lakshmi Machine Works and RXI 240 produced by Kirloskar Toyota Textile Machinery Manufacturers Limited. Both these frames are mechanically designed and engineered suitably to run at the maximum spindle speed of 25000 rpm. Several Indian spinning mills have bought these two models of ring frames in the last 7 years. However, many of these spinning mills run these frames at around the maximum speed in the range of 16000–18000 rpm, thereby under utilizing these expensive machines.

Fortunately again, some 8–10 adventurous spinners in India have tried high speed spinning, and are now successfully running their ring frames at maximum speeds of 20000 plus, ranging from 20500 to 24500 rpm. They have discovered through many trials and errors, and several well-planned experiments—to their immense relief—that no fusing of polyester fibres takes place and the end breaks can be controlled between 1 and 4 per 100 spindle hours. They found that the hairiness does go up marginally, and that their existing ring tenters could piece up broken ends without any extra strain due to the higher delivery speed of the yarn coming out of the front rollers. Though the power cost went up, the production in grammes per spindle shift (g/ss) did go up significantly. So, their conclusion is that high speed spinning of polyester blends is technically possible, since no real deterioration takes place in either spinning performance or in quality of spun yarns. And most importantly, high speed spinning of polyester blends turned out to be not only commercially viable but it also added to their mill's profitability in no small way.

But will, what worked in a few mills work also in all other mills? Can all mills really speed up their ring frames to their mechanical limits? This would be feasible only if the theoretical basis behind such attempts at increasing productivity at ring frames is sound.

Sound basis for speeding up

Let us consider the genuine fears faced by the conscientious spinners about the effect of higher spindle speeds at ring frames on yarn quality and on ring frame productivity. We will juxtapose the theoretical knowledge with the practical experience to check whether theory predicts the practical results, or whether the practical results obtained by a few spinners are coincidental, and their 'luck' cannot be reproduced elsewhere.

(a) Fibre fusion

The friction of the traveler rotating in contact with and around the ring at a rotational speed of 12000 rpm means that the traveler goes around the ring 200 times in a second. For a ring with diameter of 45 mm, the linear speed of the traveler works out to about 102 km/h. The metal to metal dry friction at this high linear speed along a circular path under the pressure exerted by the rotating yarn tension generates considerable heat. (Braecker have found that part of the spin finish on the fibre does go onto the ring and so the ring traveler friction cannot be strictly called dry). We all are familiar with the phenomenon of traveler burning which occurs due to the heat generated by this friction. The steel wire of the traveler turns brown first and then gradually turns blue; the temperatures corresponding to this colouration of steel alloys used to make travelers are in the range of 240–360 °C respectively. Travelers that have turned blue continue to be used for spinning of yarn until either they break owing to wear or get replaced as scheduled after several more days in service. As a rough estimate, about 20–30% of travelers are blue at the time of replacement. And we also know that the melting temperature of polyester is 260 °C. Therefore, the fear that the heat-sensitive polyester fibres may melt i.e. fuse, and still remain on the yarn surface is very real.

Implicit in the above thinking on high temperature leading to fibre fusion is a simple assumption, namely, the yarn passing through the traveler will come in contact with the very hot surface at the traveler. Does it really? Let us see how the yarn passes through the traveler at the ring.

Figure 1a shows the path of the yarn being twisted as it comes out of the front pair of drafting rollers, goes through the lappet hook placed centrally above the ring, and then through the traveler on to the bobbin mounted on the spindle.

Figure 1b shows the cross section of the flange of the ring and the way in which the traveler sits on it. The two ends 1 and 4 of the elliptically shaped traveler remain free from contact with the ring. The friction between the ring and the traveler occurs at the contact point 2, which is somewhat away from the point where the passing yarn touches the traveler at point 3. So, the question is to be now phrased somewhat differently. Will the heat generated just a few millimeters away at the contact point 2 traveler up to the yarn point 3? To answer this question, we need to know about conductivity of steel.

Figure 2 shows the heat distribution along the length of the traveler schematically.

The conductivity of steel is so poor that the entire spread of heat occupies only a millimeter or two along the length of the traveler. The highest temperature reached due to friction with the ring does not even reach the end 1, which is quite near the contact point 2.

This can be verified in practice very simply. At the time of traveler change, collect about 100 travelers carefully without letting them break during removal. Separate a few travelers that have turned blue and few others that may still be only brown. Examine the ends of near the blue portion of the traveler. You will find that on most of these travelers the end is quite normal—no browning or bluing has occurred. (If some ends are

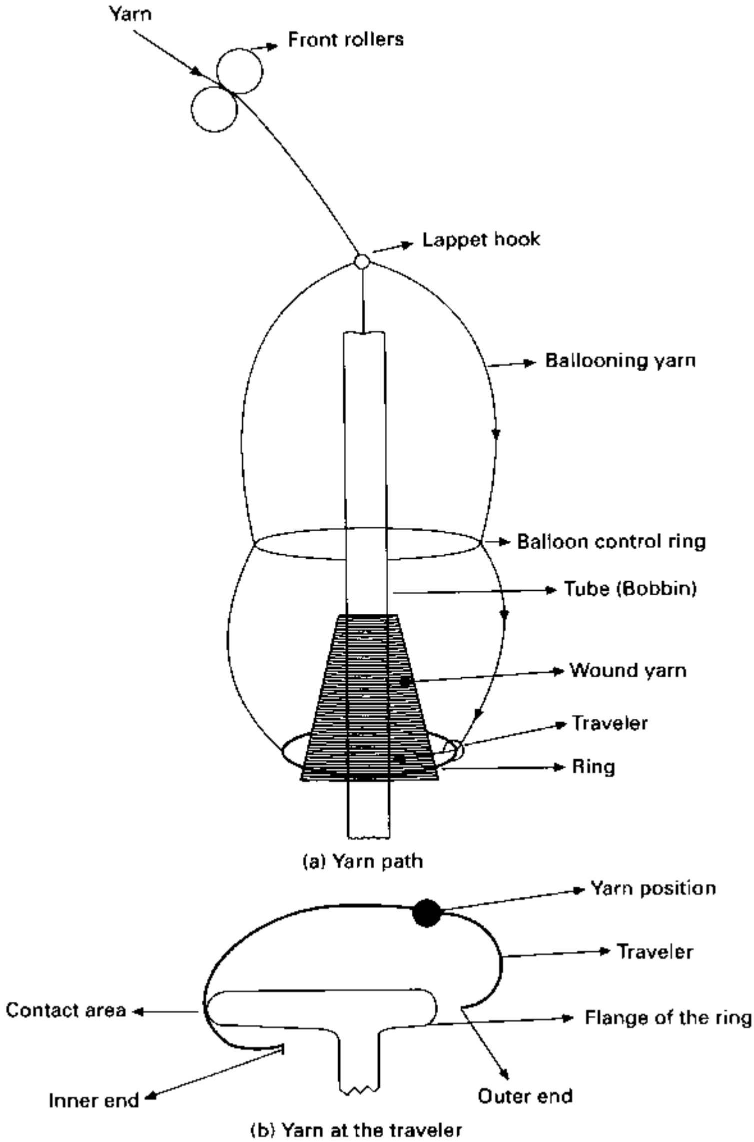

Figure 1: Yarn passage at ring frame

found blue, then that end 1 must have been in contact with the ring either continuously or intermittently. Such faulty runs do occur rarely).

So if the end near the blue spot does not receive any troublesome conducted heat, how can the point of yarn contact 3 get any heat at all? That this point 3 is also of normal colouration can also be confirmed by

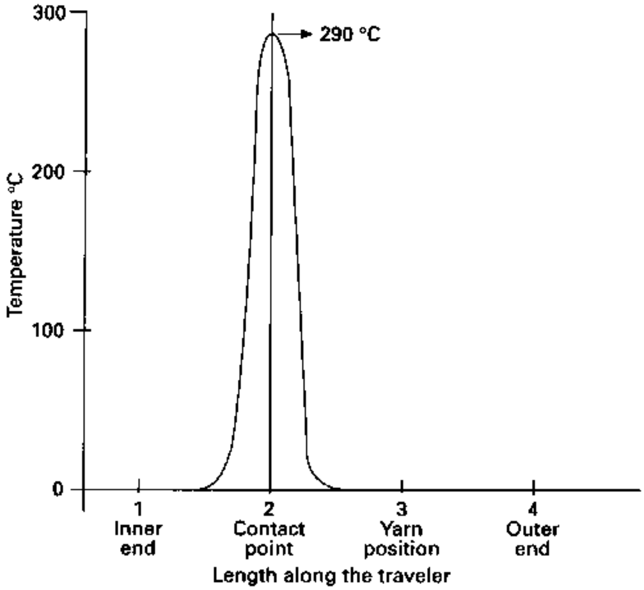

Figure 2: Heat distribution on traveler

observation. Without exception, the point 3 will be found to have the normal colour of the traveler. This portion may shine due to frictional contact with running yarn and may also be observed to have been worn down due to yarn friction. But this portion would never show even the brown colour, leave aside the blue colour which is indicative of the highest temperature that can occur on the traveler.

Thus we can see that fibre fusion—the melting of polyester staple fibre ends projecting from the surface of the yarn due to high temperature on the traveler—is next to impossible. Fibre fusion does not take place at spindle speed of 12000 rpm even though the travelers turn blue. It cannot take place even at 25000 rpm even if a much greater proportion of travelers turn blue in the same running period (of say 7 days).

(b) Speed at piecing

Piecing a broken end on a ring frame is indeed a skilled job. Only those individuals with good finger dexterity combined with good eye-hand coordination last as tenters. The piecing operation consists of 4 major elements.

- Stopping the rotating spindle (bobbin)
- Locating the broken yarn end on the surface of the yarn package and picking it up by fingers.

- Threading that end through the traveler and taking it up to the front roller nip.
- Joining the yarn end with the untwisted strand coming out from the nip of the front rollers (and going into the suction clearer duct).

Piecing is the main job element of ring frame tenters. When the spindle speeds become very high, the first reaction of the ring frame tenters is about the difficulty in stopping. A little hesitation in gripping the rotating bobbin can singe the skin of fingers or palm due to frictional heat. A quick grasp avoids such singeing, which can take place even at spindle speeds of 10 000 rpm. Tenters are known to have complained of singeing problem when going from 10000 rpm to 16000 rpm also. This problem does not really exist for any skilled worker (or even for a semi-skilled supervisor working as a tenter). Even so, spindle brakes that can be activated using the knee have been developed long ago and are standard equipment on modern ring frames. 'Knee brakes' not only avoid singeing of hand, but also keep both hands free for piecing. The fourth operation of joining the bobbin end with the drafted fleece near the front roller nip is normally done at delivery speeds of about 20 m/min at 12000 rpm. The time available for laying an overlap of about 1 cm is of the order of three hundred of a second (0.03 s). At 24000 rpm, this time reduces to half this value, namely, 0.015 s. Even the value of 0.03 s looks impossible to manage manually. But as everyone who has tried to learn piecing at the ring frame knows by experience that the piecing 'takes place' by itself quite quickly and easily. Almost the same thing happens when the time needed is much smaller.

Tenters, rarely, if ever have complained about the difficulty of piecing broken ends at high speeds. The number of attempts to manage a piecing also does not increase to any significant extent at the higher spindle speeds, nor does the proportion of bad piecings increase. Well trained workers who can manage the total operation of piecing in about 6–7 s continue to manage the same number irrespective of the spindle speed.

(c) End breakage rate

Every spinner finds it necessary to control the end breakage rate at a 'manageable' level and this level is not a technical decision. The right or the optimum level of end breakage rate is decided by several factors acting together in diverse directions.

- The end breakage rate should be low enough to permit high spindle allocation so as to keep labour cost low.
- If kept at very low level, then the spindle productivity in grammes per spindleshift gets restricted because the higher the spindle speed, the higher are the breakage rates.

- The spindle allocation to the tenter should be such, that given the end breakage rate, the suction clearer waste should not be more than 1.5%.
- The better the yarn quality the fewer are the end breaks; but producing very high quality yarns would require expensive raw material and many controls on the process, making that quality level possibly non-profitable.
- The mechanical condition of the ring frame also affects the breakage rate; the cost of excellent maintenance can be very high compared to the advantage gained from the lower breakage rate.

Let us consider the relationships between the spindle allocation, work load of the tenter, suction clearer waste and the end breakage rates at the ring frame. The proper workload is 85%, the optimum suction clearer waste is 1.5% and the normal piecing time is 8 s (assumed on the higher side of the good value of 6 s)

Then,

$$\text{Effective permissible end breaks/100 spindle hours} = \frac{125}{n} - \frac{30}{\sqrt{c}}$$

where n = number of ring frame sides of 220 spindles attended by a tenter and c is the yarn count Ne.

$$\text{Effective breaks} = \text{Normal breaks} + 3 \times \text{roller lopping breaks}$$

Since clearing a roller lapping and then piecing a broken end requires about 24 s instead of normal 8 s.

Using this formula, we can decide the permissible breakage rate for the given allocation or decide the allocation for given breakage rate.

Consider a mill spinning 36 Ne polyester-viscose yarn with allocation of 2000 spindles per tenter. Assume further, that 1 in 10 end breaks results in a lapping.

The permissible effective breakage rate is then

$$b = \frac{125}{8} - \frac{30}{\sqrt{36}} = 15.5 - 5 = 10.5$$

This means that the actual breakage rate is about 8 breaks per 100 spindle hours, of which, 1 break is with lapping.

But most mills work their ring frames with total breaks of 2–4 per 100 spindle hours. This means that their tenters are not loaded up to 85%. In fact, in most mills, the tenters' work load is found to be around 60%.

Therefore, the first conclusion about end breakages is about how many more breaks per 100 spindle hours the mill can tolerate without any adverse effect on management of ring frames by the tenter.

Consider the next yarn quality; the characteristics of yarn found worth including in the prediction equation were: lea count strength product (CSP), yarn count (Ne), CV% of lea count (V), yarn unevenness % (U), thin places/1000 m (at 50%) and thick places per 1000 m (at 3), and of course the spindle speed (rpm), spindle lift (L) and the front roller speed (FRS).

Let B denote the end breakage rate per 100 spindle hours, where only the single breaks at spindle position are counted (without including the multiple breaks due to lashing or breaks due to traveler flying etc). These are termed as 'spindle breaks'.

Spindle breaks/100 spindle hours =

$$\left\{\left(\frac{S}{1{,}20{,}000}\right)^{R} + \exp\frac{(\sqrt{\text{thick}/10})}{600}\right\} \times \text{FRS} \times 60$$

where S = spindle speed in rpm, thick = thick places (3)/100 km and FRS in front rollers speed and

$$R = \left(\frac{1}{\left[0.03b, \log(6+10) + 0.056\left(\frac{L}{25.4}+2\right)\right]^{2}}\right)$$

$$\times \exp\left[\left(\frac{M}{3400}\right)^{2} - \frac{\sqrt{\text{thin}}}{70} - \frac{U}{110}\right]$$

where again,

$$M = \frac{csp - 0.54 \times V^{1.5} \times C}{1 + (0.03\,V1.5)}$$

This relationship is indeed awfully complex; but it predicts the end breakage rate correctly in over 85% of the cases with an error of only ±1 or 2 breaks per 100 spindle hours. Fortunately, we do not need to use this relationship and not to do any computations at all.

What we need to understand is the nature of relationship between yarn quality, spindle speed and end breakage rate shown in Figure 3.

Obviously, this graph is a representative but true version of what happens in mill situations.

For a very good yarn, a given increase in spindle speed increases the breakage rate only marginally; but increases much more for lower quality of yarns. Most spinners know this from their experience. When the count is fine, the breakage rates for a given spindle speed are lower than for medium counts. Again, experience tells us the same thing.

This equation for predicting end breaks was developed for cotton yarns;

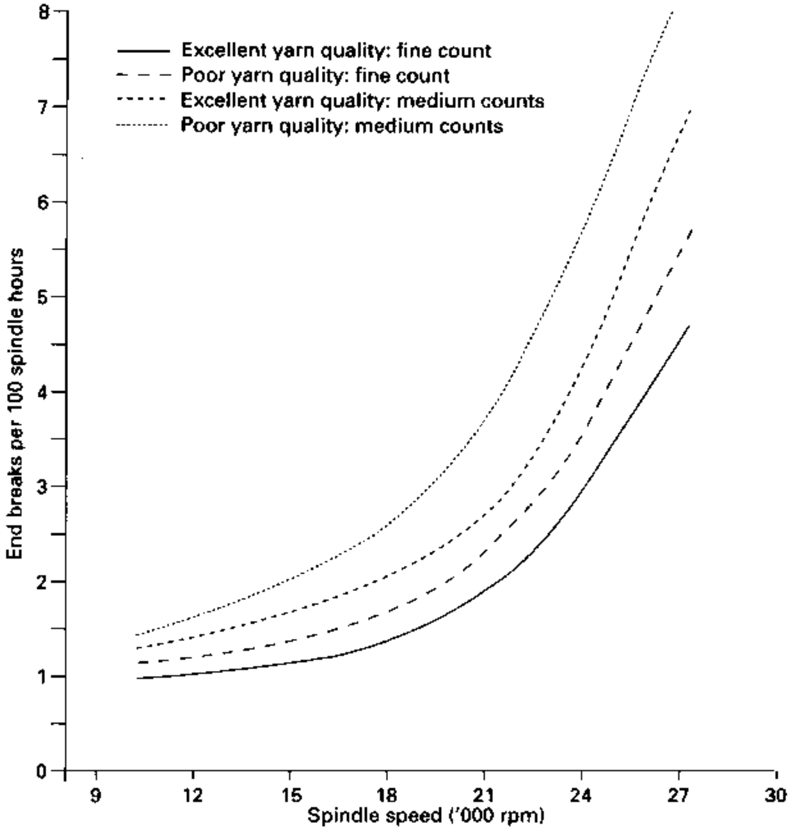

Figure 3: Dependence of end breaks on spindle speed

will it apply also to polyester and polyester blended yarns? The answer is YES and NO. Yes, it will apply in principle—the nature of equation would remain the same, but the constants would change. No, if used as it is, the constants would not be appropriate to predict accurately the breakage rates for polyester blended yarns.

In other words, the nature of the graph will remain the same; and mill experience with polyester blends also confirm these trends seen in Figure 3.

Therefore, the conclusion is simple; if we want to increase the spindle speed to high levels, we must ensure that the yarn quality parameters are at excellent levels. The better the yarn quality, the higher is the achievable spindle speed at the desired level of end breakage rate.

The yarn quality parameters to be controlled are the strength and the variability of yarn thickness over different lengths.

Given excellent yarn quality, the fear that high speed spinning would lead to unmanageably high end breakage rates is ill founded. No such disaster will occur in mill practice.

We know that the end breakage rate depends heavily on the machine conditions. Does the above formula take care of that also? Yes, another improved version takes account of machine condition P, which is 1 for a ring frame in excellent condition and can go down to 0.8 or so for 15-year-old machines with poor condition of rings and spindles etc.

Just as the inferior yarn quality shows higher breakage rates, the ring frames in poor mechanical condition will also give more end breaks at any given spindle speed. As the spindle speed increases, the end breakage rate will increase much faster on the ring frames in poor mechanical condition than on those in excellent conditions.

(d) Traveler life

The heart of high speed spinning is the traveler and ring combination. The quality of the traveler and that of the ring cannot be assessed by instrumental testing of characteristics of these vital elements of spinning technology. Of course, the manufacturers of rings and of travelers know which properties to test and to control at optimum levels during production, starting right from selecting the composition of the metal to be used. The spinning industry the world over knows that they are doing it right, since very high speed spinning is successful in many mills. But the fact remains that all the tested characteristics of a traveler put together do not help in predicting traveler performance or life, nor do tested characteristics of rings help in predicting the ring performance or life. Here, performance denotes mainly the resultant end breakage rate and life refers to the time period for which the ring or the traveler can be considered serviceable. Therefore, given the state of technology and research & developments as in 2008 AD, the only way to assess the performance of rings and travelers is to take practical trials over long periods on at least one ring frame (at least about 400 spindles).

New rings need some 'running-in' to 'smoothen' the traveler path around it; just like new automobiles need to smoothen the working of the new pistons in the new cylinders. This smoothening is best done at relatively lower speeds. Technology and engineering developments have reduced considerably the time required for running-in of rings and also of travelers.

New travelers need running-in: a fact which is also known to mill technicians. When the count changes on a ring frame, the different traveler number (weight) that needs to be used must be run-in before this traveler number starts giving the minimum number of end breaks possible with its use for the new count of yarn. Similarly, when the spindle speed is increased by more than about 5%, the track made by the traveler on the ring also shifts somewhat, even if the traveler count is not changed. Therefore, some running-in is needed.

A good measure of the need for running-in of rings is the percentage of travelers that get burnt during the first running for just one shift 8 h. Burnt travelers are those which show blue colour at the contact point with the ring. Brown coloured travelers are termed half-burnt. If this percentage is over 60% or so, considerably more running-in of the ring is needed. If the percentage is less than 5–6% the rings are well run-in, and the traveler track smooth enough. Spinners in most mills are aware of these facts and therefore use a running in procedure for brand new set of rings on the following lines:

- Run the ring frame at about 20% lower speed than normal.
- Change traveler every shift for 3–4 shifts.
- Increase the interval between changes to about 3 days, for 3–4 changes, and then stabilise at about 7 or 10 days as standard interval.

This procedure normally serves the purpose of keeping the average end breakage rate on the ring frame nearly the same over the service life of, say, 10 days of the traveler. However, the spinners interested in high speed spinning need to do something more. They need to assess the running quality of the traveler in terms of its possible impact on end breakage rate and also on yarn hairiness (please see the next sub-heading for more on controlling hairiness). A measure that comes nearest to the prediction of end breakage rate is the percentage of burnt travelers. It is a general experience that when the percentage of burnt travelers reaches about 30%, it is better to change the traveler. Waiting till this proportion goes over 50% or even up to 80% may show poor results by way of increase in the breakage rate or in the hairiness of yarn.

Why do burnt travelers result in more end breaks and higher hairiness in the first place? This is because the tempering of the traveler i.e. the hardening treatment given to travelers by heating and quick cooling gets destroyed. Secondly, the traveler starts wobbling during the rotation around the ring. This happens also because of the wear brought in by its contact with the ring. In cases where this becomes excessive one can literally hear the 'traveler chatter'. Thirdly, the wear of traveler due to contact with the running yarn can create sharp edges that abrade the yarn, making it more hairy and more prone to break. These effects are small and occur only on in an unknown and not easily assessable fraction of the semi-burnt and burnt travelers. Let us take an illustration: burnt travelers are 50% and half of these give rise to 30% higher end breakage rate. Assume that the average breakage rate is 3 per 100 spindle hours. It would increase by $3 \times 0.25 - 0.3 = 0.2$. It is rather difficult to detect an increase of average end breakages from level of 3.0–3.2. Therefore, it is better to err on the safer side and set the traveler change cycle by permitting about 30% of travelers to get burnt. This life span is then the right or the optimum service life of the traveler for all practical purposes. It is possible to increase this average percentage of burnt travelers at replacement up to even 60%; if—and only if—consistent testing of end breaks and hairiness show no deterioration. This can be tested by collecting yarn from the first day of the traveler cycle and comparing the quality with the sample collected from the day on which 60% burnt travelers are noticed.

If deciding upon the right change cycle for a traveler is so difficult and so vogue or approximate, the decision on the service life of a ring is even more so. No amount of testing by instruments nor visual observation and assessment of wear can help us decide whether a particular ring will result in end breakages at the normal good rate or at much higher rates. And again, what percentage of 'bad' rings in terms of increased end breaks and/or increased yarns hairiness can we tolerate? Here, we do not have the option of testing yarn quality or end breakage rate on the same rings as new and old (say 1–3 years), unlike in the case of travelers where the back material remains the same over its life cycle of a few days.

Fortunately, research at ATIRA, has shown that the behaviour of 'good' and 'bad' rings—i.e. the entire set of rings on one ring frame considered together—is exactly like the behaviour of 'good' and 'bad' yarns in Figure 3. If the spindle speed in increased on 'good' (new but well-run-in) rings, the end breakage rate increases very slowly with increasing speed. But on 'bad' rings whose service life is over (say after 3–4 years of use), the increase in end breakage rate is much more.

In any trial or experiment to verify this type of behaviour of old rings and new rings when working at high spindle speeds, three precautions must be observed:

- The lower spindle speed to be chosen needs to be at least 10%, preferably 20% less, to make the possible difference in the breakage rate (and also in the yarn hairiness) detectable easily.
- The travelers—whether of the same number or changed (usually of lower weight for the lower spindle speed) number—need to be run-in well before the study for observing the end breakage rates is conducted.
- It is desirable to install a set of new rings on one side of the experimental ring frame where rings are, say, 3 years old. The new rings should be run-in properly at the lower sped till the traveler burning rate becomes almost as low as normal. Then the end breakage rates would be seen to be nearly equal on both the sides (at the lower spindle speed.)
- Travelers need to be run-in again on the new rings when the normal higher spindle speed is tried out. When the percentage burnt travelers is between 20% and 30% at the higher speed on the new rings, the observations on breakage rates can be taken.

If the old rings are found to give 25% more average breakage rate then the normal 4, based on observations over at least 2 doffs (more than 2000 spindle hours), they need to be replaced. Then the life cycle can be considered to be of 3 years for this count at the working higher spindle speed.

Since the average breakage rate is to be controlled around the desired level of around 4 per 100 spindle hours, the rings need faster replacement when high speed spinning (spindle speed greater than 20000 rpm) is implemented.

This discussion on the behaviour of rings and travelers in the context of our need to control the end breakage rate and the hairiness of yarn brings out four imperatives for ensuring success of high speed spinning. Those spinners who opt for high speed spinning must:

- Choose the right combination of ring and traveler that gives the least end breakages rate. Many trials over long periods would be needed or substantial time period of experience would be needed to decide upon the right combination. And the right combination is the one that gives a breakage rate of about 4 at over 20000 rpm over the life cycle of traveler.
- Select the right traveler count that gives the least end breakage rate at the required high spindle speed. First check that the balloon control rings (BCRs) are positioned at beginning of the doff in such a way that their distance from ring rail is 4 compared to their distance from lappet hook as 5, i.e., the BCRs are set a little below the middle position. Then the optimum traveler count is that which gives some constriction to the ballooning yarn at the shoulder portion of the yarn traverse at the beginning of the doff. If the traveler is too light, the ballooning yarn will bulge out and lash against the balloon separates; but it is too heavy and the ballooning yarn will not get restricted at all at the BCR.
- Ensure that the traveler change cycle is decided upon based on percent burnt travelers.
- Ensure that 'old' rings are replaced by 'new' in good time.

(e) Yarn hairiness

Does yarn hairiness really increase with increasing spindle speed? Given the information from (a) and (b) about the position of the yarn in the traveler and the smoothness of traveler surface, there seems to be no theoretical reason to expect such increase. The little tendency towards more hairiness because of the increased linear speed of yarn is offset by the increase in yarn tension that would make the yarn a little more compact and so less prone to hairiness. While this is so far most yarn constructions, the conditions are different when polyester with 51 mm fibre length is used to increase productivity, since the longer staple can give the required tenacity of lower twist levels (hence higher front roller speed and corresponding increase in g/ss.) The effect is doubly troublesome: the use of longer staple results in longer protruding ends from the yarn surface, and the lower twist level makes the yarn more prone to abrasion. Hairiness of such yarns is not only higher at the ring frame but also increases more at the next process of winding. Therefore, mills using 51 mm polyester can go for high speed spinning only if the end use is for doubled yarns.

Is the hairiness of yarn a desirable quality or an undesirable characteristic? Is hairiness a disadvantage, an unwanted feature or is it immaterial, i.e. of no consequence either way? The answer is not a simple 'yes' or 'no'; the desirability or otherwise of hairiness depends upon the end use for which the yarn is to be used.

- High hairiness is undesirable for
  - hosiery: circular or warp knitting
  - use as warp or weft on airjet looms
  - shirting and dress materials
- High hairiness is desirable for
  - knitted or woven fabrics with good thermal insulation.
  - soft, raised fabrics
- Hairiness is immaterial when the ring span yarns are doubled or plied more than two fold for different purposes such as
  - use in suitings as warp and weft
  - industrially needed ply yarns.

Doubling of single yarns suppresses the hairiness to a great extent, like simple doublings of two reduces the imperfections by over 80%.

Let us consider a case where high level of hairiness is undesirable. Where hairiness is undesirable, it is because of two distinct reasons: it increases end breakages on the looms and reduces thereby the productivity; it results into formation of pills on the fabric surface after prolonged use by the wearer and thereby spoils the appearance. (In fabrics like denim, high hairiness can cause shade variations.)

So, the mills wanting to opt for high speed spinning need to be concerned about yarn hairiness only if it is undesirable, and this can differ from count to count in the same mill.

It often appears in mill practice that the yarn becomes more hairy after the spindle speed is increased. Correct choice of traveler type and count, combined with the right frequency of traveler replacement together help to avoid such an increase.

But one thing is clear: conditions that aggravate hairiness may exist at the 'border line' level at the low spindle speed being worked. When the spindle speed is increased, these potential troubles start becoming active and cause the hairiness to increase.

Another important matter about hairiness is the limitation of the validity of instrumental measurements available at present. Let us look at the measurement first and then at the factors leading to increase in hairiness.

The capacitive measurement of hairiness is basically an indirect assessment; it is consistent but somewhat gross. It can be used confidently to detect large differences. The photoelectric counting of producing fibres at different distances from the surface of the yarn is a direct measure and is a more reliable assessment. Measurements done by either kind of instrument shows that the variability of hairiness values within bobbins and between bobbins is high. Coefficient of variation (CV%) of hairiness index ranges between 20% and 30%. Therefore, care should be taken to take a good representative sample from at least 20 bobbins at 3 different places corresponding to beginning, middle and end of doff. Average values of two different samples—like at spindle speeds of 18000 and 24000 rpm—based on such 40 readings are really different only if the higher value is 25% more than the lower value of hairiness index that usually ranges from 2 to 6. Otherwise, the observed difference is only due to sampling variability.

When the difference is found real and the high speed yarn turns out to be more hairy, it is desirable to cross check by visual observation. But any visual observation by any observer can be biased: in fact, it is invariably biased. Those who feel that the higher spindle speed cannot really increase hairiness will see no difference, while a salesman who has to market this yarn will see a big and 'obvious' increase in hairiness. This kind of bias is a natural human phenomenon. A procedure to eliminate human bias and to come to reliable conclusion is given below. This procedure has been used successfully in mills over several years.

Prepare 10 pairs of black boards of yarn wrapped around it with distance between successive wraps equal to two times the diameter of the yarn. Each pair should contain 1 board from the lower speed and 1 board from the higher speed.

- Number the boards from 1 to 20, whereby each pair 12, 34, 56 to 19, 20 has either the odd or the even number as high speed yarn. The odd numbers are allotted at random and are to be kept confidential.
- Ask at least 6 persons, says 2 each from spinning department, sales and marketing, and management to judge each pair and to record their result as 'More Hairy: board numbers 1,4,6,7 etc'. Each observer judges there 10 pairs independently, without knowing the classification done by any other observer. Each must say that yarn on one of the pair boards is more hairy. No freedom is given to say "Both are equally hairy".
- Decode all the 60 results and find out how many results show the high

speed yarn as more hairy. Let this number be A and the number for low speed yarn more hairy will be B (= 60 – A).

- Use the formula $\frac{(A-B)^2}{A+B} > 4$ to conclude whether the high speed yarn is really more. If the value of $\frac{(A-B)^2}{A+B}$ is substantially higher than 4, then the difference in hairiness is so visible that every one will notice it. If the value is less than 3, the likelihood of the difference being real is very small, not withstanding the fact that instrumental readings have shown some difference.

The mechanical conditions on the ring frame that aggravates hairiness are essentially rough surfaces in the path of the yarn from front roller nip to the bobbin.

- Wire of the lappet guide
- Wire of the balloon control ring
- Wire of the traveler
- Surface of the ring flange

Besides this, eccentric centering of spindles within the ring causes large increases in hairiness at different positions of the ring rail over chase and over doff.

All these items occur at random on different spindle positions, leading to 'defective' i.e. much more hairy yarn bobbins. Good machinery maintenance is the only way to ensure good control on yarn hairiness. On ring frames with such defective spindles, high speed spinning can lead to an increased average level of hairiness.

In conclusion, mills which want to go for high speed spinning must ensure that

- Hairiness is controlled based on the need as decided by the end use.
- Condition of the parts in the path of the yarn and spindle centering is excellent.
- The instrumental test results on hairiness are visually confirmed by the paired comparison test.

(f) Power cost

About 60% of the power consumption of a spinning mill is at the ring frames, and the power cost is about 8% of sales. And power consumption at the ring frames is mainly because of the spindles and bobbins rotating at high speeds with ballooning yarns under tension. The spindle power constitutes about 70% of the ring frame power. We also know that the power consumption of spindle assembly varies with the square of the spindle speed.

Let us consider the increase in power consumption when the spindle is increased by 20%. The spindle power will be higher given by the multiplier $(1.2)^2 = 1.44$ by 44%. The ring frame power will increase by 44% of 70% i.e. by 30.8%, and the total power therefore will increase by 60% of 30.8% i.e. by 18.48%. Therefore, the profits will reduce by 8% of 18.48% i.e. 1.5% of sales. This is a substantial reduction in an industry where the average profitability is about 4% of sales.

As against this extra cost that decreases the profit, the gain in productivity is 20%. The contribution rate for polyester blends is usually around 30% (contribution = sales price – variable costs). Therefore, when the sales increase by 20%, the contribution increases also by 20% and the gain in profit is 20% of 30% i.e. 6.0%.

So, the net effect on profits is an increase of 4.5% as percentage of sales. Since the profitability is about 3% of sales at the slower speed, it would become more than doubled with high speed spinning. This simple method helps us to reach at least one conclusion with confidence—namely, the gains from productivity at ring frames are much more than the increase in power cost when going in for high speed spinning.

In short, theoretical considerations, practical experience based on use of technological thinking, and use of available quantitative information put together shows us that all the six fears normally expressed about high speed spinning are undue fears. *Such fears should not hold back the technical and managerial staff of spinning mills from attempting high speed spinning on a large scale on all ring frames. And this is true not only for yarns from manmade fibres, but also for yarns from natural fibres like cotton and wool.*

These considerations show that spinning of polyester and blends at the highest workable spindle speed is technically quite feasible, and the fears usually experienced by mill technicians are unfounded. The fact that the power cost increase is unlikely to be too large to make the higher speeds economically unviable is also reassuring. It is necessary to look at the economics of high speed spinning carefully before recommending it as a goal to all spinning mills.

Higher profitability

A higher spindle speed invariably leads to a higher production in g/ss since the possible reduction due to increased suction clearer waste and the reduced machine efficiency owing to more number of doffs is only about 1% when the speed increase is about 10%. Therefore, every increase in spindle speed invariably reduces the conversion cost of yarn, i.e. the cost of converting fibres into spun yarns. Today, the average or typical value in the yarn market for the conversion rate in rupees per kilogram is given by the expression: 0.8 × yarn count Ne. For illustration: for spinning 30s 100% polyester, the conversion rate would be 0.8 × 30 = Rs 24 per kg. This is what some one who gets his fibre converted to yarn would need to pay the contracted spinning mill. This rate would have some minor profit for the spinning mill included in it. Assuming the profit, at about 2% of sales, would be about Rs. 2 per kg, the mill's own conversion cost would be Rs. 22 per kg or 0.733 × Count. High speed spinning will bring down this conversion cost to about 0.67 – 0.70 × Count depending upon the amount of increase in production; i.e., will reduce this cost by Rs 2 or 3 per kg. This saving is the increase in profitability with high speed spinning.

Let us take a concrete example. A spinning mill of 25 000 spindles is able to improve its productivity by 22% by running ring frames that much faster. This mill produces 30s 100% polyester yarn and had the productivity of 240 g/ss before the speed increase. Now, with the increase in ring frame speed, they get 295 g/ss shift i.e., an additional 45 g/ss i.e., 135 g per spindle day, or 3375 kg/day. Thus, if the mill had not speeded up their ring frames, then it would need 4688 additional spindles to produce this additional quantity. Today it costs Rs 20 000 per spindle to set up a new spinning mill up to spindle point. So, the cost of putting up 4688 additional spindles would be Rs 93.75 millions of capital expenditure. Add to this the other costs of interest on capital till the repayment of loans is complete. Also add the cost of additional building and workers. These entire additional costs equivalent to capital expenditure of about Rs 100 millions are avoided by going over to high speed spinning.

Therefore it is quite logical—technically feasible and economically profitable—to run ring frames designed to run at spindle speed of 25 000 rpm at speeds above 20 000 rpm.

As we all know, the working spindle speed depends upon the count spun; finer counts permit higher spindle speeds than medium or course counts. Currently, the maximum speeds being actually run by those mills that have adopted high speed spinning in their mills for the past few years are: 20s – 20 500 rpm, 24s – 21 500 rpm, 30s – 22 000 rpm, 40s – 23 000 rpm, 50s – 24 000 rpm and 60s – 24 500 rpm. Mills with LR6 or RXI 240 ring frames should compare their current maximum speeds with the maximum speed being used today by good mills in the country (India) as given here. If their working speeds are much below these levels, they should seriously consider going in for high speed spinning with a view to become globally competitive.

Having concluded that high speed spinning of polyester blends is technically feasible and commercially viable, the next question is, "How to go about making it a success?" The consultation experience gained in the process of helping two mills that are running their ring frames **at the highest spindle speed in the world**—grey spinning at 24 500 rpm and dyed fibre spinning at 22000 rpm—is of great help in outlining a practical plan of action. This experience is not just from these 2 mills, but from other mills that have been similarly guided and helped in their attempts to speed up their ring frames successfully. This book is a product of these experiences in the implementation of high speed spinning on shop floor. The purpose of putting down these experiences based on sound theoretical footing in a book form is to urge and to help all the spinning mills in India equipped with modern ring frames to run their ring frames at a maximum speed of 20000 rpm or more, and thereby add substantially to their profits and so continue to be globally competitive in the fiercely competitive markets of the 21st century.

However, high speed spinning does not mean just speeding up the ring frames. That has to be done only after the performance of polyester fibre (or blends) on all preparatory and spinning machines is at a level as specified, and certain checks are done daily, meticulously and without fail, at all stages of spinning preparation and at the ring frame itself. This is to ensure that the performance of the fibre at high speed spinning is maintained at the same level of acceptability as earlier, both in terms of quality and end breakage rates. If all the guidelines given in this book are faithfully and intelligently followed, every mill spinning polyester and polyester blends will be able to increase its spindle productivity close to the level set by the mechanically possible highest spindle speed.

If theory supports high speed spinning and practical experience of few mills show that this is commercially possible, why do many apprehensions still prevail in the Indian spinning industry against such a move to higher speeds? Equally, it is also important how come this phenomenon of achieving such super-high speeds is restricted as yet to the spinners in India or to the Indian spinners working abroad? A review of the past would show how the polyester fibre industry grew in India, how the government policies affected technical decisions, and how forces of competition led to bold experimentation on the shop floor and in the markets. We are sure that such understanding will go a long way in spurring the movement towards much higher spindle productivity in spinning mills all over the world.

2

Historical Perspective

In 1941, two research scientists Dr John R. Whinfield and Dr J.T. Dickson of Calico Printers Association of Manchester in UK were awarded the patent for their discovery of 'polyethelene terephthalate', the polyester polymer. It is called poly-ester because it is a polymer brought after a reaction between an organic acid Dimethyl Terephthalate (DMT) and an organic alkali Monoethylene Glycol (MEG) to form an organic salt-ester. Imperial Chemical Industries (ICI) bought this patent, and planned to put up the first polyester plant in UK. DuPont in the USA came to know of these developments. Earlier, Dr Carothers, Head of DuPont Research, had invented nylon and neoprene polymers in around 1932. He had also looked at the polyester polymer then and had put it aside because its melting point was too low. However, DuPont got interested in the newly designed polyester polymer and struck an exchange deal with ICI. ICI gave DuPont know-how on polyester, and in return, DuPont shared knowledge on nylon with ICI. Both companies together put up British Nylon Spinners as a joint venture company to manufacture nylon in UK. However, DuPont were faster than ICI in producing polyester commercially, and were the first to start commercial production of polyester in the world, since their polyester plant went on stream at Kinston in USA. The UK plant of ICI started production a few months later. For the next 15 years, ICI and DuPont dominated the world polyester scene. Only after the patent expired would several others get into this expanding polyester field: Hoechst in Germany; Toray, Teijin, Unitika and Kuraray in Japan. And so began the polyester expansion that is still continuing with Indian names such as Terene from CAFI in the beginning and much later as Recron from Reliance.

The fibre regenerated from natural cellulose such as wood was the first of the regenerated fibres now known as viscose. First patented in 1892, viscose production started around 1899 by the German firm Vereinigte Glanzstofffabriken AG in Oberbruch. The process was improved by JP Bemberg AG in 1901 that made this artificial product look similar to silk. Rayon was only produced as a filament fiber until the 1930s when it was discovered that broken waste rayon could be used as a staple fibre.

PSF was produced commercially and used as staple fibre for spinning yarns from about 1950 in the USA first, and in the UK next. The beginning was made by the brand name Terylene of ICI of the UK, Dacron of DuPont in the USA. Polyester staple fibre (PSF) came to India as an imported fibre for spinning yarns from blends with cotton at the initiative of ICI in late 1950s. By the time a mill was put up in India for spinning yarns from polyester–viscose blends, it was about 1960. The first Indian factory started producing viscose in 1951. The first factory to produce polyester in India started in 1965.

This period in the industrial growth of India was that of almost total control by the government on production of any item, especially the items that affect the daily life of the common man. Cotton and manmade fibres as raw materials, and yarns made from them in spinning mills came under this category. Essentially, the government decided who will produce what, in what quantities under the 5-year plans for the country as a whole. This was the famous 'License Raj'. As a result, the policy frame work encouraged handloom weaving to protect the large number of handloom weavers and almost stopped any expansion or modernisation of looms in the organised sector of composite mills. On one hand, the policies encouraged a controlled growth in power loom weaving on small scale, helped establishment of co-operative cotton spinning mills in rural areas, allowed putting up of spinning mills of all kinds for supporting the decentralised weaving activity. On the other hand, the government taxed heavily the manmade fibres like polyester and viscose that were considered as a threat to cotton yarns, on which a large number of handloom weavers and cotton farmers depended for their livelihood. Moreover, these fibres were seen as 'rich man's fibres', and so as deserving of higher taxation. These policies, like any policy of any government, had some desired and some undesired effects: small-scale weaving factories of less than 20 workers mushroomed uncontrollably, and had to be 'regularised' several times. By 1975, these factories started also using spun yarns made from staple manmade fibres and filament yarns for producing men's suiting and women's sarees respectively. By 1990, the production of fabric in the decentralised sector was about 85% of the total fabric production of the country as against a mere 20% in 1950. After India entered the free market era in 1991, the restructuring of the textile industry took place even faster, and by 2005, the composite mills produced only about 4% of the fabric. The power looms, as the decentralised weaving sector came to be known, produced over 80% and the rest is produced ostensibly on handlooms, with subsidy from the government. In short, the spinning in India is done mainly in medium-size mills in the organised large-scale sector, the weaving is done in the small-scale power loom sector, and the bleaching, dyeing and printing is done mainly in the medium-scale sector. We need to look at the past developments in the polyester and viscose production in India against the background of this re-structuring of the textile production system in India during the period 1950–2005. The way in which the fibre producing industry was allowed to establish capacities, to expand them, and to operate in the exclusively domestic market had several repercussions on the setting up of spinning mills for manmade fibres, and on the working of these spinning mills in the context of achieving good levels of quality and productivity.

Polyester fibre production

Polyester staple fibre (PSF) was introduced to the Indian textile industry in early 1960s by several companies including ICI Ltd. Subsequently in 1965, India's first PSF plant was set up by ICI Ltd from the UK.

The early phase

The ICI plant was named CAFI (Chemicals and Fibres of India Ltd) and was put up in Thane near Mumbai. At the start, the plant had a capacity of just 2000 tons per annum (tpa). Later, this plant was allowed to expand to make 6100 tpa as decided by the Government of India.

Then in 1973, India's second plant—Indian Organic Chemicals Ltd (IOCL)—also of 6100 tpa started production at Manali Chennasekkadu near Chennai. The next 2 years, saw 3 more plants coming up, each again of 6100 tpa. These were Swadeshi Polytex Ltd (SPL) at Ghaziabad near Delhi, JK Synthetics Ltd (JK) at Kota and Calico Fibres Ltd (CFL) at Vadodara. Thus, India had then 5 PSF plants with a total capacity of 30 500 tpa in 1975. However, in the period 1975–1985, the actual PSF production was around 21 000–24 000 tons; the capacity utilisation was between 70% and 80%.

The technologies used by different plants were as follows:

	Plant	Technology	Plant type
1.	CAFI	ICI	Batch
2.	IOCL	Chemtex	Batch
3.	SPL	Zimmer	Continuous
4.	JK	–	Batch
5.	CFL	ICI	Batch

Only one plant—SPL—had continuous polymerisation which made polymer continuously and fed it directly to melt spinning machines, while other 4 plants had batch polymerisation in which the polymer made in batches of a few tons each, when ready, was cast into chips. Later, chips from different batches were blended, bone dried, melted and then fed to melt spinning machines. The continuous polymerisation (cp) route was energy efficient. SPL needed 1.1 kWh of electricity to make 1 kg of PSF, while batch plants needed 2.2 kWh to make 1 kg of fibre. Moreover, the continuous polymerisation system enabled a more consistent quality of PSF to be delivered to the customers mills. Also all the five plants used DMT as the major raw material, which was not necessarily the best choice amongst the 2 available materials: DMT and PTA (purified teraphthalic acid).

Deniers made those days were 3.0, 2.0, 1.5 and much later 1.2. The cut lengths were 38 and 51 mm. Only SPL and JK made high tenacity fibres of 6.0–6.4 gpd, while the other three plants produced medium tenacity fibres of 4.8–5.0 gpd. Later JK introduced trilobal (essentially triangular) fibre in coarser deniers 3, 6 and 15.

The second phase

The policies of the government started becoming less restrictive from about 1985, when a new textile policy was formulated for the first time involving the research institutions and industry experts. Then in 1986, Reliance Industries Ltd put up a real large plant of 60 000 tpa at Patalganga near Mumbai, when the total capacity of India for production of PSF was almost half of this, at 30 500 tpa. This plant had a cp capacity of 240 tons per day against the SPL's cp of 22 tons per day. This plant was based on the Du Pont technology and used PTA instead of DMT as major raw material. Then in the next 5 years, 4 other plants—all with cp—went into production. Thus India had 5 new plants:

Plant		Technology	Capacity (tpa)	Year of starting	Location
1.	Reliance Industries Ltd (RIL)	Du Pont Chemtex	60 000	1986	Patalganga, Maharashtra
2.	India Poly Fibre Ltd (IPL)	Du Pont Chemtex	30 300	1987	Barabanki, UP
3.	Orissa Synthetics Ltd (OSL)	Du Pont Chemtex	35 000	1987	Boulpur, Orissa
4.	Bongaigaon Refineries & Petrochemicals Ltd (BRPL)	Du Pont Chemtex	30 000	1988	Bongaigaon, Assam
5.	JCT fibres Ltd (JCT)	Zimmer	50 000	2001	Hoshiarpur, Punjab
		Total	180 300		

Except Reliance, the other 4 plants started their operations using DMT as the main raw material but changed over to PTA after a few years.

By 2001, the total PSF capacity in the country was 1 80 300 tpa of the new 5 plants plus 30 500 tpa of the old 5 plants bringing the total to 2 10 800 tpa. However, the actual production of PSF in the country in the period 1987–1997 (before JCT Fibres started up) hovered between 98 072 tons and 1 26 359 tons; a capacity utilisation of 60–70%. The local market was much smaller. Even Reliance was hurt. Initially, it could operate only at 50% capacity making only about 2500 tons per month. Then in 1988, Du Pont came to their rescue and ordered 2500 tons per month from them; then Reliance could run their plant at full capacity. Others did not have this advantage, so all the 4 plants—IPL, OSL, BRPL and JCT—and the previous 5 plants became sick. A shake up cum consolidation took place in the PSF industry.

The third phase

During this critical period, in 2004–2005, Indo Rama Synthetics Ltd (IRSL) put up a PSF plant of 1 32 300 tpa with Continuous Process, using Japanese Toyobo technology, at Butibori near Nagpur. Soon thereafter, in 2006, Bombay Dyeing and Manufacturing Co Ltd (BD) put up a PSF plant of 450 tons per day basically to consume their in-house production of 500 tons per day of DMT. Bombay Dyeing had put up a DMT plant at Patalganga in 1985; and by 2002–2003 the demand for DMT had petered out, and had forced the closure of the plant. Then, Bombay Dyeing decided to put up a PSF plant of 1 47 000 tpa so as to consume their own DMT. But they found after running this PSF plant for a few months that DMT as a raw material was not commercially attractive. To cut their losses, they changed the plant to PTA.

Bombay Dyeing plant has a unique arrangement to inject molten polymer of a master batch (of any speciality) into the transfer line that carries the polymer from cp to melt spinning machines; thereby enabling the company to make any speciality including black, flame retardant, anti–bacterial, etc, without affecting their cp.

From 1993 onwards, production of PSF in the country was on an upswing. In 1993, the production was 186 719 tons; in 1997 it went up to 428 041 tons; it remained steady between 1991 and 2002 at around 560 000 tons; and in 2006, touched 660 581 tons.

Current status 2008

The current status of the 12 PSF plants in the country is shown below:

S. no.	Plant	Current status
1.	CAFI	Batch plant scrapped. CP plant shifted to RIL, Patalganga and now stopped
2.	IOCL	Stopped making standard fibres Makes black and other shades in dope dyed and some specialties
3.	SPL	Closed down
4.	JK	Closed down
5.	Calico	Closed down
6.	Reliance	Put up another plant at Hazira of 1 45 000 tpa
7.	IPL	Taken over by Reliance—plant running Made black fibre in cp—an achievement
8.	OSL	Taken over by Reliance—currently closed
9.	JCT	Taken over by Reliance—operating
10.	BRPL	Plant closed down
11.	IRSL	Have further expanded by 1 55 000 tpa at Butibori
12.	BD	In production

Today, India has just three main players in the PSF field: Reliance Industries Ltd (with 744000 tpa), Indo Rama Synthetics Ltd (with 300000 tpa) and Bombay Dyeing (with 148 000 tpa). About half of the world production of PSF is now from China, and India is perhaps the second largest producer of PSF. The global markets are extremely competitive, whereby each fibre producer strives for a higher market share and for better customer satisfaction. Consequently, a large variety of fibres are now available to the Indian spinning mills.

Polyester fibre types

The product range today is:

In deniers

- Normal semi-dull – 0.8 microfibre, 1.0, 1.2, 1.4, 2.0 and 3.0
- Full bright – 1.2 sewing thread, 1.8 and 2.5 trilobal

In dope dyed

- Black and in many other shades
  In cut lengths (mm) – 32, 38, 40, 44 and 51

The more popular denier/cut lengths are as follows:

- 1.4d × 44 mm used by most synthetic mills for spinning 100% polyester and polyester–viscose blends for coarse and medium counts up to 40s
- 1.2d × 44 mm used for finer counts 40–60s
- 1.0d × 44 mm used for the finest yarns, 60s/70s//80s polyester/viscose counts
- 1.2d × 38 and 1.0 d × 38 mm for the blends with cotton

At one time 1.4 × 51 mm was the most popular denier/cut length for all synthetic mills, but then export specifications and the need to lower imperfections forced spinners to go to 44 mm cut length, though the twist multiplier (TM) had to be increased from 2.5–2.6 to 2.9–3.0.

Export–Import

India has been importing around 7 000 tons of PSF per year even after the capacities increased substantially by 2003–2004. Exports account for about 28 000 tpa as given below:

Imports/exports (metric tons)

S. No.	Financial year	Imports	Exports
1.	2001–2002	25 148	26550
2.	2002–2003	20 417	16988
3.	2003–2004	7 602	28 129
4.	2004–2005	11 496	47 782
5.	2005–2006	9 962	41825
6.	2006–2007	10 579	122 447
7.	2007–2008	12 129	NA

Comparing the import and export figures for 2006–2007 with PSF productions in the same year, it will be seen that:

1. Imports just are 1.3% of the production, and would consist mostly of speciality fibres, and can be considered as negligible.
2. Exports are 15.5% of the production, which is creditable.

Further scope for growth

It would appear that the total indigenous production has reached its plateau and further increases in capacities are not needed. But the figures of per capita consumption show a different picture. All textile fibres taken together, the world average is around 9.7 kg per capita, i.e. per person in the population per year. Out of 9.7 kg, the PSF accounts for 1.5 kg per capita. The same figure for India is 4.9 kg of all fibres, wherein cotton predominates, and wool and silk are in miniscule proportions. The per capita consumption of PSF in India is only 0.6 kg. The trend is for the per capita all fibre consumption to increase in India as the levels of income increase, and the proportion of polyester to cellulosics will gradually come to about 40:60 as it has become the world over, especially in the warmer climates. Consequently, the PSF consumption in India will rise to a level of about 1.5 kg per capita, showing a 3-fold increase over the next decade or so. Major growth sectors are uniform fabrics and home furnishings, where the penetration of polyester fibre is small.

Speciality fibres

Speciality PSFs have not become common in India. Earlier, JK and later Reliance popularised the Trilobal (a fibre with triangular cross-section) in full bright lustre to give 'glitter' to suiting. Apparently, the popularity of this fibre has reduced recently. Reliance had made cationic dyeable fibre; but it did not catch up. Reliance's 'Cotluk' fibre (a dull fibre similar to cotton) is showing some promise. Reliance's sewing thread fibre—also in full bright lustre—has made good headway. Reliance is able to offer flame-retardant fibre and anti-bacterial, anti-fungal fibre from the earlier Hoechst's plant in Germany, which is now owned by Reliance. Both these fibres have not made much headway in the industry as of 2008.

The minimum denier produced in other countries, particularly China and S.E. Asia for PSF has been 1.4d. However, the need of the Indian industry was for finer deniers, both for spinning finer counts such as 60s and for obtaining higher productivity at ring spinning. Therefore, fibres of 1.2d and below can be considered to be some kind of speciality fibres. Reliance's 1.0d fared very well; it had definite advantages over 1.2d; such as higher blend yarn strength by 8–9%, lower unevenness by at least 1.0U%, a 20% reduction in imperfections and hairiness. And what was more important for the end users of yarns, was a gain of 2–6% in weaving efficiency, the gain being higher for shuttle-less looms. SPL had developed 0.9d much earlier than Reliance's 1.0d; but then 0.9 turned out to be a commercial failure.

However, 0.8d fibre, called microdenier fibre, has picked up volumes and could be considered a success.

Reliance and IOCL both offer 'black' dope-dyed fibre; while IOCL offers several shades in dope-dyed qualities. These dope-dyed fibres are generally in the range of 1.2–3.0d.

Educating the customer

The early entrants in the production of polyester staple fibres had established 'End User Applications Research and Development Laboratory' at their fibre-producing plants. Extensive application-related work was done by these laboratories-cum-pilot spinning/weaving/knitting units in the UK, the USA and Germany. Thus, considerable fund of knowledge on products and on process parameters for using PSF alone, or along with cotton, viscose, acrylic and wool was available to the Indian producers of PSF. However, every item had to be adapted to meeting the Indian needs in terms of products and in terms of the kind of machinery available in the mills. The fibre was totally new to the spinners; the few textile colleges that were functioning in India around 1960s were in no position to deal with these brand new fibres coming in the markets.

CAFI, being the first PSF producer in the country, had to provide excellent technical service to customer mills. CAFI made available considerable literature to mills on the subject of spinning weaving and chemical processing of PSF, its blended yarns and fabrics. The PSF producers, who followed CAFI, also provided technical service. Later, SPL came out with many publications. Since SPL was the only producer on cp then, they attributed in every publication all 'good' properties of PSF solely to cp, which is not correct. The importance of technical service started to reduce by late 1980s as more of mill technicians began to understand from their own experience about 'how to process PSF'. However, such learning left a lot of ignorance about PSF and its properties. The technical publication of Reliance, named 'Polyester Perfection', was well received. Many spinners still preserved bound volumes of the Polyester Perfection. Its publication was ceased around 1996, since the requirement had reduced considerably. Later, it re-appeared in a different format that was less technical and more commercial. The other two PSF producers in India do not seem to be interested in bringing out any technical or commercial periodical on a regular basis.

Mention must be made of the workshops held regularly by Reliance at Patalganga. Spinning managers of customer mills were taken there in batches of 20–25, were lodged in bungalows, and were taken around the PSF plant to familiarise them with the production process and the quality control system. They also benefited from 8 sessions—each of 1.5 h—in 2 days of lectures by prominent technologists from mills, research associations, machinery makers, and dyes manufacturers covering various aspects of polyester spinning. The topics included spinning of PSF on airjet system and on open-end rotors and spinning of dyed fibres. The theoretical basis involved in measuring yarn evenness, imperfections and faults, as well as of other tests on tenacity, etc was brought out to them, along with the right use and limitations of test methods.

Raw materials for polyester

The raw materials used for producing polyester in any form—fibres, filaments or films, etc—are either PTA and MEG or DMT and MEG. As indicated earlier, the use of DMT as the main raw material has been found to be uneconomical and also added to the problems as the by product is methanol.

PTA

India has now 3 companies making PTA.

	Company	Year of starting	Production capacity (Metric tons per year)
(i)	Reliance Industries Ltd	1988	1350000
	(a) Patalganga plant		
	(b) Hazira plant	1998	120000
(ii)	Mitsubishi Chemicals PTA(I) Ltd	2000	425000
(iii)	Indian Oil Corporation	2007	600000
			2495000

The production of PTA in metric tons in the last 3 years has been:

Year 2005	1768550
Year 2006	2107119
Year 2007	2355832

The capacity utilisation in 2007 was 94.4%, and the share of Reliance was 59%.

During these years, PTA was not exported at all, and the imports were:

Year 2005–2006	107245
Year 2006–2007	124227
Year 2007–2008	488858

Imports in 2007–2008 are quite large, at about 19.6% of the production capacity. With the PTA plant of IOC working at full capacity, the country would become self-sufficient. In fact, some quantity of PTA is likely to be exported.

MEG

Four companies manufacture MEG in India. One of them, India Glycols Ltd, produces MEG from sugarcane molasses, while others make it from petrochemicals.

	Company	Year of starting	Production capacity (tpa)
(i)	Indian Glycol Ltd	1989	25000
(ii)	Indian Petrochemicals Corp Ltd*	1973	13900
	(a) Vadodara		50000
	(b) Nagothane		120000
	(c) Gandhar		
(iii)	National Organic Chemicals Ltd*	1976	10000
(iv)	Reliance Industries Ltd	1992	550000
(v)	SM Dyechem Ltd#		60000
	Total		828900

*These companies are now with Reliance Industries Ltd
Closed in 2008

Production of MEG in the last 3 years:

Year	Production (metric tons)
2005	533493
2006	891935
2007	910249

Reliance holds 69.6% of the total capacity; and the capacity utilisation in 2007 was at a creditably high level of 109.8%.
While there were no exports; the imports were:

Year	Production (metric tons)
2005–2006	94485
2006–2007	162603
2007–2008	20683

The import in 2007–2008 amounts to only 2.5% of MEG capacity and so can be considered to be negligible.

DMT

India has four plants to make DMT, but these have remained closed since 2005–2006.

	Company	Year of starting starting	Production capacity (tpa)
(i)	Bombay Dyeing & Mfg Co	1985	165000
(ii)	Bongaigaon Refineries & Petrochemicals Ltd	1985	45000
(iii)	Indian Petrochemicals Corp Ltd	1973	30000
(iv)	Garware Petrochem Ltd	1996	60000
		Total	300000

Production of DMT in the country in the past 3 years was:

Year	Production (metric tons)
2005	210049
2006	62412
2007	9170

There was no export of DMT; the imports were:

Year	Production (metric tons)
2005–2006	6480
2006–2007	11076
2007–2008	4121

We could consider the production as well as the usage of DMT to be almost zero now.

We thus note that India is now almost self-sufficient in terms of the two raw materials PTA and MEG required for the polyester industry. Possibly, one more MEG plant of about 120000 tpa is needed, if the 60000 tpa plant of SM Dyechem does not get revived.

Spinning of polyester blended yarns

Indian spinning mills started using PSF in the early 1960s. The PSF was imported, mostly from ICI of UK, and their Terylene was used as a premium new fibre for blending with cotton. Terylene—cotton blended yarns were spun and fabrics were produced and marketed by the progressive composite mills. One of the first textile groups to go into polyester in a big way was Thackerseys. The first spinning mill to run polyester/cotton was Crown Mills of this group. A few spinning mills were established solely to produce polyester–viscose blended yarns. The viscose staple fibre had been well established in India by then, and was priced between the cotton and the PSF, which was about 3 times the price of cotton. The first spinning mill to run polyester–viscose blend was Bharat Commerce and Industries

(BCCI), Nagda. They were pioneers also in dyed fibre spinning. Later, Modi Spinning and Weaving Mills, Modinagar, and Kiran Spinning Mills, Thane (near Mumbai) were the mills who took up and enlarged the spinning of polyester–viscose blends in India.

The amount of PSF recommended by the fibre makers was from 50% to 80%, preferably at least 67% for ensuring good crease recovery properties in the fabric. The new, prestigious and costly fibre was given gentle treatment on the spinning preparatory machines, and was spun at lower spindle speeds than cotton at ring frames. The PSF–viscose spinning mills also worked the fibre blends carefully and at low rates of production so as to ensure good quality in this 'expensive' yarn. It is also to be noted that the kind of machinery available in most Indian mills during the period 1960–1975 or so, was of a vintage about one generation behind the good mills in the world. After about 1970, several mills—both composite mills and spinning mills—modernised their machinery on a large scale. The new spinning mills that came up for cotton as well as for manmade fibres after 1960 had a much higher technology incorporated on their machines. But the real boost to go for the best machines in the world in Indian mills took place after export of yarn was stabilised around 1985–2006 and certainly after the opening up to market economy in 1991. Till 1985, the textile mills were licensed to produce either from cotton, or from wool or from manmade fibres. Composite mills making mainly cotton-based yarns and fabrics were not allowed to start spinning polyester or polyester–viscose blends, or to use filament yarns of polyester or nylon or viscose in their fabrics. The policy change introduced in 1985 towards a multi-fibre regime was welcome by the Indian industry. The existence of separate spinning mills for manmade fibres (commonly known as synthetic spinning mills), and the small capacities of the early PSF plants were all a result of the planned and excessively controlled economy of the country during the period from 1960 to 1985.

The legacy of spinning PSF at slow speeds to 'manage' good quality stayed for quite some years; and this legacy reduced only very gradually. The government gradually realised that PSF is not a 'rich man's fibre' but is rather a 'common man's fibre' that lends longevity to apparel about 3–5 times that of fabrics made of cotton fibres. As the indigenous production started increasing, the taxation (duties) on the PSF reduced substantially over a period of time. The lower prices of PSF and viscose, and the intense competition in the domestic and export markets led the mill managements to change their attitude and they encouraged the technicians to experiment with higher productivities. By 2005 or so, the time had arrived when the cotton fibre was as expensive as or even more expensive than polyester and viscose fibres, as has been the trend elsewhere in the world. India was given a period of 1995–2005 for preparing itself to integrate its businesses with the world economy under the World Trade Agreement. After this integration, the textile industry is fully exposed to competition from other textile countries of the world, not only in the export markets, but also in the domestic markets. The government is not expected to protect the Indian makers of textiles by charging high import duties on imports. The protectionist regime of 1950–1985 was gradually dismantled by the government through policy initiatives, till by 2005 India joined the WTO fully. It can be said without any hesitation that the technical journey of the PSF from a low productivity fibre to a high productivity fibre paralleled the developments in sophistication of textile machinery and improvements in the policies of the government by way of less taxation and freedom to establish new capacities without having to take 'permission' from the state.

Early efforts

The consumption of PSF got a boost when India's first PSF plant of CAFI went into production in 1965. CAFI had a monopoly until 1973, when the PSF plant of IOCL went on stream. In the period 1965–1972, CAFI developed several polyester-blended fabrics at their Textile Pilot plant and provided excellent technical service. They made fabrics out of blends of polyester with cotton, viscose, acrylic, linen wool, cut silk, jute and even human hair. The counts chosen by them were for use in the Indian markets, which were different from the markets in Europe or the USA. While 20s and 30s counts were the need in those markets, the Indian markets needed counts as fine as even 60s for making comfortable shirting for wear in Indian summer. CAFI regularly circulated full details of fabrics developed to all their customers. These services helped the spinning departments of the composite mills to accept polyester staple fibre quickly. CAFI similarly helped the new spinning mills that were established for producing polyester–viscose yarns. CAFI, following the idea used earlier by all PSF producers, ensured that a 'brand image' is created for their fibre named Terene in India, as differently from Terelyne in UK and for export from UK. They even experimented with a new idea; the formation of a 'Terene Club' of mills who used exclusively Terene PSF. CAFI advertised the fabrics—mostly, polyester cotton shirting and suiting—made by the mills which joined the Terene Club, along with the extensive advertisement of their fibre. Also they insisted on stamping a line 'Made from Terene polyester staple fibre' on every meter of finished fabric. This was considered one more step in their brand-building efforts. However, a number of mills did not like the idea and opted out of the Terene Club. Once four other PSF plants started then there was no shortage of PSF, the idea of the 'Terene Club' could not continue for long. The PSF quickly became a commodity fibre rather than an exclusive fibre with special name, though each PSF maker had coined their own names for their PSF.

Note needs to be taken of the fact that India had established as many as five cooperative textile research associations (CTRAs) during the period from 1947 to 1960 for conducting applied research in the field of textiles. These were three for cotton fibre based mills, one for jute and one for 'art silk', as the filament yarns from viscose, nylon and polyester were called at that time. This movement to establish research activity on a cooperative basis by the textile mills started with the registration of the Ahmedabad Textile Industry's Research Association (ATIRA) in November 1947, immediately after India became independent. ATIRA started working in end 1949 and was soon followed by BTRA in Mumbai, and SITRA at Coimbatore in Tamilnadu. SASMIRA came up in Mumbai for the 'Silk and Art Silk' mills, while the erstwhile IJMARI (the Indian Jute Mills' Association Research Institute) converted itself to IJIRA (Indian Jute Industry's Research Association). Later, three more CTRAs came up, by 1975 were added Wool Research Association (WRA) in Mumbai; Manmade Textile Research Association (MANTRA) in Surat, Gujarat; and NITRA for mills in North India in Ghaziabad, UP. Since the PSF was being spun mostly on the cotton-type machinery, it was for the cotton-based CTRAs to take up work on PSF, viscose and other manmade staple fibres like acrylic. None of the three cotton-based CTRAs felt like doing any applied research in the area of manmade staple fibres for two reasons—membership of two of them ATIRA and BTRA—consisted mainly of composite mills that were allowed to use PSF only with cotton and no filament yarns in the warp sheet for fabrics. Consequently, the attention of these two TRAs was on spinning and weaving of polyester–cotton blends. SITRA, in the south, did not feel involved since its membership was almost entirely of cotton spinning mills. The only time ATIRA looked at the viscose fibre was in around 1976–1978, when the cotton shortages and the high price (with high import duties) of imported cottons made the government to compel cotton spinning mills—composite mills included—to mix indigenously produced viscose fibre up to 10–15% in cotton mixings. Later, some work was done on optimisation during 1983–1985. The other equally important reason was that the fibre producers were doing an excellent job. Any entry from the CTRA's would have been difficult in the absence of any different or better technical know-how, and would have proved redundant. As described earlier, the fibre producers from Europe and USA had set up large application laboratories: the Hoechst applied research laboratory for their fibre Trevira was about two times the size of ATIRA in 1966–1967, and employed three times more persons. Consultants from these CTRAs did keep up with the new knowledge on manmade fibres and helped their member mills going in for use of PSF and viscose through consultation, as an when the mills needed such help. After the government allowed composite mills to use filament yarns as weft, some work was also done with the industry groups on how best to weave this, etc. Thus, the role of textile research associations in the growth of the PSF industry was negligibly small.

Production of blended yarns

As mentioned earlier, three mills were pioneers in the field of manmade-fibre spinning: Modi Spinning Mills at Modi Nagar, UP; Bhilwara Spinners Ltd at Bhilwara, Rajasthan; and Kiran Spinning Mills at Thane near Mumbai, in Maharashtra. The technicians in these mills got a first-hand experience of learning about the new fibres and the difficulties faced in running these fibres well on the cotton-type machinery. These mills became the first training grounds, because many technicians used the experience gained in these mills by taking better job positions in other mills that were established later for spinning of manmade fibres. Later, these pioneering technicians headed many new blend spinning mills in the country. After 1980 or so, when PSF became easily available, several composite mills took up PSF for blending with cotton. Major customers then were—Hindustan Group of Mills in Mumbai, Calico Mills in Ahmedabad, Binnys in Chennai, Madura Coats in Ambasamudram, Mafatlals in Mumbai, Navsari and Nadiad, Jayashree in Kolkata, Lakshmi Vishnu in Solapur, Morarjee Gokuldas in Mumbai, Delhi Cloth Mills in Delhi and others. The composite mills as a group were more concerned with keeping the cost of spinning their own yarns low as a good support to their weaving and finishing activity. In general, the ring frame productivity in terms of production per spindle shift was less in composite mills, but the allocation of spindles to a tenter was much higher. This happened to be one more reason why the PSF was run at slow speeds in the industry. The PC-blended shirting and suiting generally constituted only about 5–15% of the loom programme—production—of composite mills. The place of PC suiting in the market was taken by the more versatile and more colourful PV suiting made from doubled yarns, mostly fabric dyed in the early stages and fibre dyed in the later stages. Most of these PV suiting fabrics were produced on the power looms in the decentralised sector in cost-effective ways. The PC shirting continues to a good extent today, but the yarns are made in spinning mills and the fabric on power looms. The trend after 1995 has been towards checked or striped 100% cotton shirting. With the restructuring that took place in the textile mills in India from 1970 to 1995 or so, about 250 out of the 280 composite mills had to close down mainly because their cost of production could not match the low costs of the decentralised system. Today, quite a number of these pioneers are closed. Consequently, the entire spinning of PSF by itself or in blends went to spinning mills that were more particular to achieve high productivity at ring frames.

During 1970s and even later, several synthetic spinning mills came up particularly in North India: Rajasthan Spinning & Weaving Mills at Bhilwara and Gulabpura, Rajasthan Textile Mills at Bhavanimandi, Banswara Syntex at Banswara, Jaipur Polyspin at Reengus Modern Syntex at Alwar, Modern

Threads at Raila, T.I.T. and Birla Textile Mills at Bhiwani, and Deepak Spinners at Baddi. They developed their own techniques of running PSF, and most started using the fibre length of 51 mm instead of the 38 mm recommended by PSF producers to make blending with cotton easier. The longer length helped them to reduce the twist multiplier from about 3.5 to 2.5/2.6 or so, giving a much higher front roller speed at the ring frame. These mills succeeded in achieving a much higher productivity at the ring frame spindle point, albeit at a small reduction in the quality of yarn.

New Indian developments

Around 1980–1985, two significant developments took place. One in which synthetic mills took the initiative was development yarns made from own dyed polyester fibres blended with dope-dyed viscose supplied by the fibre producer in 2–3 shades. The leading mills in this change were Bharat Commerce and Industries, Nagda, MP, and several spinning mills in Rajasthan. These fibre-dyed single yarns were doubled and used for making suiting without any need for sizing the warp sheet. The fibres used were 1.4d × 51 mm for polyester as well as for the viscose component. Bhilwara, Rajasthan, became the biggest centre in India for the production of this type of suiting on power looms. This development is purely an Indian phenomenon, as dyeing PSF (51 mm then, and 44 mm later) and subsequently spinning it is not practiced in any other country. The idea was to make polyester/viscose suitings to look like polyester/wool suitings and make them available at a much lower cost. (For that matter, weaving on decentralised power looms is also an entirely Indian phenomenon that goes against the general economic theory of large business size giving cost advantages. While it is true even in India that the overhead expenses per unit of production reduce with the size of the manufacturing unit, decentralised weaving became economical in India because of three reasons. Firstly, the wage rates were about half or less; secondly, a worker could be fired if his production and quality were not satisfactory; and thirdly, the taxes and duties were favourable for the small-scale industry. The smaller units were kept outside the purview of the Industrial Disputes Act which made it very difficult for the large organised sector textile mills to reform or to remove non-sincere or inefficient workers. Unionisation of workers in the organised sector further compounded the difficulties and the judiciary bent backwards to protect workers' livelihood; India was in the grip of the 'socialistic pattern' of mixed economy from 1950 to 1985–1990 that had the disadvantages of both the systems—capitalism and communism.)

The second development—also unique to India—was what came to be known as "carbonisation". If necessity is the mother of invention, here the necessity was forced by the regulation that the composite mills shall not weave fabrics with filament yarns as warp. The Calico mill of Ahmedabad was in a big way in the market for printed sarees and they felt a new fabric structure with pure polyester in the warp direction would give an excellent feel, texture and durability to the saree. Their R&D department came up with the idea of spinning a PSF cotton blended yarn, and then removing all the cotton from it by treatment with sulphuric acid. This process was termed 'carbonisation' since the cotton fibre turned into carbon on treatment with sulphuric acid. As a process, carbonisation was not patentable, so other mills could also use this process freely. The sarees and other ladies dress materials made by this process became quite popular for some period. For saris, the standard count for both warp and weft was 62s 65/35 blend of 1.2d × 38m PSF with combed cotton, and this count was spun with a high twist of 42 tpi or 5.34 of a tm. After the fabric was dyed/ printed, it was treated with 60% sulphuric acid to dissolve the cotton component. The warp and weft counts became 90 and the twist multiplier then became 4.2, and so no pilling would take place. Initially, this process was used exclusively for saris, and mills who were prominent were Lakshmi-Vishnu Mills, Solapur, besides the Calico mills. Later this process was also used for fabrics meant for children wear. Carbonising made the polyester fabric soft and supple. Two remarkable things to be noted about this development are: firstly, it came not from any of the cotton-based research associations, but from a progressive mill, and it was a result of a bad restrictive policy of the government. After 1985, the multi-fibre policy came into existence, and all mills were free to use whatever material they wished in their mills. Secondly, the filament weaving industry in the decentralised sector of power looms, mainly from Surat, had captured the saree market. They used only filament yarns of a wide variety to make attractive sarees and these sarees needed no ironing and lasted for long years, about five times the cotton sarees. ATIRA did come up with a small publication on due care during carbonisation, but this process died its natural death by mid-1980s.

Technological progress

Till about 1970, PSF was not available easily; the demand exceeded the supply which was kept at a low level by the government policies. Also, because the PSF was at least twice as expensive as cotton, it was treated by the mills like a VIP is treated in public life. Right from its entry in the mill, it was kept separate. The mixing with cotton in composite mills or the stack mixings in the blend spinning mills was very carefully made. The number of persons employed was of no consideration. A light treatment was ensured in the blow room. A good amount of waste was removed from the fibre in the blow room and in carding even when it was not needed. Partitions were put up around machines running polyester cotton blends in cotton spinning mills to ensure that the PC yarns are not 'contaminated' with cotton fibres. Machine speeds were very low; because the spinner has always believed that a lower production rate gives better quality at all machine stages in spinning. The metallic wire cards would run at 6 doffer rpm, or just about 13m/min; draw frames at 100m/min, fly frames at about 700 rpm and ring frames at spindle speeds of 10000–12000 rpm, for counts ranging from 30s to 60s. All these production rates were less than 75% of the level sustainable with good quality on the given technology of the machines. Over the next decade from 1970s, two changes took place supporting each other in the quest for higher productivity. Gradually, the spinners realised from their experience that the yarn quality does not deteriorate with increase in speeds. They were being spurred by the mill managements to continuously reduce costs. Some became bold and increased their machine speeds successfully. Many more followed immediately, and a sort of race to demonstrate the maximum productivity started in all the mills in the country by 1985 or so. During this period, many new mills came up with world class spinning machinery, made in India as well as abroad. These machines were designed for much greater productivity without any loss in quality. Many a mills modernised their machinery to sustain and grow in the competitive markets. As a result of this twin change over time, the normal speeds in good PSF and blend spinning mills in 2008 are: cards run at 180–200 m/min, draw frames up to 750 m/min, fly frames spindles at 1200 rpm and high speed ring frames at spindle speeds ranging from 16000 to 18000 depending upon the count. A few mills run PSF on rotor spinning machines, and still fewer mills use air jet spinning machines in India. The open-end (OE) spinning machines are used mainly for coarse cotton spinning in India, with weft yarns for denims occupying a place of pride. Most other mills use cotton mixings containing a large proportion of waste cotton on their OE rotors.

Industry growth

In 2008, the scenario in India is somewhat as follows: the total number of spinning mills is about 2200, of which medium and large scale mills (with more than 20000 installed spindles), are 1608. Of the 230 composite mills that exist on paper, only about 30 mills produce fabrics and process them. Of the total of about 1600 spinning mills, about 220 are solely for manmade fibres. The installed spindles in India are about 34.25 million, and the utilisation is around 80%. The 20% loss in utilisation is mostly because of the total stoppage of non-remunerative old spindles.

The production of all spun yarns in the country for the last 3 in million kg was:

Year	Cotton	Blended/Mixed	Synthetics	Total
2005–2006	2521	588	349	3458
2006–2007	2823	635	355	3813
2007–2008	2948	674	378	4000

Considering the latest figures of 2007–2008, cotton yarns account for a major portion of 73.7% of all spun yarns produced in the country. India is still cotton dominated. Blended yarns comprise 16.8%, while pure synthetic spun yarns are only 9.5% of the total spun yarn produced in India.

The manmade fibre spinning industry is fairly well distributed in India amongst the textile states. The ranking of states for production of blended and synthetic yarns in 2008 is:

Rank	MMF-blended	Synthetic
1	Tamilnadu	Tamilnadu
2	Rajasthan	Punjab
3	Maharashtra	Maharashtra
4	Himachal Pradesh	Andhra Pradesh and
5	Gujarat	Madhya Pradesh

Several mill groups consume more than 1500 tons of PSF per month at present. These are:

1. Rajasthan Spinning and Weaving Mills Ltd. with mill units at Bhilwara, Gulabpura, Banswara and Ringus. All are in Rajasthan.
2. Rajasthan Textile Mills—with units at Bhawanimandi, Kathua and Baddi.
3. Surya Group, Hyderabad based—Suryavanshi, Suryalata, Suryajyoti and Rajvir—units in several towns in Andhra, and at Nagpur and at Rajana in M.P.
4. Aditya Birla Group—units in Bhiwani and in Kolkatta.
5. Sounderrajan Group—units in Dindigul.
6. Nahar Group—units in Punjab and Haryana
7. Vardhaman Group—units in Punjab and Haryana
8. Sangam Spinners Bhilwara

The polyester cotton blended yarns are also produced mostly by the spinning mills that used to work exclusively for cotton earlier. In recent times, some manmade fibre spinning mils have also started making PC blends.

A major feature of the MMF spinning mills in India is the very strong emphasis on spindle productivity—grammes per spindle shift. The local market for blended/MMF yarns is highly competitive; and only the spinning mills whose conversion cost is the lowest make profits and, that too, at very moderate level of 2–5%. (It may be noted in passing that this situation of extreme competitiveness and low profits is also common to Indian cotton spinning mills. In fact, financial results over 5 decades demonstrate that the average profitability of all types of textile mills taken together is around 5% of sales, as against the industry average of about 10% in India. In general, the textile producers are known to be in fiercely competitive markets all over the world and the textile profitability is much lower than that of the rest of the industries. One generic reason for this is that the ratio of annual turnover to establishment capital is between 0.8 and 1.1 (at the most) for textiles, while it is higher than 1.5 for most other industries.)

A few of the blend spinning mills are going downstream into fabrics and apparels to enhance their profitability through value addition. In this route, they would need to be competitive with the operators in the decentralized power loom and clothing sector. This trend of different types of value additions would get strengthened in time to come.

The national product mix

As seen earlier, the Indian spinning industry is still predominantly cotton biased, because cotton is in big demand both in the domestic and in the export market.

The product wise and count wise distribution of blended and 100% polyester yarns (in million kg) as in the year 2006–2007 is shown below.

S. No.	Blend	Count range							Total
		1–10	11–20	21–30	31–40	41–60	61–80	81–100	
1	CV	0.64	1.82	10.47	4.63	0.45	0.13	0.04	18.43
2	PC	9.68	25.77	54.93	36.50	36.30	32.63	1.52	207.33
3	PV	7.74	56.50	153.60	60.28	40.66	4.73	0.35	323.86
4	PO	3.44	13.33	14.43	8.36	3.43	3.85	0.03	46.90
5	PVC	0.49	0.13	0.22	0.26	0.39	0.07	–	1.56
6	P	16.63	40.91	66.51	20.29	47.45	16.20	0.44	208.43

Legend: C–Cotton, V–Viscose, P–Polyester O–Other fibres

It will be seen from the above table that:

1. Polyester/viscose is the most dominating blend accounting for 49.3% of all blended yarns spun. And within P/V blend, 21–30s is the most common count being spun, with 31–40s being the next followed by 11–20s. The count range 41–60s is also fairly popular.
2. Polyester/cotton is the next popular blend. Here the count range is quite wide. Though 21–30s is the most popular count group, the other

count groups excepting the coarsest and the finest are not far behind in popularity.

3. Polyester/viscose/cotton seems to be the least made blend.
4. Blends of polyester with other fibres like acrylic and wool are fairly popular.
5. Spinning of 100% polyester spun yarns is quite important. Here also, like in polyester/cotton blend, the production is well-distributed in different count ranges.
6. Spinning of super fine counts 81s onwards is negligible.

In fact, India has a tradition of fine cotton spinning; cotton yarn counts like 110s and 140s were regularly spun in this country. Even as of 2008, one mill does spin 200s in pure cotton. With the availability of super microdenier polyester fibre of 0.5d, it should be possible for Indian mills to spin super fine counts like 100s, 120s up to 160s. A mill in South did spin 160s out of this fibre in 100% polyester with a view to offer to the world a range of fine and super fine fabrics not made by any country so far. Shirting in 2/120s, dress material in 2/100s, super fine bed sheets in 2/100s, saris in 2/110s with high and normal twists are some of the possibilities.

In other countries of the world, the finest count spun is 45s (Ne); and the fine count group above 40s accounts for about 6% of the total production. The remaining 94% of production is in the range of 20–40s. India has almost 22% of production in the fine and superfine range—this fact differentiates the Indian PSF spinning industry from that in the other countries. This pattern of proportions of blends and of counts would remain approximately the same for several more years to come.

Some remarkable facts about the product mix in India are as follows:

- Proportion of doubled yarns is estimated to be above 70% and all the doubled yarn is used for suiting.
- Greater use of the finer deniers—0.8, 1.0 and 1.2—compared to rest of the world, where 1.4d is the dominant denier.
- Almost 70% of cut length used is 44 mm, while in the rest of the world, the standard cut length is 38 mm.
- Spinning of own-dyed polyester fibre blended with dope-dyed viscose of 44 mm or 51 mm cut lengths, with fibres of different shades mixed together, to give visual effects similar to polyester/wool worsted range of suitings at much lower cost.
- Use of coarse denier trilobal/triangular fibre in blends up to 30% in dyed fibre spinning to give a sparkling effect in suiting. This trend seems to be diminishing.
- Speciality fibres like flame retardant, anti-microbial and moisture management, etc yet to be consumed in commercial quantities by Indian spinners.

Export of polyester spun — 100% and polyester blended yarns — was 24 489 metric tons and 65 373 metric tons respectively in the year 2006–2007. These export figures are quite creditable considering the international competition from China and S.E. Asian countries.

Production of PSF in the same year 2006–2007 was 791 160 metric tons. If we assume that the blend composition of blended yarns exported was 65/35, then the polyester content in yarn export works out to 68 520 metric tons or 8.7% of polyester fibre produced. This performance is really good.

The MMF and blend spinning industry in India is facing several problems as of the year 2008. The market is stiff with too many spinners competing, the power situation is bad in several states causing stoppages of up to 2 days a week for mills with no standby power generation of their own, and a severe shortage is felt of both skilled and unskilled workers. The booming Indian economy with a growth rate between 7% and 9% is making the rupee stronger vis-a-vis the US Dollar, and this trend will continue to make the exports continually less remunerative. Especially, the competition with the neighbouring countries with weak economies and weak currencies will become gradually more unfavourable to Indian mills.

It is this broader long-term context that the MMF spinning mills in India should look at the need to strive for highest speed spinning of polyester staple fibre and its blends. In order to survive the fierce competition from within and without, each of these mills must strive also to modernise and automatise now to be ready to face the future. This book from the Textile Association India is a small step from India's premier textile professional body to help the Indian textile industry grow.

3

Getting Ready to Go for High Speed Spinning

The success of a spinning mill that wishes to speed up its ring frames depends heavily on the quality of the fibre. The spinner in the mills is not fully aware of how his counterpart spinner of the filament yarn makes the PSF easily spinnable on his textile processing machinery. The elaborate system of quality control during the production of PSF consists of controlling as many as 20 parameters. It is advisable for the spinner to be aware of these physical and chemical characteristics and their impact on the spinnability of the PSF as well as on the quality of the spun yarn.

The other important but not so precisely measurable requirement is that of the capability of the mill technical and managerial cadre for undertaking the task of high speed spinning and making it a success.

This chapter covers both these requirements: first, the technical and then, the managerial.

Fibre quality parameters

The following 20 physical and chemical properties of PSF are routinely tested by PSF producers, and the parameters checked and controlled are about 30.

1. Average denier (D) and its CV%
2. Tenacity g/d (T) and its CV%
3. Elongation at break (E) % and its CV%
4. Tenacity @ 10% elongation (T10) and its CV%

5. Crimps/25 mm – Crimp Number (CN)
6. Crimp Stability (CS) %
7. Crimp Take Up (CTU)
8. Spin finish % – Oil Pick Up (OPU) %
9. Dry Heat Shrinkage (DHS) %
10. Dyeability (DYE)
11. Fused fibres – mg/10 kg of fibre (FF)
12. Long Fibres – Over length (OL) and Multi length (ML)
13. Di-Ethylene Glycol (DEG) %
14. Surface Oligomers (OLG) %
15. –COOH Group (COOH)
16. L Colour (L)
17. B Colour (b)
18. Intrinsic Viscosity (IV)
19. Melting Point °C (MP) and
20. TiO_2 % (TiO_2)

Each of these properties and parameters has some bearing on the performance of PSF in the down stream spinning department, starting from the blow room till ring or rotor spinning. The impact of relevant properties on the dyeability of the fibres, and its effect on the quality of yarns and of fabrics also needs to be understood by the spinning technologists since their yarns need good acceptance in the markets. Let us overview briefly how each property affects the mill performance, and how the PSF maker ensures trouble free working of the fibre on mill machinery and good yarn quality.

Denier

Most PSF producers keep the actual denier a little on the finer side of the nominal denier, e.g. 1.2D is always 1.16, 1.4D is around 1.35 etc. This way of erring on the safer side increases the spinning limit of each nominal denier; it can be spun to a somewhat finer count. The finer denier helps spinners to obtain a little higher strength as well.

Theory tells us that to form a spun yarn on a ring spinning frame we need a specific minimum number of fibres to ensure that the strength of the yarn at the appropriate twist is sufficient to withstand the stresses the yarn has to undergo during the processes of winding to weaving etc. The strength of the yarn is a combined result of slipping force needed to pull the fibres apart, and the breaking force needed to break a fraction of the fibres in the cross section. Increasing the twist helps to increase the force required to prevent slipping, but it also reduces the strength owing to the inclination imparted to fibres. Thus, there exists an optimum level of twist at which the yarn formation is good. Extensive experimentation and practical experience has shown that the PSF yarn needs at least 62 fibres in the yarn cross section to achieve adequate strength at such a level of twist. (To form a spun yarn on Open End spinning frame, we would need at least 110 fibres, therefore one has to use finer deniers on OE.) Experience shows that the number of fibres needed to ensure success of high speed spinning is around 80. Thus, for the currently available deniers, the upper limit of spinning is as follows.

	For normal spinning	For high speed spinning
0.8D	100s	80s
1.0D	80s	75s
1.2D	75s	60s
1.4D	62s	50s
2.0D	40s	–
3.0D	30s	–

The variability in denier is as important to the spinner as the variability of spun yarn count is to a weaver. Normal value of coefficient of variability (CV) of denier is 4–6%. Higher values indicate lack of control in the PSF plant and could lead to poorer yarn strength, more strand or yarn breakages at every stage, and greater unevenness in down stream spinning.

Tenacity

PSF is available in the following tenacity range:

Super high tenacity	–	7.5 g/d
Normal high tenacity	–	6.2–6.5 g/d
Medium tenacity	–	4.8–5.2 g/d
Low pill fibre	–	3.5–3.6 g/d
Super low pill	–	2.8–2.9 g/d

The super high tenacity fibre is used mainly for making 100% polyester sewing threads for stitching blended polyester apparels. For high speed spinning, the normal high tenacity fibre is preferred. The medium tenacity/low pill/super low pill fibres cannot be run at high speeds. The low pill fibre is available in the denier range from 2.0 to 4.0, and is meant mainly for suiting as the end use. The super low pill fibre is meant for polyester–wool or polyester-worsted suitings.

The elongation at break decreases as the tenacity, g/d, increases. The values obtaining today denier wise are as follows:

High tenacity denier	Elongation % at Break
0.8	12
1.0	14

1.2	16
1.4	18
2.0	22
3.0	25

For medium tenacity fibres, the % elongation is much higher:

3.0d: 40–45%; 2.0d: 25–30% and 1.4d: 20–25%

We have two technologies for the manufacture of PSF. One is German, Zimmer/Fleissner, in which fibre is made with comparatively lower values of percentage of elongation at break. The other is Japanese wherein the percentage of elongation at break is always higher. To give an example: for 1.2d × 44 mm fibre—the German equipment would give tenacity of even 6.8 g/d and elongation at break of only 17–18%; whereas the other equipment would give a tenacity of 6.4 to 6.6g/d but elongation of 21–22%. The polyester fibre with higher elongation at break gives higher yarn strength in polyester/viscose blends, since the elongation at break of the viscose fibres is also high. Thus, at the time of break, the load sharing between the two types of fibres is better.

Tenacity @ 10% (T10)

This value of tenacity at elongation of 10%, T10, is important in blend spinning with cotton, for this value is directly co-related to blend yarn strength. Since the elongation of break of cotton fibres is of the order of 8–10%, the load sharing at the time of break is better when the polyester fibres develop high stress at such elongations. The actual value of tenacity @ 10% elongation can be determined precisely from the stress/strain curve of the fibre. Values of T10 for high tenacity 1.4d are around 4.8–5.0, for 1.2d around 5.0–5.5, and for 1.0d around 5.5–5.8.

In fact, the value of 10 for the percent elongation has been chosen because the percent elongation at break of cotton fibre is around 8–9%. Since the percent elongation at break of viscose is around 13–14%, many spinners ask for T14 i.e. Tenacity @ 14% elongation.

Clearly, T10 or T14 is neither meaningful nor important while spinning 100% polyester yarns.

Crimp number (CN)

This is the number of artificial crimps or waviness introduced in the fibre. This number does not vary much with different fibre producers. It is around 12 ± 2 per 25 mm for finer deniers like 0.8/1.0/1.2/1.4 and is 10 ± 2 per 25 mm for coarser deniers like 2.0 and 3.0. Crimps are put in the fibres to develop cohesion between fibres, and it is only because of sufficient crimping that a card web gets formed and a sliver is produced and maintained. Crimps lower and higher than those specified above would lead to processing problems. Lower crimps give problems at cards—web would fall down; sliver would be very open and bulky; and during drafting, fly generation would increase. Higher crimps do not allow easy drafting; and sliver would have noticeable thick and thin places. The quality of cohesion given by crimps is far superior to the cohesion generated by spin finish.

% Crimp stability (CS)

If a crimped fibre with Co crimps per cm is straightened and released 500 times, and the residual crimp left is Cr, then
Crimp stability % = Cr/Co × 100.

A good value for this property is 70–75%. It is not enough to have 12–10 crimps per 25 mm for finer fibres, the crimp stability of 70% is also required. If percentage of crimp stability is lower than, say, 60%, then the fibres would lose crimp very heavily during drafting—especially at draw frames—leading to high fibre loss. This could be so bad that up to 30% or even 40% of fibres could get lost, as if some suction force has been applied above the draft zone. This CS is related to the temperature of the fibre tow during crimping. This temperature should be around 100 °C. An easy way for a spinner to test this property CS for the fibres being used is to count crimps per 25 m of polyester fibres in finisher drawing sliver. This value should be around 10 for finer fibres and 8 for coarser fibres. If so, then the crimp stability is 70% plus and a spinner need not worry about too much fibre fly occurring.

Crimp take-up (CTU)

Polyester fibres can be crimped with shallow or deep crimps. Deep crimps are preferred as they gives much better cohesion with lower number of crimps per 25 mm, which helps in making the drafting process smoother. Crimp take up is measured by first keeping a relaxed fibre on the foot rule, measuring its relaxed length; then gently straightening it, and measuring the straightened length—taking care not to stretch the fibre during this measurement. Then

CTU % = Straightened length/Crimped length × 100. A good value of CTU is around 15–17%. A lower value indicates shallower crimps.

Oil pick-up (OPU)

This is a measure of percentage of spin finish put on the fibre. A spin finish can contain up to 18 different compounds. These are chemicals that control fibre to fibre friction, which is held at a high value of 0.40–0.45 μ. The fibre to metal friction is maintained very low between 0.10–0.15 μ. Then there are compounds that do not allow bacterial growth in spin finish when fibre is stored in godowns; and also added are chemicals to ensure low foaming on draw lines during fibre manufacture.

Oil Pick-Up is measured by a solvent extraction method, but it takes several hours to get the result; so fibre producers follow a short 30 minute rapid extraction method to get a fairly accurate value of OPU. This method is good enough for controlling OPU quickly during production of polyester staple fibre.

Normally, the manufacturers of spin finish suggest that a specific level be maintained by the fibre producer; usually this level is 0.14–0.15% on weight of the fibre material. Thereafter, the 'Technical Services Department' of the fibre producer checks the actual performance of the fibre in different customer mills and then does the required fine tuning of the percentage add on of the spin finish.

Lower levels of spin finish would lead to generation of high static charge at the card. This would make the card web turn upwards towards the doffing roller and get lapped over it. The sliver would become very bulky and choke at the coiler calendar rollers. This lower add on of spin finish would also result in high fly generation. It would also cause frequent bottom roller lappings at every machine and at drafting zones. Higher spin finish would lead to a very compact sliver, and may cause drafting problems and would lead to frequent lappings of fibres on the top rollers at every machine.

In India, fibre producers offer fibres with just one level of spin finish to all spinning mills irrespective of the machine speeds in the mill and the season of the year. A mill, which runs cards with card sliver delivery speeds of around 200 m/min, draws frames at over 50 m/min, roving spindles at over 1000 rpm; and ring frames at spindle speeds of over 20 000 rpm needs a much higher level of spin finish up to 0.18–0.20%. Such a mill needs to use an over spray system in the mixing room, and add extra finish on the fibre to make it work satisfactorily.

Outside India, mills do not overspray and so, a fibre producer has perforce to make fibres with 2 or 3 levels of spin finish to suit different mills, since the customer needs have to be satisfied for staying in the market. If the fibre producer wants to retain mills that run polyester and blends at higher speeds as his customers, then he needs to cater to their specific need by supplying fibres with the right amount of spin finish.

Dry heat shrinkage (DHS)

This is the percentage shrinkage shown when PSF is held at 180 °C for 20 minutes. Internationally, this value is around 4%. This value is loosely related to the amount of finished fabric—whose shrinkage in boiling water is less than 1%—obtained from 100 m of grey fabric. A good value is 97 m. A fibre with a DHS of 8% may give 95 m of finished fabric. A 2% loss in length is quite costly to a dyer or a chemical processor.

Dyeability-merge number

Every PSF producer holds a bale of 'standard' fibre whose dyeability is 100 on computer colour matching system. Every day, a sample from the day's produce is dyed along with a sample of standard fibre and dye take up of the daily sample is compared with the dyed 'standard' fibre. If the dye take up is within 100 ± 4, which is the international standard, i.e., between 96 and 104, the day's supply is marked with the same standard merge number 10 indicating that there is no variation in dyeability.

The merge number put on the bales of polyester fibre has alphabets and numerals denoting the lustre, denier, cut length and the dyeability.

The alphabets for lustre may be: FB (full bright), B (bright), SD (semi-dull)

The denier could also be shown as alphabet: A = 0.8d, B = 1.0d, C = 1.2d, D = 1.4d etc.

The cut length of the fibre may be denoted by a single numeral: 3 for 38 mm, 4 for 44 mm, 5 for 51 mm and a two digit code for dyeability.

A typical example is: BA3-10.

This stands for Bright, 0.8d, 38 mm, and a standard dyeability of 10 making it a fibre of standard merge. If dyeability goes high, then the last number could go up to 11 or 12 as the case may be; and if the dyeability goes down, then this number could be 8 or 9 as the case may be. Normally, only a small proportion of about 3–4% of the total fibre production shows higher or lower dyeability than the standard 10. Such fibre bales are marked with appropriate low or high merge numbers are sold to those customer mills where the end use is not for dyed fabrics, or where the need for stringent quality control does not exist in the markets they operate.

In view of the above situation, the recommended general practice for mills working with polyester fibres consists of two DON'Ts: do not mix bales with different merge numbers, even from the same fibre producer; and do not mix fibre bales supplied by different fibre producers. These precautions are recommended to avoid any possible problem of streaks in the dyed fabrics, knitted as well as woven.

Exceptions do exist. In Indonesia, one blend spinning mill routinely blended PSF from 2 or 3 different fibre producers. The biggest surprise was that even though mills altered the percentage of each brand of fibre in the mixing quite frequently, the mills claimed they have never received any dyeability related complaints.

One fibre producer from Indonesia manages the range for dyeability within ±1 of 100, in place of the accepted limits of ±4. This fibre producer guarantees that a spinning mill could take any single bale, Bale 1, of its fibre any time and spin 100% polyester yarn out of the bale. Then take another Bale 2, spin this bale to the same count in 100% polyester and creel 50% cones from Bale 1 and 50% comes from Bale 2 in a creel on a circular knitting machine. Dye the knitted fabric, the fibre producer guarantees that no streakiness at all will occur. Mill experiences have verified such claims.

Fused fibres (FF)

Fussed Fibres are those where two or more fibres get fused together at some places along their length. These include the 'married fibres' as well. Married fibres are those fused all along their length. These are formed mainly during the melt spinning operation. PSF producers assess these by carding 10 kg of fibre on a standard card, collecting the flat strips produced and then removing fused fibre bits/hard bits/married fibre bits and weighing them. International standard upper limit is 30 mg of all fused and related fibres per 10 kg of fibre. One PSF producer from Indonesia maintained an unbelievably low value of 5 mg of fused fibres per 10 kg of fibre, showing thereby the level of excellence that can be reached in fibre production. Fused fibres—being totally amorphous in nature—take up very deep colour on dyeing. If a fabric were to contain a larger quantum than the standard 30 mg per 10 kg of fused fibres, the dyed fabric would exhibit several dark dyed spots.

Long fibres

Any cut fibre whose length is more than the nominal cut length by 10 mm is considered as an 'over length' fibre. Multi lengths are fibres whose cut length is 2 or 3 times the nominal cut length i.e. in fibres with nominal cut length of 38 mm, multi lengths could be 76 or 104 mm in length. The usual standard for long fibres—over lengths plus multi lengths—is that they should be less than 20 per gm of fibre.

Diethylene glycol (DEG)

DEG is generated during polymerisation and the quantity generated is normally around 1.00–1.25%. In a way, the amount of DEG controls the dyeability of the fibre. Higher DEG content would lead to higher dyeability, but would affect the tensile properties adversely. Some manufacturers of partially oriented yarn (POY) add a small quantity of DEG along with TiO_2

and a catalyst at the start of polymerisation to improve the dyeability of their products. PSF manufacturers do not add DEG.

Surface oligomers

Oligomers are polyester polymers of low molecular weight in the range of 3000–4000, and a small percentage of around 1% is produced during polymerisation. Whenever fibre to metal friction occurs during the processes of spinning, these oligomers can come out as a fine powder and get deposited on the surfaces. If the amount of surface oligomers is greater than 1% due to some thing going wrong in polymerisation, the effect is seen on ring frames at the travelers. The entire ring rail would get covered with a fine white powder. Fortunately, this phenomenon does not hurt either the spinning performance in terms of end breakage rate or the yarn quality.

However oligomers do pose a fairly serious problem during spinning of dyed polyester fibres. When the polyester staple fibre is dyed at 130 °C in a HTHP (High Temperature High Pressure) dyeing machine for more than 40 min as required for dyeing of dark and extra dark shades, then oligomers from the core of the fibre migrate to the surface. Then the oligomers on the fibre surface go up to 3.0–3.5%. If these are not removed during reduction clearing, then the speeds of all spinning machines from card to ring frames would be affected and may have to be reduced. However, if an oligomers remover like Hoechst's Leomin OR is added to the reduction clearing bath in concentration of 1.0–1.5 g/l, then most oligomers get removed. Electron microscope photos of surfaces of PSF dyed using Leomin OR show quite clean surfaces compared to the surfaces of PSF dyed without the use of Leomin OR. Extensive consultation experience in several mills has shown that the use of oligomers remover of the right kind helps mills to speed up all spinning machines easily by 15%, and sometimes even by 25%.

COOH group

The number of COOH group is around 30–35 for polymer made on a continuous polymerisation process, and 60–75 for polymer made on a batch plant. COOH Groups have no effect on spinning of PSF.

L Colour: In the L a* b* system used for colour measurement with spectrophotometers and computers, the L number is a measure of whiteness, where the standard of whiteness is magnesium oxide, which is taken as 100. Most PSF get values of 90–92.

b Colour*: The b* value of the polymer is a measure of its position on the yellowness to blueness axis. Every PSF plant produces PSF of a 'b' colour within a narrow band—could be of 1.0–1.2 or some other values. If the polymer suffers some chemical degradation during manufacture, then the b colour will go up depending upon the amount of degradation. If the b colour were to shift from 1.0 to say 1.4, in one batch, then the yarn spun from PSF with a 'b' colour of 1.4 may get wound on the same cone where the normal yarns of b colour 1.0 are wound. On such cones containing mixed yarns, the yarn with 1.4 of b colour would give higher fluorescence under UV light causing rings to appear during inspection of the cones in a UV chamber. If the b colour shifts by more than 0.4 or so from the normal value, then the higher degradation could cause dye variation. In actual practice, by and large, the presence of rings under UV light does not affect the dyeability of the fibre.

Intrinsic viscosity (IV)

The PSF polymer meant for apparel end use is kept at an intrinsic viscosity of around 0.63. For polyester meant for Pet bottles, this viscosity is higher at about 0.80. The intrinsic viscosity of the polymer is directly related to the tenacity of the fibre. PSF which are of low pill type have lower IVs of around 0.50.

Melting point (MP)

The melting point is characteristic of each kind of polymer. Melting point of normal PSF polymer is around 260 °C. Fibres can fuse or melt if the temperature reaches such high values any time during processing them in spinning or chemical processing. However, such a situation does not occur at all.

Titanium dioxide (TiO_2)

TiO_2 is a dulling agent added to the polymer. The normal levels of TiO_2 in different lustre are:

TiO_2 (%)	Lustre nomenclature
0.05	Super bright or full bright
0.10	Bright
0.20–0.30	Semi-dull
0.50	Dull
0.70	Extra dull or full dull

Sewing thread fibres and trilobal fibres are usually made in super bright lustre. Bright fibre usually has some optical brightener added along with

TiO_2. Semi-dull—the most popular lustre type—has normally 0.30% TiO_2. Dull and extra dull fibres are used for ornamentation to form shadow stripes in the fabric.

Optical brightener (OB)

Optical brightener or Optical whitener is added to give a 'white' look to the final fabric. OBs are available in reddish, greenish and bluish shades, but the last one is more popular. The OB compound is added along with TiO_2 and catalyst before the start of the polymerisation. Normally, about 180–200 ppm is added. The North American market takes only OB-added fibre.

Yellowing of polyester blended white fabric takes place because of UV radiation in sunlight. Addition of OB in the polymer slows the yellowing of the white fabric.

Overview

This brief descriptive and simplified write up will enable spinners to understand the interrelations between various fibre properties and the performance of the PSF in a—spinning mill. The spinner will attempt high speed spinning only when the fibre type being used by the mill permits high sped spinning. In case the spinner faces working difficulties or quality problems when working with PSF or blends, he/she would be in a better position to take appropriate corrective actions. More importantly, he would know whether the fibre is likely to be responsible for the felt trouble, or the working conditions and parameters under his/her control.

Capability of the mill

A spinning mill desiring to run their ring frames at high speeds has to satisfy the following pre-conditions so as to ensure success in their efforts.

Ring frames

The mill must have modern ring frames like Lakshmi's LR6 or Kirloskar Toyota's RXI 240 with the right HP of the main driving motor. These ring frames are designed to run at the maximum speed of 25000 rpm. As mentioned earlier, this is the highest commercial speed possible in the world for ring frames. If a mill does not have these modern ring frames, it could think of modifying their existing ring frames like Lakshmi's G 5/1—if in good mechanical condition—to be able to run at higher speeds of 20000 rpm plus. Some mills have followed this path; but it must be stated that the number of mills that have modified their ring frames to run at high speeds is very few indeed. This possibly is not the best method, though it is attractive in terms of low cost of change over. More mill experience is needed to give clear cut views on the possibility of converting existing ring frames of different makes to high speed spinning frames.

However, those mills that run their polyester or blended counts at speeds much below the mechanically feasible highest speed recommended by the makers should make a serious effort to reach that level of spindle speed.

When a mill with LR6 or RXI 240 type ring frames runs them at a maximum speed of 18000 rpm, it should plan to run these ring frames at spindle speeds of over 20000 rpm depending upon the count being spun. Today, the maximum speeds being used in India on high speed spinning are as follows: for grey fibres: 20s – 20500; 30s –22000; 40s – 23000; 60s – 24500; and for dyed fibres: 20s – 20500; 30s – 22000; 50s – 22000.

Balancing preparatory

The first point a spinner should consider is, "Will my spinning preparatory equipment be able to feed the ring frames if run at the desired high speeds?" In most mills, spinning preparatory and ring spinning are well balanced. Very few mills have surplus production of spinning preparatory. So, a spinner must look at the following points:

- Going coarser by 10–15 % in spinning preparatory.
- Ensuring that all his spinning preparatory equipment is being run at the highest speed. Many mills run preparatory machines at much slower speeds e.g. DK 780 cards running at 100–120 m/min, whereas these machines can easily run at 180–200 m/min without any loss in quality of yarn. Similarly, several mills run RSB 851 Draw frames at 450 m/min, while there are mills that run this machine even at 750 m/min.

Extensive research work done in the Indian textile research institutes have shown that the draft at cards plays no role in the quality of sliver, assessed always on the basis of yarn quality parameters. At cards, the production rate should be increased preferably by speeding up the doffer delivery (as recommended above), than by coarsening the hank. For a given production rate in kilogram per hour, the combination of highest doffer speed with the finest hank delivers the best quality at that production rate. Therefore, card sliver may be made coarse by up to 10–15% after the maximum doffer speed is used, and the balancing requires further increase in production.

At draw frames and speed frames, small reductions in the total draft, made by adjusting the front zone draft, to make the strand coarser are beneficial for quality. The ring frame drafting conditions need to be re-optimised if the draft has to be increased to take in the coarser roving as feed.

Testing laboratory

The spinning mill must posses a fully equipped physical testing laboratory, wherein the following instruments are a must.

1. Latest model Uster evenness tester with imperfection indicator and spectrogram.
2. Uster Classimat system.
3. Uster Tensorapid or Tensojet single thread strength tester
4. Roller eccentricity tester
5. Duroshore hardness tester for cots
6. A manometer to measure vacuum in suction clearer tubes at fly frames and at ring frames
6. A meter to measure top arm pressure – TARP gauge
7. Stroboscope – optional
8. Single thread twist tester
9. Yarn appearance board winder and ASTM boards
10. Thermohygrographs – daily and weekly models.

Here, the trade names or specific manufacturer is mentioned with a view to make the level of sophistication required in the test instruments clear. Instruments from other makers with similar outputs can be used equally effectively.

Today, most modern spinning mills do possess Uster evenness tester with imperfection indicator. Spectrogram is also usually purchased, but is not regularly used. However, if a mill wants to run ring frames at high speeds, analysing spectrographs, particularly at draw frames, is imperative. The Uster Classimat system is necessary for mills that export yarns and are particular about quality. Uster Tensorapid or Uster Tensojet single thread strength tester is needed to measure the single thread strength and the percent elongation at break.

The next set of small instruments given under 4–11 help a mill to maintain its equipment in top condition all the time. The Roller eccentricity tester is used to measure eccentricity of bottom rollers, mainly at the front pair of drafting rollers at ring frames. The roller eccentricity should be less than 0.008 mm. Duroshore hardness tester is used to check the exact hardness of the cot. Normally for polyester blend spinning, a value of 83° duroshore hardness is recommended for the front top rollers at ring frames. Softer cots of 70° duroshore hardness do give advantage in evenness and imperfections, but wear out much faster. Also they could get damaged easily.

A stroboscope enables the spinner to watch the actual movement of traveler rotating at tremendously high speeds along the ring at visually 'slow speed'. Such observation can help in choosing the right type of traveler in terms of its weight, shape and wire cross-section. Stroboscope enables the spinner also to observe the balloon shapes while running the spindle at high speeds. Such observation helps to adjust the position of balloon control rings and also to check the amount of bulging of the balloon at the BCR and possible lashing against the balloon separators.

The utility of twist testers and yarn appearance board winders is well known. In spite of using instruments like the Uster imperfection testers, many spinners still do get appearance boards made to judge visually the appearance of the yarn in terms of its unevenness and, especially, the neps. After all, the market judges the final product, yarn or fabric, by visual observation, which is known to be quite sensitive to even small differences and integrates the information in a different manner than any instrumental measurement.

Production staff

The production staff should ideally work as a team and should be fired by a burning ambition to run their ring frames at the real high speed. The head of the department must provide the leadership to weld all the staff into a fighting team, both by appreciating good work and pulling up people gently but firmly if they make mistakes or have overlooked details. He must himself be fired to run his ring frames at good high speed and must lead discussion on this subject frequently.

Quality assurance

To be able to run ring frames at high speeds continuously, day in and day out, several checks have to be made daily on every machine in the department from cards to ring frames. A high-speed spinner cannot afford to have 'off spec' working at any machine since it could hurt the working at ring frames. Therefore, a well-staffed, active and alert Quality Assurance department is a must. The head of the QA Department should be a qualified textile technologist, preferably with R&D (research and development) background, so that he/she can design experiments on the shop floor and use statistics to draw the right conclusions with less effort and at low cost. Only a skeleton staff is recommended in the night shift to carry out studies like snap rounds in ring frame section for counting cause wise spindles not producing yarn. The staff has to be trained to specifically look for and identify bad working machines and also workers giving poor performance. If a machine/worker shows 'off spec' working, then QA should immediately alert the shift in-charge/senior staff members so that they can come to the shop floor and take immediate corrective action. QA should continue to monitor the concerned machine or worker till its performance is back to normal. Speed—quickness of actions—is essential here to ensure that off spec working is controlled as soon as possible, and is almost eliminated.

A library of textile books should be part of the QA department. Also, mills should subscribe to several textile magazines, which QA should circulate. Also, if there is a specific article on a subject of direct interest to spinners, QA should summarise the article and circulate the same to all technical personnel in the department. Mills should encourage QA personnel to attend conferences and technical seminars along with production personnel and on returning, QA person should circulate a summary of the proceedings to all.

Labour unions

The last, but the most important point is that the management must take the labour union(s) into confidence before starting any trials for going over to high spindle speeds. The unions must be assured that a revision of salary could be done if high speed spinning trials are a success; so that the unions do not resist or stop high speed trials. In some mills, unions have not allowed ring frames at higher speed even when the trials were a success. In some other mills, union allowed only two or four frames to be run at high speed and stopped speeding up of the remaining ring frames. While by and large, end breaks per 100 spindle hours do not go up appreciably, the roving replacements increase proportionally to the increase in productivity. Also, the number of doffs per shift go up. As is well known, about 10–15% of ends break during the operation of doffing. Though help is made available to the tenter for piecing such breaks at the start of a new doff, his/her workload does increase somewhat when the number of doffs increase. Finally, the ring tenter has to repair the breaks; so over all a ring frame tenter's work load does increase at high spindle speeds. As indicated earlier, this increase would still not take the workload of the tenter to the expected level of 85%, for which he is supposed to be paid. This can be checked by conducting fresh work load studies; and the exact amount of increase in the work load should be determined. Managements should take this into account while negotiating higher wages, which are expected to be given to the worker group at ring frames on the principle of sharing the monetary gains of the mill with the concerned workers. It is to be emphasised that such increase in workload does not take place at any other stage because of going over to high speed spinning; neither in the preparatory, nor at the post spinning stages.

Mill managements must be generous in rewarding technical staff, including QA staff, when high-speed spinning becomes a success. The reward may not necessarily be in monetary terms but could be sending the employee and his family to a nearby hill station or a resort for a few days, gifting some useful items such as a Plasma TV or a home theatre or something similar.

Or a wonderful party may be thrown to all the staff with their wives. What is being given is incidental; it is the gesture that a person's contribution to enhance the productivity with high speed spinning of polyester blends is being recognised by the top management is really important. Experience in a few mills shows, the top management just ignored the achievement of those who helped to run polyester blends at high speed and that led to loss of morale and migration of staff to other mills.

4

Control on Processing Parameters

Let us now assume that a blend spinning mill meets all the pre-requirement to run their ring frames at higher speeds. This mill has the right kind of ring frames, the spinning preparatory is in a position to produce the extra production needed, the quality assurance staff is well-trained, and has a good testing laboratory at their disposal. The production staff is enthusiastic and the labour unions are willing to help.

But even then, the mill just cannot speed up the ring frames. It still needs to take several steps to ensure that

- The proposed increase in ring frame speed does not lead to any noticeable deterioration in spinning performance, vital yarn properties and winding cuts.
- The consistency of 'good' working at all machines has to be maintained over long periods of time extending over several years.

It should not happen that after sometime, say, a year or two, a slow and gradual deterioration sets in. And then one day, suddenly, the mill finds high-speed working to be a miserable failure. In other words,

- There should be a built-in mechanism to check for any deterioration and for alerting all concerned as soon as any deterioration is detected. The 'who' and 'how' of all possible corrective actions has to be pre-decided, so that the responsible person takes the right actions quickly for improving the situation back to normal.

Since a large percentage of mills work with grey—undyed—fibres, we will consider the precautions to be taken for grey fibre spinning first. We will then follow up with spinning of dyed fibres in comparison with that of grey, bringing out the additional precautions to be taken. Thereafter, working difficulties common to both will be dealt with based on case studies.

Spinning of grey polyester blends

Mixing of bales

The mill must blend bales from at least 4 different trucks when issuing bales daily to blowroom, essentially to ensure a uniform quality of feed over a long period, e.g. if a mill uses 16 bales per shift, then these 16 bales should be taken randomly from 4 trucks, taking 4 bales per truck.

Fibre producers, by and large, tend to dispatch bales of 'A' grade quality serially to mills, i.e. Bale no. 1–30 go to Mill A, 31–60 to Mill B and so on. At present, the draw line—the final machine on which fibre is made—has high capacities of 120–200 tons/day, i.e. 5–8.3 tons/h. A truck holds 10 tons of fibres. This quantity is made in 1h 15 min to 2 h of production. In these 2 h or so, the essential fibre properties like the values of spin finish, crimp and dyeability do not fluctuate; they remain absolutely steady. But from day to day, there will be some variation. Normally, such variation is within narrow limits that could be different for different fibre producers. Let us take an example, Indian fibre producers have a limit of 100 ± 8 for dyeability, which means fibres with a dye take up of 92 and that of 108 would have the same merge. Let us assume a mill gets one truck of a dyeability value of 92 and the next truck has this value as 108. As is the practice today, a spinning mill takes bales from the first truck until all bales get used up. Then the mill takes up bales from Truck 2. Yarns spun from Truck 1 and Truck 2 can come together on one or on several cones at winding, and also in the fabric in both warp and weft. With certain sensitive dyes this could result in the formation of streaky dyeing with warp way streaks or of weft way bars. By blending bales from say 4 trucks, the variation in the vital fibre properties gets evened out, and the feed to cards is material of homogenous quality. That the fibres produced on different days are somewhat different in their characteristics is a result of the natural phenomenon of variability, the fibre producers strive to keep such variability to the lowest level possible. However, fibres produced on different days would always have some small amount of differences in quality characteristics, as experience in technical service departments of fibre producers has confirmed. Therefore, blending bales from at least four different trucks is strongly recommended.

Fibre producers are normally reluctant to blend bales made on different days in one truck. One fibre producer is known to follow the practice of blending in one truck bales made on 10 consecutive days by picking up 3 bales from each day. This fibre producer has not received a single complaint of dye variation for over 10 years. So, spinners who are lucky to get a truck in which fibre bales made on different days are mixed do not need to blend bales from 4 trucks.

In modern mills, like most mills in Indonesia, polyester blend spinners use automatic blending systems like Blendomats to feed polyester fibre to the blow room. In such systems, 36 bales are lined up and the bale plucker takes a little bit of fibre from each bale. If these 36 bales are taken from 4 trucks—9 bales from each truck—this method would mean a blending of bales over 40 days. When such blended material is fed to the blowroom, the feed is absolutely uniform and so, in turn, is the working steady and uniform at all the stages of spinning preparatory and ring spinning. The day-to-day variations in yarn properties are observed to be nearly absent.

So, either a fibre producer should blend bales made on different days whilst despatching fibre to mills, or a spinning mill has to do the blending of bales made on different days—so that finally the feed in the mill is uniform, which will give consistent working at all machines at all times.

Adding spin finish

In India, the blend spinning mills are not air conditioned; only air cooling type of humidification is provided, not refrigerative cooling. In many mills, humidity levels are controlled manually and, in many others, automated systems are in use. Where the system is manually controlled, the variation in RH is relatively higher. Therefore, some variation in RH of the department occurs in the day, from morning to noon, and from evening to night. As seasons change from summer to monsoon and to winter, the average level of RH can be maintained somewhat, but the temperature can not be controlled independently of the RH, as is possible with full air conditioning using refrigerative cooling. Moreover, each spinning mill sets its own standards of RH to be maintained in the department. Therefore in India, the fibre producer delivers fibre with a uniform add-on percentage of spin finish to all mills, irrespective of the machine speeds (In Indonesia, as mentioned earlier, a fibre producer has to deliver fibre with 2 levels of spin finish: 0.15% for mills running their cards at 90–100 m/min, and 0.20% for units which run their cards at 180–220 m/min. Excepting India, spinners in other countries refuse to add spin finish themselves). Therefore, in India, particularly for polyester/viscose blends, mills have to put an overspray on the polyester component. The standard method is to make an emulsion of an anti-stat—a chemical formulation to prevent generation of static electricity at points of contact of polyester fibres with metals—and a cohesive agent in proportion of about 85:15 and to spray this solution manually on the polyester component during building up of blend stacks. Such spraying is done by unskilled workers and is in most cases very uneven. There could be portions of fibre that have two or three times more spin finish than required, and there may be other portions which are relatively dry and have not received any finish at all. However, it is hoped that while the stack is held for 24 h after spraying, some re-distribution of spin finish would probably take place. Also, this method involves workers weighing polyester and viscose fibre separately, bringing the fibres to the stack area, spreading the polyester fibre evenly, spraying the finish, then laying viscose uniformly, and so on until the stack of 3–7 tons is made. The stack is kept for 24 h and then vertical cross-sections are taken and fed to the blowroom.

The manual spraying system should be replaced with a fully automatic spray system by every mill which wants to opt for high speed spinning. Such a system has been available in India for the past 10 years or so (under the trade name of Unispray). Any such system has the following features:

- A large capacity tank to make a finish solution of a standard strength, say 1%
- One small stainless steel tank near each hopper bale breaker—(assuming the mill has more than one line)
- A gear box for driving the finish pump; the amount of spin finish to be sprayed on the fibre is controlled by changing the change pinion on the gearbox
- An oscillating arm with a very fine nozzle to spray the spin finish in a fine mist on the fibre which is moving up on the inclined lattice and on lumps moving down after being thrown by the evener roller
- An inter-lock system to stop spraying if the bale breaker stops for any reason.

This system gives an absolute uniform percentage of additional spin finish on the fibre. Since the finish is sprayed in a very fine mist, the fibre lumps do not get wet as such; and the material that goes to chute feed cards works without any problem at the cards.

Another advantage of the automatic system is that the manual process of stack mixing gets eliminated, leading to saving of labour cost. Mills need to put weighed quantities of polyester and viscose on the creeper lattice. In the process, viscose fibre also gets some additional spin finish; but this does not hurt the fibre performance at machines.

Over 100 spinning mills in India have already installed automatic spraying system. It is strongly recommended that any mill desirous of improving productivity and profitability by going for high speed spinning should install such a system before making any attempt to speed up the ring frames.

The performance of fibre at each machine from carding onwards must meet the conditions stipulated hereafter, so that the change over to high speed spinning becomes sustainable successful.

Carding

The unevenness of the card sliver should be around 3.5–4.0 U% and the variability of 5 m (6 yd) wrappings should be around 0.5–0.6 CV%. Neps in the card sliver should be 1.0 neps/g or less. There should be no measurable static charge on the web; instrumental measurement should show nil or a negligible reading. The card web should be clean, transparent to about 90% and should not show any neps, entangled fibres, fibre clusters and fused fibres. The sliver breaks at cards should be almost nil per shift, and the running efficiency of the cards should be 97%.

Cards are being run up to 200 m/min on grey fibres. Therefore, to ensure good quality, the card clothing should have 750 or more wire points per square inches cylinder-flat settings of 10, 10, 10, 8, 8 thou give very good results, also in terms of removal of fused fibres, etc in the flat strips. Excellent maintenance at cards and a good control on the feed from the blow room ensure that such levels are achieved and maintained at cards.

Autolevellers at cards do not contribute much towards reducing the variability of 5 m wrappings. This is not surprising, since cards are mostly equipped with long-term autolevellers, and even the medium-term autolevellers at cards cannot deal with such variability. CV of card sliver wrapping as high as 9% has been found in a mill with autolevellers working on every card in the mill. This, evidently, is an extreme case. It is important to understand that CV% of card wrappings of around 0.5% is achievable with or without autolevellers at cards. It is advisable to have autolevellers at card to ensure that the long-term variability of the delivered sliver material is well-controlled.

As we have seen earlier, the short- and long-term variability of the yarn has a major influence on the breakage rates at ring frames, especially at very high spindle speeds. The yarn variability is measured only at two cut lengths of about 1 cm (U %) and 100 m (lea count CV%). But even the very long-term variations over say 1000 m also affect the end breakage rates. The U% of card sliver, which indicates variability of cut length 1 cm at the card, corresponds to a cut length of about 20 m in the yarn (The length gets multiplied by the drafts at draw frames, fly frame and ring frame: say $8 \times 8 \times 10 \times 30$ = approx 2000). Therefore, a good control on the U% of card sliver improves the control over the relatively medium-term variability at the yarn stage. It is true that the impact of card sliver variability is reduced considerably because of the 64 doublings that take place at draw frames. This reduces the variability to one-eighth of the original. Therefore, this U% of card sliver is not of much importance to mills that run their ring frames at comfortably low speeds. But for those mills that need to keep the end breakages down to 3–5 per 100 spindle hours even at spindle speed like 24 000 rpm, a strict control on card sliver U% is unavoidable. Similarly, the 5 m wrapping at card corresponds to 10000 m of yarn, and its control helps to keep the very long-term variability of the yarn at the low levels needed for high speed spinning.

Draw frames

At the draw frames, the standard doubling and drafting of 8 × 8 is to be adopted. In one mill, the CV of card sliver wrapping (5 m) was as high as 9% and the mill was doing a doubling and drafting of 6 × 6. A change over to doubling and drafting of 8 × 8 showed that the CV of finisher drawing sliver (5 m) which was earlier as high as 0.70% came down to 0.35. Here, too, the theory of doublings works in practice. When the total doublings were increased from 6 × 6 = 36 to 8 × 8 = 64, the expected improved variability is given by (original CV% × $\sqrt{36/64}$) = 0.70 × 0.75 = 0.49.

The unevenness—Uster U%—of the finisher sliver should be around 1.7%, in any case below 2.0%. The spectrogram taken at the speed of 50 m/min should show no peak anywhere in the range of wave lengths covered by it, from 3 cm to 5 m. CV% of finisher sliver wrapping of 5 m should be between 0.20 and 0.25, though the best achievable value would be as low as 0.15. To ensure this, the mill should check every week that the autoleveller on the finisher sliver is working properly. For this test, feed 7, 8 and 9 slivers, run the draw frame for few minutes each and take average of 4 wrappings every time. Ideally, the three averages should be the same; they may differ in the third decimal place owing to sampling variation (The expected error in the average values based on 4 readings is $2 \times \text{CV\%}/\sqrt{4} = 2 \times 0.25/2 = 0.25\%$). In case, a mill finds that the functioning of draw frame autolevellers is not consistent they can consider giving a service contract for maintenance of autolevellers to a reliable party.

These standards at the draw frames—U% of 1.6 and that CV% of 5 m wrappings 0.25%—are based on the working of certain 'good' mills in Indonesia. These mills get regularly around 3–5 breaks/1000 spindle hours at ring spinning when running their ring frames at 14000–16000 rpm. The best values in India for ring frame breaks are 3–5 breaks/100 spindle hours, i.e. the Indian values are TEN TIMES bigger! In view of this, these parameters were chosen for the very first consultation given in India for achieving high speed spinning of polyester blends. Consultation experience in many more mills showed that achieving these parameters really helped in speeding up ring frames up to 24500 rpm without any ill effects. The theoretical reasoning behind this phenomenon is easy to understand. These low values of variability at draw frames ensure that the medium- and long-term variations in the yarn are kept very low; U% of sliver corresponds to a cut length between 2 m and 4 m in the yarn, and the wrapping of 5 m corresponds to 1000–2000 m in the yarn. Therefore, the U% and the CV%

of 100 m of yarn remain low. As seen from the equation given in Chapter 1 for predicting end breakages from yarn quality, such low values would ensure that speeding up of the ring frame increases the end breakage rates only marginally. It can be said with confidence that the finisher sliver should be made as even and uniform as can be humanly possible under industrial conditions. Such extremely even sliver provides the strong base needed for high speed spinning to be run successfully and sustainably.

In mills that are very particular about their working, spectrogram is taken from each draw frame delivery once a week. Some of these mills have installed software that indicates the defective machine part when the spectrogram shows any peak or a bulge. Spinning mills keen on going over to high speed spinning are strongly recommended to acquire the right software and to use the spectrogram tests to keep the sliver as even as possible.

Speed frames

The unevenness of roving should be around 3.0–3.2 U% and should not exceed 3.5 at all. Knowing the U% of finisher draw frame sliver, it is possible to calculate the U% of roving assuming the drafting system at roving is adding only allowable irregularity. By and large, total draft at fly frame is between 8 and 10. However, a few spinning mills that use 11–12 of a draft at roving find their U% is high. Reducing the total draft to 8–10 reduces U%. Spectrogram of each of the 2 roving bobbins should be taken from near the gearing end, in the middle and from off-side, taking equally from front and back rows. This measurement on 12 bobbins should be repeated once a month. Here also, no peak in the spectrogram is accepted; and mills should get software to immediately identify the defective part. The CV of 15 m (15 yd) wrapping should be around 0.5%.

Breakages at roving should be controlled to less than 1 per 100 spindle hours. With modern speed frames, this performance is not difficult to achieve. An important check is on the stretch of the roving that takes place at the time of winding on to the bobbin. This should be checked at two positions of the doff: when the bobbin is empty at the start of the doff, and when it is full at the end of the doff. For doing this test, select full bobbins at random—4 from front row and 4 from back row. Take 4 wrappings from each roving and work out individual bobbin's average and an overall average. Then on the same spindles, put empty bobbins and run the roving frame until material equal to 4 wrappings (about 60 m) is wound. Then stop the machines, remove the bobbins and take the wrappings again. Work out the percentage stretch for each spindle from the wrappings of full and empty bobbins. The stretch should not be more than 1%, i.e. the difference in the wrappings from full and empty bobbins on the same spindle should be less than 1% (The error due to sampling variability is a maximum of +0.75%

to –0.75% of the average of 4 readings, when the CV% of wrappings is 0.5%. Therefore, even when no real stretching is taking place, a value of up to 0.75% is possible due to sampling error).

Ring frames

At the ring frames, U% and imperfections of the spun yarn should be between 5% and 25% of Uster statistics for the relevant count and blend. The CV% of lea count (120 yd or 100 m lea) should be about 1.3%. Breakages taken over a full doff need to be controlled between 3 and 5 breaks per 100 spindle hours. Alternatively, a snap round be taken in the entire ring frame section, noting down number of spindles that are not producing yarn due to various reasons such as spindle (single yarn) break, lapping on top or bottom roller, roving break or roving exhausted or roving missing, and any other cause including mechanical problems such as tape breaks. This total number of 'ends down' gives a good idea of the working, which includes the end breakage rate and the manner in which the tenters are performing their job. In the case of short ring frames of up to 480 spindles, 1 spindle per frame not producing yarn is acceptable; and 2 spindles per frame are acceptable for the longer ring frames from 481 to 1008 spindles. This technique of snap rounds is quick and accurate enough to give an idea of the working in the department because all ring frames are covered. Moreover, all positions of ring rail over the doff get included. Ideally, an average of 10 rounds spread over an entire day gives a reliable idea or working. The strong but complicated relationship that exists between the end breakage rate and the corresponding ends down loss has been well researched by ATIRA (End Breaks in Ring Spinning, by TA Subramanian and AR Garde, ATIRA, 1976). The way in which the tenter patrols the frames, and the time for which a spindle on which an end is broken waits for the attention of the tenter together decide the ends down loss for a given end breakage rate. The number of spindles 'not producing yarn' is also dependent on the working system of the tenter. We give below a couple of examples based on consultation given to mills. In a mill, 8–10 spindles per ring frame were found with top roller lapping. Immediately, the percentage of over-spray of the spin finish was reduced, which gave relief. In another mill, the total number of spindles not producing yarn was 8 per frame; and out of these, 7 were due to roving break or roving exhausted. Obviously, the tenters were slack. Explaining and talking to each worker and tightening the supervision to ensure that the tenters adhere to the right work practices brought this value down to 0.5 within a couple of days.

Two other checks that must be done at ring frames regularly, as are being done by excellent mills in Indonesia and India, are as follows: surface condition of top rollers and the suction clearer pressure. These may be started as daily checks and can be reduced to weekly checks if the incidence of unacceptable values is small.

- Check by visual observation the condition of surfaces of front top rollers for any kind of damage. The incidence of 'damaged cots', even in good mills, would be found to be 5–7%. Ideally, there should not be a single damaged cot working in the mill. What corrective action should be taken here? Can we recommend grinding of the entire set of top rollers on that side of the ring frame when this percentage goes beyond 15%? I suppose piecemeal grinding of only the damaged cots is not recommended nor done.
- The value of yarn clearer suction (such as the Pneumafil system) should be at least 200 mm of water on the off-side, i.e. near the end of the ring frame side away from the suction fan.

The control on the relative humidity (RH) in the department should be within ± 2% of the expected RH of 55% to be kept in the ring frames section. As mentioned earlier, thermo-hygrographs should be installed in the spinning department at a number of appropriately selected places. This instrument automatically records temperature and RH in the department continuously over 24 h; just one look at these graphs tells how good a control on temperature and RH the mill actually has. Thermo-hygrographs are relatively inexpensive and reliable, and need no labour except to change the paper once everyday. The number of air changes in the department does not need a separate control when the RH and the corresponding temperature are being controlled automatically; these usually lie between 25 and 30 per hour, but can range from 15 to 35. The number of air changes is neither a design factor nor a control factor: the number of air changes gets decided depending upon the volume of the ring frame department and the amount of heat load generated. The smaller the volume and the greater the heat loads, the more is the number of air changes. Therefore, when going over to high speed spinning, the number of air changes would increase to keep the RH at the pre-set level. Even the minimum number 10–15 is more than sufficient to keep the atmosphere in the department comfortable for workers.

Winding

At the winding stage, mills must ensure that the cuts per 100000 m are around 25–30; and that the increase in average yarn hairiness and average yarn imperfections is not more than 25% over ring frame values.

The cuts per 100000 m need to be controlled at this level in order to manage good machine efficiency of around 80% or more at automatic winding, while still clearing the yarn to get rid of more than 80% of the objectionable yarn faults. The settings of the electronic yarn clearers are done with this point of view. These settings should not be changed, should not be made less strict after increasing the spindle speed at ring frames. If the resultant yarn quality is not good enough in terms of incidence of faults (Classimat), these cuts will tend to increase. Such increase should be investigated and appropriate improvements should be made in the yarn quality to bring back the number of cuts to the level of about 30.

It is important to realise that increase of even 100%, i.e. a doubling of numbers on hairiness and imperfections can occur on spindle positions where the yarn guides and other items in the yarn path have damaged surfaces. A system of inspecting the surfaces along the yarn visually—and by touching the part with fingers where needed—about once in a month needs to be started and maintained.

Another useful check is to determine the number of winding cuts per 100000 m on rewinding the wound cones at the same speed and the same clearer setting. This number should ideally be zero, if the fault clearing efficiency of electronic yarn clearers is assumed to be 100%. In reality, this efficiency ranges between 80% and 90%, and any attempt to tighten the settings to get near 100% efficiency leads to excessive cuts due to unwanted breaks. Therefore, in mill practice, a value of up to 5 breaks per 100000 m at the re-winding test is considered acceptable.

Conclusion

It must be stated that each of the several mills running polyester blends at real high spindle speeds of over 20000 rpm have achieved and maintained the various parameters mentioned above. These mills run polyester blends successfully at maximum speeds ranging from 20500 to 24500 rpm, and at least one mill has been and is running at the spindle speed of 24500 rpm for the last 7 years continuously. Thereby, it is confirmed that

1. These values are practically possible to obtain under Indian mill conditions.
2. These values can be maintained over long periods continuously.

Spinning of dyed fibre

The properties of the polyester fibre change drastically due to the process of dyeing. There is a need to clearly understand the nature and severity of such changes, and appropriate modifications made in the processing parameters to ensure good working. Mills in the business of dyed fibres already make several adjustments, but the mills that want to go for high speed spinning need to be very particular in managing these problems arising from dyeing of fibres.

When PSF is dyed in a HTHP (High Temperature High Pressure) dyeing machine at 130 °C for approx 45–60 min, depending upon the depth of shade to be dyed, the following six changes take place in fibre properties:

1. Fibre length reduces by 7–8%
2. Fibre denier becomes proportionately coarser
3. Fibre loses its strength by 15–20%
4. Fibre crimps get reduced by 10–15%
5. Oligomers from the core of the fibre come on the surface, and add to the 1.0–1.25% oligomers already on the surface, taking the total to around 3.0% or near about.
6. Fibre finish applied by the fibre producer is completely washed out, and the fibre surface becomes rough. This necessitates a fresh dressing of the fibre so that it can work well on the spinning machinery.

Each of these disadvantages—created by the process of fibre dyeing—need to be counteracted.

Mills should set the drafting rollers at draw frames, especially in the back zones, according to the reduced fibre length. Optimising the settings with the use of spectrographs to get the minimum unevenness is worthwhile. The denier going coarser brings down the spinning value, because the number of fibres per cross-section would reduce for a given yarn count. Therefore, mills should use 1.4D fibre only for the count range 30–40s, and 1.2D for 50–60s range. The loss in fibre strength and crimps may be compensated to a limited extent by additional twist (per inch/cm) at the yarn stage, if such a step is required to control the end breakage rate. The use of finer denier as indicated earlier also helps.

To remove the 3% or more of oligomers that would come on the surface of the dyed fibre, the dyer should use a product like Hoechst's Leomin OR. Using such oligomers remover (in the concentration of 1 g/l for dark shades and 1.5 g/l for extra dark shades) in the reduction clearing—whether acidic or alkaline—helps to remove almost all the oligomers. Scanning electron microscope photos of dyed fibres with and without OR in reduction clearing clearly show clean fibre surfaces with OR and several oligomers particles adhering to the fibre surface without OR. A mill is able to increase the speeds of all machines from cards to ring frames when OR is used; and so the additional cost of OR which is around Rs 1.0–1.50 per kg of dyeing is more than recovered by the mill. A spinning mill dyed a rather heavy shade of 14% black and used more than 2 g/l of OR in reduction clearing; it could spin this shade at normal spindle speeds. The mill staff admitted that they would just not have been able to run the fibre in the spinning department without OR. Use of some OR is much better than using 2 reduction clearings that some dyers use with critical shades.

It is necessary for a spinner to check and control the moisture content of both, the own dyed polyester fibres and the dope dyed viscose fibres received from rayon producers (like Gwalior Rayon). A portable moisture meter is available. The instrument has prongs that have to be pushed right inside either in the loosely dyed polyester fibres or in the bales of dope dyed viscose fibres. The moisture content can be read directly on the meter. The instrument is not as accurate as the usual method of bone drying the fibre in an oven and determining the moisture content by subtraction of weights before and after. But it is quite satisfactory as a control tool, since the precision is not critical for such mill work. The acceptable limit of moisture is about 3–5% for PSF, and about 10–12% for viscose staple fibres. Once it is confirmed that the moisture contents are OK, the next step of putting on the right type of spin finish can be taken.

Re-finishing

The starting material for dyed fibre spinning is own dyed PSF that is given the right type and amount of spin finish. This PSF is then blended with dope dyed viscose. Usually, two or three different shades each of PSF and dope dyed viscose are blended together in appropriate percentages to obtain the desired shade as specified for the end use, which normally is men's suiting fabric. The first requirement of dyed fibres is of good lubrication. In order to avoid the fibre surface getting rough after dyeing, a spin finish similar to Nopcotex F—which is a waxy emulsion—is put in the last rinsing bath in the dye house. The concentration used of 1.0–0.8% concentration, the pick up is only 10%. Thus, the OPU (Oil Pick-Up) is either 0.10% or 0.08%.

In the spinning department, when a stack mixing of dyed polyester is made along with dope dyed viscose, a 75/25 blend (against 85:15 blend used in grey PV mixing) of spin finish similar to Nopcotex LV40 (antistat) and Nopcotex 2152P (cohesion agent) is sprayed on the polyester component. The proportion of the cohesion agent is increased to 25% in the blend of spin finishing agents to obtain a much higher cohesion that compensates for the loss of crimps during dyeing. Occasionally, particularly if trilobal fibre is included in the mixing, then even a 50/50 blend of anti-stat and cohesive agents are used.

The amount of total spin finish to be added depends upon:

- The depth of shade. Darker shades need higher amount of spin finish. While medium shades could have an OPU of say 0.5%, dark shade will need 0.6% or 0.65% OPU; and on extra dark shades, mill may put 0.70–0.75 OPU.
- The fibre denier of PSF. Finer denier will need less amount of spin finish.
- Presence of trilobal fibre in the blend. A trilobal fibre is difficult to

crimp because of its triangular shape. So the number of crimps per 25 mm is always 2 or 3 units fewer than the normal crimps in the semi-dull round cross-section fibre of comparable denier. The trilobal fibre has less number of crimps to start with and dyeing reduces the same further, so residual crimps in the trilobal fibre are much lower. So the cohesive part of the finish has to be increased to compensate for the lower number of crimps. Normally, mills use around 10–15% of trilobal fibre to give a glittering effect and a small increase of about 0.05% over the normal would suffice. But should a mill decide to use 65% trilobal in a PV blend, the spin finish on the trilobal fibre would need to be as high as 1%.

- Seasonal changes need to be made in India in the amount of spin finish, since Indian spinning mills are not air conditioned (refrigerative cooling) as in other countries. They are only humidified; so the moisture content in the inside of the mill is influenced by RH in the outside air (The RH in the department is controlled within limits, but the moisture content per cubic metre changes because of the different temperatures in different seasons for the same level of relative humidity. A good way to judge such differences in inside temperature is to go by the RH of the outside air). RH in the outside air is at its minimum in winter—it goes down to 10% in Rajasthan. So, mills use a high value of spin finish of up to 0.8% in winter. In summer, it is brought down to 0.5 % or so; and in the rainy season, the add-on of finish is at its lowest, around 0.3%. So the spinning technicians have to be alert to moisture changes in the atmosphere outside the mill and alter their pick up accordingly.
- Achievable machine speeds are those where the working of the machine is smooth, without lapping, choking, fibres flying off, etc. These troubles increase with machine speeds. Therefore, mills that run all their machines at higher than normal speeds when they opt for high speed spinning do need higher amount of spin finish on the dyed fibre.

The spin finish formulations used by mills in India are most often unauthorised copies of Nopco chemicals—Nopcotex F, LV40 and 2152P. These spin finishes were developed in the USA in early 1960s and brought to India in early 1970s by Nopco Chemicals India Ltd. for use on grey polyester fibre. The spinning speeds used for PV blends were low then—card speeds were 12–15 m/min, draw frames at 33–40 m/min, fly frames at 700 rpm and ring frames at 12000–14000 rpm; and the fibre-dyed spinning had not arrived on the scene. The spinning conditions changed radically in the decade of 1980, and the scenario in the 21st century is as follows.

International spin finish manufacturers like Takemoto and Matsumoto from Japan and Schill & Schillacher, and Schwarz and Zimmermann from Germany have not taken any interest in tailor-making specific spin finishes for dyed PSF using modern chemicals. Such a development could bring the performance of dyed fibres on spinning machinery at par with that of grey fibres. One likely reason for this apathy or omission could be the fact that spinning of dyed PSF is purely an Indian phenomenon. Consequently, the market for these specialised spin finishes would be only in India. Another factor could be pricing of these special spin finishes vis-à-vis the prices of these chemicals produced in India. The market for these special spin finishes for dyed PSF is small. Something like 6000 tons of PSF fibre is dyed every month by several Indian blend spinners; and with an average OPU of say 0.35%, the market for these spin finishes would be of around 21 tons/month or 252 tons/year. Considerable research and developmental work should have taken place in India over the past 20–30 years amongst the Indian spin finish makers—unfortunately no worthwhile research efforts have been put—the only work that has been done is how to reduce the cost of spin finishes but without bothering its impact on the performance of treated fibres on spinning machinery. Therefore, what might have started as a 'reverse engineering' process in those early days when the IPR—Intellectual Property Rights—regime in India was comfortably slack, would have changed to development-based improvements in the later years. Therefore, it is quite likely that the spin finishes available as of now in India are such that they serve the requirements of dyed fibres well. However, it is high time for at least one of the large international spin finish manufacturer to come to India and to serve this niche market in competition with the Indian firms. Such globalised competition would hopefully lead to even better spin finishes for the use of the Indian spinners.

Pending availability of well-designed specific spin finishes for dyed PSF, due credit must be given to our spinning technicians for using their ingenuity to employ finishes not really designed for dyed fibre spinning. They have successfully run dyed fibres at real good speeds after optimising the finish: at speeds of 120–170 m/min at cards, up to 750 m/min on finisher draw frames, 1200 rpm on fly frames and at spindle speeds ranging from 18 000 to 22 000 rpm at ring frames.

Ideally, dyed fibre mills should be able to measure the fibre friction between fibres, and between fibre and metal for every lot received from dyeing. Using such an instrument, the spinner can optimise the proportion of the components of spin finish. A simple but an accurate instrument is needed for such measurement. One of the Indian textile research associations could help here. It is also necessary to identify the most suitable friction values that give excellent performance of the lot on all spinning machinery and yield spun yarns with minimum imperfections. Then, the mills should have two chemical formulations at their disposal: one that increases friction and another that reduces friction. And the mills should be told the approximate dosages of those two chemicals to alter friction values. So ideally, each mill would have all lots with appropriate optimum values of inter fibre and fibre metal friction. Thus, each lot would work excellently and also give even yarns with very few imperfections. Can this dream be realised? (An exhibition was held during the 63rd All India Textile Conference at Ahmedabad, in January 2008. A simple and reliable fibre friction tester developed by the National Institute of Design, Ahmedabad was exhibited. This instrument has additional facility of testing the single fibre strength and has now been licensed for commercial production. This instrument should be available commercially from the beginning of 2009. The price is likely to be less than Rs 100000; therefore, the instrument could prove quite affordable to mills.)

Once the spin finish is optimised, the spinning processing stages from card onwards need to meet the same specifications as listed in detail under Chapter 3 for the grey fibres.

Card

- U% of card sliver be around 3.5
- CV% of 5 m wrappings to be around 0.5
- No neps or less than 1/g in sliver
- Clear web with no static charge

Finisher draw frame

- U% of sliver 1.6–1.8
- CV% of 6 m wrappings—0.20–0.25
- Autoleveller to correct 100% when feeding 7 and 9 slivers
- No peak in spectrogram

Speed frame

- U% of roving—3.25–3.50
- CV% of 1.5 yd wrapping around 0.5
- Breakages to be between 0 and 1/100 spindle hours
- Stretch between empty and full bobbins to be <1%.
- No peak in spectrogram

Ring

- CV% of count 1.0–1.25
- U% of yarn to be between 5% and 25% of Uster statistics* imperfections around 25% of Uster statistics*

- Breakages to be less than 5/100 spindle hours
- Snap round for spindles not producing yarn to be less than 1.0 per frame of up to 480 spindles and less than 2 for longer frames.
- Yarn appearance boards should not show viscose neps

It must be mentioned here that Uster Statistics do not have different standards for fibre-dyed yarns from short fibres of 44 mm and 51 mm fibre lengths; therefore, we are forced to use the values given under grey yarns for these fibre-dyed yarns as well.

There are quite a few spinning mills in the country that more or less meet the above specifications regularly and run fibre-dyed PV blended counts of 30–40s at spindle speeds between 20 500 and 22 000 rpm on LR6 ring frames with as low as just 1 break/100 spindle hours.

Mixing/Blending

One problem that most spinning mills face is presence of high number of neps from darker or lighter shades of viscose, particularly when mixed with light- or dark-shaded polyester and or viscose. Sometimes, the incidence of neps goes so high that the mill is forced to over dye the fabric in black or some such real dark colour. The only proven way to solve this problem is to pre-card the dark/light-coloured dope dyed viscose at slower speeds and with tighter cylinder–flat settings so as to have nil neps in the card web. Later, this all viscose sliver is broken into small pieces either manually or by using a sliver breaking machine and is then blended with other components at the stack mixing stage.

It is difficult to adopt the automatic spray system for dyed fibre spinning because

- Lot size is small at 100 or 200 kg per pot.
- Each lot may have 2 or 3 shades in PSF and VSF.
- Each shade has to be accurately weighed and then blended intimately so that the final shade in the fabric is exactly as desired.

Therefore, there is no alternative to making a stack mixing. In fact, it becomes easy and convenient to spray the spin finish on polyester components as they are laid in the stack. (Please see the Chapter 6 on High Speed Polyester Spinning—Tomorrow)

Sometimes odd blends like 90% black polyester and 10% white (grey) viscose or vice versa have to be spun. To get an accurate and even blending of the minor component (say less than 25% in the blend), it is better to have as many layers as possible of a small quantity of each colour as possible and feasible, e.g. build a stack of 10 kg of black then spread 1.1 kg of white uniformly over it (The slightly higher quantity than given by 10%

percentage of viscose is to compensate for the greater losses expected in blow room and cards). Then lay another 10 kg of black then spread 1.1 kg of white and so on. Ideally, there should be say 100 layers. Take a vertical section of the stack and feed to the blowroom.

A spinning mill tried putting Nopcotex F in a mixture of LV40 and 2152P so as to avoid putting F in the last rinsing bath, where only 10% of F goes on to the fibre and 90% goes literally 'down the drain'. The F could not go into a proper emulsion; it gelled up into fairly big lumps. Consequently, the finished fibre got loaded on the licker-in at the card and the trial was a failure. So, F should be put on the fibre only in the last rinsing bath.

In dyed fibre spinning, the lot sizes can be as small as 200 kg. After passing through blow room and cards, these machines have to be stopped for about an hour to thoroughly clean them, and thereby to ensure that no 'contamination' takes place from one to the other differently coloured lot. The industry would welcome some innovative Indian firm to design and develop vacuum-based suction cleaning systems for this purpose. It should be possible, at least at the blow room, to clean the line thoroughly in less than 15 min.

Chute fed

Dyed fibre mills do not prefer chute feed cards because the pipes need to be cleaned once in 15 days or even earlier so as to remove oligomers, un-reacted dyes and other chemicals deposited on the inside surface of the pipes. It is recommended to avoid the use of chute feed system even when the lot sizes are large enough.

Roller buffing

Mills running dyed fibres need to buff the top roller cots at all machines far more frequently than done on grey fibres. An extreme example is of a mill running dyed fibres that buffs all draw frame cots every week and all cots on fly and ring frames—lightly—every 15 days. Against this, there is another mill also running dyed fibres that grinds its fly frame and ring frame cots once in 60 days. The only difference between the two mills is that this second mill uses an oligomers remover during dyeing. This brings out the importance of keeping a good control on the surface oligomers in dyed fibre spinning.

Traveler life

Similarly, the mills that do not use an oligomers remover at the dye bath find that the life of travelers becomes very short. One mill reported a life of just 3–4 days for (Braecker) travelers when running 33s dyed fibres at 22 000 rpm. On grey, the life of (Braecker) travelers was 9 days when running 60s at 24 500 rpm.

'Bad' shades

Dyed fibre spinners often find that a few shades work badly in the department and yield yarns of poor quality. When the working is bad in spite of taking all the precautions listed above, the fibre dyers should check whether they can use alternative dyes to obtain the same shade. They should choose dyes that need shorter dyeing times, so as to reduce the extent of deterioration in fibre properties during dyeing.

Two other items are important for spinners of dyed fibres; however, these are not related to spinning at high speeds. These are mix-ups and remnants.

Mix-ups

Unwanted mixing up of fibres from a lot of one shade into that of another is the 'Number 1 Problem' in mills producing fibre dyed yarns. A lot of checks and counter checks have to be continuously carried out to keep any such contamination to the minimum. Some mills make one or two QC investigators go round the spinning department with shade cards in hand. They particularly inspect all creels at breaker and finisher draw frames, and at roving frames. They check every ring frame to ensure that the roving bobbins in the creel are of the right shade. In these mills, a ring frame could have three or four shades running with only one idle spindle in between. And they need to check winding machines more frequently to ensure that no wrong bobbin is in the bins. Many times the shades are so similar that only a trained person can locate them. All these precautions have to be taken to minimise mending in the fabric, which is quite costly.

Remnants

Another problem is remnants of shades in fibre form that have been stopped due to lack of continuous market demand. These can be used in future, say within about a year, if identical shade is to be produced again. Some mills blend all such remnants together and spin a coarser count for selling it to make items like coarse *durries* (simple carpets). It is best to plan for almost no remnants, and most mills manage to keep the remnants below 1% of the total production.

Problems faced at ring frames and winding

When a spinning mill—whether on grey or on dyed fibre—is thinking seriously of going for high speed spinning, it has to first meet all the conditions in spinning preparatory and ring spinning listed in detail in chapter 3. They should think of speeding up the ring frames beyond 20000 rpm only after satisfying the laid down stipulations.

Let us consider a spinning mill is running their frames at the maximum speed of 18000 rpm and now they feel that they meet all the conditions laid down. They should speed up only one ring frame to maximum speed of 20000 rpm. Check the working in terms of end breaks, lapping tendencies, fly and winding cuts cause-wise; and if every parameter is OK, then the mill should speed up other ring frames in sets of 2–4 at a time.
A mill may face any of the following problems:

- End breaks per 100 spindle hours or the number of spindles 'not producing yarn' going up
- Lapping tendency on top/bottom rollers increasing
- Yarn hairiness deteriorating
- Yarn U% and imperfections going up
- Winding cuts increasing multi-fold

Then this mill should first check whether it has really met consistently all the conditions laid down in Chapter 3. In a number of mills, it has been found that the technicians were in a hurry; (only because another spinner known to his MD had already speed up its ring frames) and certain conditions in spinning preparatory were not met consistently. One good value on one day does not mean anything in a spinning mill. The good values must be obtained daily for 8/10 days consecutively and then only one should conclude that the good values obtained are real and consistent. If a mill truly meets all the requirements laid down fully and consistently then excepting for winding cuts, the first three parameters—end breaks, lapping and hairiness—will not alter. Their values may increase marginally, but not significantly.

If the precautions mentioned under item d) of Chapter 1 about proper running in of the travelers at the higher speed are taken, the end breakage rate does not increase by more than about 1–2 breaks per 100 spindle hours. The lapping and the hairiness also remain under control at nearly the same levels.

On speeding up the spindle speed and drafting speed, the winding cuts go up significantly by some 2 or 3 times. The main reason for such an increase in the number of cuts at the same settings is 'fibre fly'. As the speed of drafting increases, the fibre in the two selvedges of the fibre strand emerging out of the front pair of drafting rollers at ring frames tend to stray away from the main group of fibres. And the higher the increase in drafting speed, the greater is this tendency. The only factor that can control this straying of selvedge fibres is the residual roving twist. Therefore, at higher ring frame spindle speeds, mills should put more twist in the roving—around 0.80–0.85 TM against the 0.65–0.75 of TM commonly used. The higher twist in roving constrains the uncontrolled movement of fibres, particularly in the two selvedges and controls fly and so cuts get controlled to a level about 10–20% higher than what mill was getting at lower speed. The impact of such small increase on the machine efficiency at automatic winding is marginal.

It is, of course, assumed that ring frame itself is not adding to end breaks; poor condition of top roller cots, lower suction at suction clearers, too heavy a traveler could be some of the reasons for increasing end breaks at ring frame. These causes would be present even at lower speeds, but their effect is felt much more at the increased speed. (Chapter 1, b)

A few case studies illustrate the situations that can occur and how these are managed by the mill.

Case 1: A mill found breaks had gone up from 5 to 8 per 100 spindle hours on speeding up one ring frame from 18000 to 20000 rpm. The roving unevenness was earlier reported to be around 3.5 U%. However a fresh check of 24 roving bobbins taken at random from the ring frame on high speed trial showed the same to be at an average of 4.0 U% with some roving bobbins showing as bad as 4.5 U%. In this mill, the monthly average was around 4.0 U%; but the spinning manager just relied on one day's readings of 3.5 to speed up the ring frames. Steps were taken at roving to reduce the total draft of 11 to 9; reduce break draft to 1.14 and to widen 3rd roller/middle roller settings from 60 to 64 mm. Only after these corrective measures, the mills got consistent values of roving U% of 3.3–3.5. Then the breakages at ring frame came down to around 5 at the higher speed of 20000 rpm.

Case 2: In another mill, though the average roving U% was below 3.5, several roving ends were seen to be tied to a creel rod and not drawn through drafting system on many ring frames. On enquiring with ring frame tenters, they said that these rovings gave frequent breaks. All those bobbins were around half full to three-fourth full. This could be a problem with stretch at roving. A check taken on concerned rovings showed that the stretch between empty and full bobbins to be more than 1.4 % as against the upper limit of 1.0%. Also, a full doff study at fly frames showed that end breaks increased sharply after the roving bobbin crossed the half way mark. Cone drum belt positions and tensions were checked and adjusted to sort out the problem.

Case 3: In yet another mill, a snap round in ring frames found 10–12 top roller lappings per ring frame. A test was made by breaking a few ends deliberately; all the broken ends lapped immediately. Reducing the overspray from 0.15% which they were using for their 40s PV mixing to 0.12 % helped the problem to be sorted out.

Mills should understand that if there are too many lappings on the top roller, then it means that the spin finish level is too high and needs to be reduced. And if there are too many lappings on the bottom rollers, it means spin finish is too less and needs to be increased.

Another point mills must ensure is that the amount of cohesive agent like 2152P must not be increased beyond 15% for grey mixings in the total spin finish. Higher amount of this chemical will increase lappings—even though the percentage of total spin finish is OK. This is because basically this chemical is sticky in nature and so will increase lapping tendency. At the same time, if this chemical is not added, then the bulk of laps, slivers and rovings will get increased to 2 or 3 times the normal size; and there may be too many choke ups. So this chemical should be around 10–15% of the total spin finish (for dyed fibre spinning, there is a need to increase the percentage of cohesive agent to 25% occasionally going to 50% as well).

Case 4: In one mill, the end breakages were around 2–3/100 spindle hours. But during snap round, the spindles not producing yarn were around 10 per frame, against the expected 1.0–1.5 per frame. Tenters were found to be not piecing up roving breaks and not immediately replacing roving bobbins when run out. This had resulted in the number of spindles not producing yarn to be as high as 8–10 per frame even when the number of spindles not producing yarn due to end breaks was only 1. Supervision had to be tightened up. For some time, supervisors had to take each tenter around his ring frames at the end of his shift to ensure that, at the time of shift change, all roving breaks were repaired and all roving replacement were done.

Case 5: Routine checks on the condition of cots on ring frames show that in good mills the number of defective cots per frame of about 500 spindles is around 5. In one mill, the end breaks per frame were too high on a few ring frames: something like 10–15 spindles not producing yarn per frame due to end breaks. A check was made on those ring frames and around 100 or 20% damaged cots were found working on those ring frames. The problem was solved when all the damaged cots were replaced.

Case 6: A spinning mill working dyed fibres at high speed found its traveler life to be around 5 days. However, a snap round found several rovings broken and tied to creel ends. Ring frame tenters, when asked showed that the travelers on those spindles were loaded full of fluff and some powder. This powder would be oligomers or un-reacted dye stuff and other chemicals

(The water used in this mill was soft and, therefore, the powder like stuff would not be some kind of salt deposition). The mill was advised to change travelers every 3 days.

In short, if the end breaks or lappings go up on speeding up the ring frames, the mill technicians should go deep and find the real cause. They should not be in a hurry to conclude that the higher speed has resulted in poor performance; most often, they will find that the cause of trouble had nothing to do with the speeding up of the ring frame.

5

Economics of High Speed Spinning

The list of fears that many spinners had about high speed spinning of polyester blends, as given in Chapter 1, included the fear that high speed spinning may turn uneconomical because of the increase in power cost due to the increase in the spindle speed. Let us now look at the total economics of high speed spinning of polyester blends including the increase in power required at high speeds.

Spinning costs

Spinning mills compute the conversion cost of spun yarns by dividing the costs into fixed and variable costs. The fixed cost and the variable costs are added up to obtain the final cost of conversion of fibres into yarns.

Fixed costs are as follows: total power consumed in the spinning mill for running all spinning preparatory and ring frames, TFOs and auxiliary machines, lighting, humidification, workshop and office; salaries and allowances of all labour, supervisory staff, senior staff; office expenses and other miscellaneous expenses including the interest and depreciation.

All these expenses are pooled together and expressed as rupees per spindle shift. This figure is around Rs 5.70 in most blend spinning mills that run their ring frames at normal speeds.

Therefore, the fixed costs per kilogram of single spun yarn is Rs 5.70 × no. of spindle shifts required to produce 1 kg of spun yarn, e.g. consider 2 mills spinning 30s 100% polyester. Mill A gets say 250 g/ss, while Mill B obtains 300 g/ss. So the fixed cost for Mill A will be 5.70 × 1000/250

= 5.70 × 4.00 = Rs 22.80 per kg and the same for Mill B will be 5.70 × 1000/300 = 5.70 × 3.33 = Rs 18.98 per kg.

Consider now the variable cost. This is equal to raw material cost + cost of dyes and chemicals + agent's commission + packing cost + freight cost, all in rupees per kilogram of single yarn.

The mill's landed price per kilogram of polyester and viscose, the blend composition, and yarn recovery (using a multiplier of about 1.03 for yarn recovery of 97%) together give the raw material cost per kilogram of yarn.

Cost of dyes and chemicals depends upon the shade dyed and varies between Rs 10–18 per kg of yarn for medium to dark and extra dark shades.

TFO costs are the incremental fixed costs that depend upon the count doubled and vary between Rs 9–18 per kg (for count range of 2/24s to 2/60s, finer yarns cost more).

Agent's commission is taken @ Rs 1.50 per kg

Packing cost is considered @ Rs 2.00 per kg

Freight – from mill godown to weaver's unit is taken @ Rs 2.00–2.50 per kg.

Economics

Now consider the economics of high speed spinning of polyester blends.

Fixed cost (Rs/kg)

We can calculate fixed costs by multiplying 5.70 with number of spindles needed to produce 1 kg of spun yarn. The variable cost will remain unchanged whether the ring frames run at 18 000 rpm or 22 000 rpm. Only the power component of the fixed costs will increase theoretically proportionate to the square of the spindle speed, which will account for later.
Let us take a few concrete examples:

Table 1: Count wise fixed costs

Count	Blend	Production (g/ss)		No. of ss/kg	
		At slow Speed	At high Speed	Slow Speed	High Speed
30s	100% P	240	300	4.17	3.33
40s	65/35 PV grey	150	200	6.67	5.00
40s	65/35 PV fibre dyed	140	190	7.14	5.26

Therefore, the fixed costs in rupees per kilogram at slow speed and high speed are as follows:

	Slow speed	High speed	Difference (Rs/kg)
30s 100% P	4.17 × 5.70 = 23.77	3.33 × 5.70 = 18.98	4.79
40s PV grey	6.67 × 5.70 = 38.02	5.00 × 5.70 = 28.50	9.52
40s PV dyed fibre	7.14 × 5.70 = 40.70	5.26 × 5.70 = 29.98	10.72

The difference in the profits is the *additional profit gained solely from high speed spinning.*

Power cost

Now let us look at the power consumption at different speeds.

Below are given two tables on power consumed by one LR6 ring frames of 1000 spindles working on different counts at different speeds.

Table 2 Mill A: Polyester yarns

Count	Speed	Power consumed in kWh for one frame/shift
30s	19500	43.71
	20500	48.38
	22000	50.25
40s	20000	40.39
	21000	43.80
	22000	46.30
60s	21000	36.19
	23000	44.62
	24000	48.17

It will be seen from the above table that

1. Coarser counts need higher power compared to finer counts at comparable speeds
2. Power required increases by 3–6% on increasing the speed by 1000 rpm for medium counts, and by about 10% for finer count.

Table 3 Mill B: 28s PV 65/35 blend

Spindle speed (rpm)	Machine run time (min)	Power required (kWh)	Production (kg)	Power (kWh/kg)
17,455	134.0	31.72	31.50	1.007
19,500	119.5	32.39	30.60	1.058
21,850	109.5	36.09	31.10	1.160

It will be seen here that

3. An increase of 1.09 kWh occurs per 1000 rpm of ring frame speed, say 1.0 kWh
4. Here, the power consumed increases by 3.5% per 1000 rpm

As mentioned earlier in Chapter 1, f) about 80% of the power consumed by the ring frame is for rotating the spindles that hold the bobbins on which yarn is wound. The power required here is more when the yarn tension is greater, like with coarser counts, and with higher spindle speeds. The quantities of increase in power consumption as brought out by the observations 1–4 can be seen in this light and are found to be consistent with the theoretical expectations.

Therefore, even if the data appear to be limited, the conclusions drawn are valid under all mill situations. Therefore, as a general rule, we can say that the power required increases by about 5% of 1 kWh for every increase of 1000 rpm in spindle speed.

Therefore, we will have to reduce the additional profit calculated in Table 1 by the increase in power cost needed for high speed spinning of polyester blends. Let us take an example: for the mill running 40s PV grey, the pure profit worked out to Rs 9.52 per kg of yarn (Table 1). We know that this mill got this profit by running their ring frames with an increase in spindle speed of 4000 rpm, from 18000 to 22000 rpm. So, then the additional power cost to be added will be 20% of electricity charges (5% for every 1000 increase in speed). Assume this mill is in Andhra Pradesh. The power cost there is Rs 3.25 per unit. So 20% of this will be Rs 0.64. The net additional profit will be Rs 9.52–0.64 = Rs 8.78 per kg.

Let us relate this pure profit of Rs 9.22 to the selling price of 2/40s grey PV yarn. This is today around Rs 140 per kg. Assuming a profit of 3% (the spinning mills in India make net profit of about 3% on an average taken over 8–10 years. The profitability is known to fluctuate from year to year within a range of –2% to +6% or so for most well run mills) the profit per kilogram of 40s PV yarn would be Rs 4.20 per kg; an additional profit of Rs 8.78 takes the total profit to Rs 12.98, almost 10% of the selling price. More important, the profitability has increased by as much as 3 times *only because of high speed spinning of polyester blends.*

One factor that many would like to include in computing the net profit from speed increase are the possibly higher cost of consumable stores like rings, travelers, cots, aprons, etc with high speed spinning. During discussions with Priyadarshini Spinning Mills—the pioneering mill that has been running their ring frames at high speeds for the last 7 years—they conveyed that they found no significant decrease in the life of these accessories and also of spares. And as far as their LR 6 ring frames are concerned, they experienced no breakdowns or any unusual wear and tear of any part. Again, this experience is not unexpected for two reasons. Firstly, the reduction in life of travelers and rings is not proportional to the speed increase, it is much less. Secondly, the cost of stores for these three items (travelers, rings and cots at ring frame) taken together is invariably less than 0.3% of the sales price of yarn. Therefore, a 10–15% reduction in the life of these accessories would increase the average stores cost of about 2.0% by a small fraction of 0.04–2.04%. Obviously, such increases are not noticeable in the annual income–expenditure accounts.

It must be emphasised that the calculations of the gross additional profit and of the additional power required for high speed spinning of polyester blends given here are to taken for guidance only. The right thing, if any mill management is still not convinced on the higher profitability of high speed spinning, is to do all this arithmetic for its own mill correctly. Start trials for high speed spinning. Once it is seen that these trials are succeeding, work out power required by actually measuring power taken up by a ring frame for a full doff. Calculate the additional profit due to running ring frames at higher speed taking into account the cost of additional power needed and then take a final decision on whether to convert all ring frames to high speed spinning. Surely, such calculations will show a significant improvement in profit per kilogram of spun yarn with high speed spinning of polyester blends in every single mill.

In fact, we can generalise this statement as follows:

Every spinning mill that happens to be working with its ring frames at spindle speeds well below the mechanical upper limit claimed by the ring frame makers, irrespective of the fibre or blends it processes, stands to increase its profitability substantially by adopting high speed spinning. Each mill should strive for reaching the highest spindle speed possible in terms of permissible end breakage rate for each count being spun.

We have assumed in the above scenario that a mill can increase the spindle speeds at ring frames by up to 20% and manage to increase the preparatory and post-spinning productions appropriately without any extra cost. But suppose a mill spinning at 16000 rpm changes over to 24000 rpm as an extreme case, a whopping 50% increase. Such an increase is unlikely to be matched at preparatory and post-spinning stages on the existing machinery set up. Let us consider this case also by considering that the mill needs to add machinery for 30% extra production in the preparatory and in winding for matching the productivity increase at ring frames. In reality, over the years, when a mill either changes its product mix or increases gradually the ring frame productivity, such a situation does occur. Table 4 shows the increased capital cost as a simplified illustration.

Table 4: Economics of adding preparatory and winding capacity 18000 spindles, 40s PV (Cost in millions)

Capacity	Installed		Additional	
Stage	Number	Cost	Number	Cost
Blowroom lines	3	15.6	1	5.2
Cards	9	15.3	3	5.1
Draw frames I	3	2.4	1	0.8
Draw frames II	6	7.2	2	2.4
Fly frames: 144s/frame	6	4.2	2	1.4
Ring frames: 1200s/frame	15	45	Nil	Nil
Winding: 60 drums/machine	6	60	2	20
Total	–	14.97	–	34.9
Production rate (g/ss)	150		200	
Production per day (kg)	7500		10000	

If we assume yarn selling price of Rs 150 and contribution of Rs 50 per kg, the daily additional contribution through extra sale of 2500 kg works out to Rs 125000. We need to subtract from this the extra cost of labour and power, which works out to approximately Rs 35000 per day, to err on the safer side. Thus, the net increase in contribution per year is Rs 32.4 millions (Rs 90000 × 360 days). The return on capital investment of Rs 35 millions is Rs 32.4 millions per year. This entire exercise is to show the order of magnitude of the benefit from high speed spinning: the payback is very fast. Each mill would need to work out its arithmetic accurately.

However, the conclusion would remain the same: go for high spindle speeds at ring frames to increase you mill's profitability.

6

High Speed Spinning—Tomorrow

The future of high speed spinning of polyester blends is tied to the future of spinning industry itself. The staple fibres spinning industry in India has several problems today; market tends to be dull for a large part of the year, severe competition at the market place, total production much in excess of demand consisting of the domestic market and the international market. The competition is from within the country and also from outside: from China and from other S.E. Asian countries. Other factors such as power shortages in many states in the country, high inflation rates that raise all costs (including labour, power and spares) continually, implementation of the Minimum Wages Act which almost doubles the wages that need to be paid to workers continuously erode the profitability of spinning mills. And added to all these, is the severe shortage of manpower—both skilled and unskilled. India is no longer a country with 'cheap' and 'abundant' labour to the extent that the advanced economies want us to believe.

Author would like to quote a recent case of a spinning mill in this context. This mill had some 25 000 spindles spinning only 30s 100% polyester yarn and its daily production used to be around 18–19 tons per day. Then, the production started going down and when it fell down to 11 tons per day, the management got panicky and called in the author. On checking all the parameters in 4 days, the author found nothing wrong with the mill technically; the ring tenters in the mill were leaving as this mill's salary was the lowest in the area. The ring frames had trainee workers with 3–5 days experience and just could not manage. The average number of spindles not producing yarn was an unbelievable value of 62! This scenario can happen in any other mill too.

Therefore, in the near future, high speed spinning has to become the standard practice, rather than an exceptional practice that it is today. The difficult markets and fierce competition will force the mills to reduce their conversion costs to the bare minimum; and the market will only become more and more difficult in times to come.

Worker shortage

Acute shortage of workers will force Indian spinning industry to go for automation in spinning mills. We hear of a 20000 spindle mill in Japan employing just 3 workers per shift, and another 30000 spindle mill in Germany with 5 workers per shift. Indian mills need not think in so drastic terms at present, but more automation to reduce dependence especially on skilled labour is certainly worth exploring right away. Many mills face worker turnovers of 20–40% per year. They keep training workers for the different jobs needed in the mill but only a fraction of the trained work force remains at work after about 2–3 years. The three positions where workers find the work load very high and the nature of work difficult or too monotonous are the ring frame piecer-cum-tenter, the ring frames doffer and the automatic winding tenter. The attrition rates at these positions are generally higher than at the other relatively not-so-tough positions. And giving higher wages does not necessarily eliminate the troubles of the spinning mills. Apparently, the workers are better judges of the elusive balance between 'work life' and 'social life' in life. The much better wages given by spinning mills compared to other employers in the un-organised sector and farming, most of them prefer to work for only 16–18 days of the month rather than the expected 25/26 days.

- Under these circumstances, the Indian spinning mills need to seriously consider fitting ring frames with automatic doffing system for replacement of ring tubes
- Automatic transport of ring tubes to automatic winding machines
- Automatic yarn piecing device that travels along the frame

The spinning mills need also to consider other areas in the process of spinning where the worker deployment can be economically reduced by using some form of automation. In the long run, competitiveness would also depend on this factor, because even those capital items that take over 6–7 years to cover the investment and interest costs, end up reducing the cost per kilogram of yarn substantially after the payback period is over.

Automation at ring frames

Automatic doffing

Such doffing system is available in India with both Lakshmi's LR 6 ring frames and Kirloskar Toyota's RXI 240 ring frames with an additional cost of Rs 2000–2200 per spindle. Also, a Taiwanese company offers a conversion kit at a cost of Rs 1600 per spindle to make doffing automatic for any make of ring frame. One or two mills in South are in the process of converting their Lakshmi's G5/1 ring frames to do automatic doffing. We have to wait and see how trouble free this attachment is under our mill working conditions.

Automatic transport to winding

Linking the ring frames with the cone winding machine is not a new invention; it has been around for over 15 years. The linking system is such that it can be coupled with any make of ring frame. Such a system will be successful in practice, only if the number of winding spindle positions connected to a ring frame remains in variant. Take as example, a ring frame with 1000 spindles producing 30s PV yarn at 190 g/ss. It can comfortably feed 40 spindles of automatic winding producing at the rate of 5.5 kg/ss; the 190 kg of ring spinning production matches with the 220 kg of winding machine production. But the disadvantage of the linking system is that the mills then can not have the luxury of changing counts spun daily as it happens often under Indian market conditions. Altering winding speed is one solution. Spinning mills will have to operate within a narrow range of counts if link corners are to succeed.

The techno-economics of linking are given below for the present conditions (Years 2008–2010) in India.

Automatic yarn piecers

Automation at ring frame piecing, again, is not new. A Japanese make of AYP was exhibited in OTEMAS textile machinery exhibition some 20 years back. The AYP performs the operation of piecing almost like a human does (The textile industry has been living with such automation at the winding machines since over 40 years. The way the automatic knotter searches out the yarn ends and pieces them is even better than the human effort). The development of AYP was then ahead of its times, even for the advanced economies. Today, with a severe shortage of skilled workers at the ring frames, time seems to be ripe for Indian spinning mills to seriously consider installing AYP. Given the Indian breakage rate of 3–5 breaks/100 spindle hours compared to the internationally accepted values of 3–5 breaks/1000 spindle hours, the economics would turn out to be more favourable in India in spite of the relatively lower wage rate. In considering the economics, the cost of labour would need to include the cost of training and of labour turnover also. And if mills are suffering losses in utilisation because of labour absenteeism, especially during marriage and festival seasons, the loss in profits due to loss of production on such days also must be considered in working out the pay-back period on AYP.

All technologists and managers know that the field of machinery development in textiles is like the Olympic Games; where every record stands to be broken every 4 years. The developments of textile machinery get exhibited first in the ITMA series—International Textile Machinery Exhibition—arranged by the European manufacturers. Quite possibly, the ring frame spindle speeds could go up to 30 000 rpm in the next ITMA or OTEMAS. AYP may then become an absolute necessity because a tenter may just not be able to piece up or be willing to work at that high speed. And those who accept to work, may last for even lesser durations on the demanding job. If a good AYP is designed and developed in India to work well at such high speeds, these would certainly turn out to be more cost effective than the imported items within India and would offer great scope for competitive export to other textile countries with many spinning mills.

Total process automation

Automation in blowroom and chute feed to carding is currently available and is used by many modern mills.

Blow room automation

With automatic blenders for feeding fibre mixings to the blowroom, the bale plucker picks up small quantities of fibre from the top of each of the 34–36 bales placed in one row and feed them to the hopper feeder. And when one row of 34–36 bales is exhausted, the bale plucker is turned through 180° to start plucking from the second row of bales placed parallel to the first one. Thus, the only labour needed is a fork lift operator who places a total of the 68–72 bales in 2 rows and goes away for doing other jobs. A supervisor comes to rotate the bale plucker through 180° when the first row of bales is exhausted. This arrangement is good for say 100% polyester spinning (or for any single fibre spinning).

For blends like 65% polyester and 35% viscose, two blendomats are needed; and the 2 hopper feeders have to be connected to a device like Rieter's Uniblend, which will blend the 2 fibres accurately to the desired blend ratio. Additionally, if spin finish is required to be put on the polyester component, an arrangement like Unispray could be fitted in the hopper of the hopper feeder. With such arrangements, the mill becomes automated till the production of card sliver.

For automatising dyed fibre spinning, we have to consider weigh pan hoppers of the kind that are used in worsted spinning. This is a standard hopper feeder which feeds a weigh pan balanced at the end of a lever; such that when a pre-set quantity of fibre is dropped into the weigh pan, the hopper feeder stops, then the pan opens and drops the fibre on a moving lattice below. Usually, a battery of 4 weigh pan hopper feeders feeds one blow room line. For fibre dyed mills in India, we would need to consider a battery of 8 weigh pan hopper feeders to one blow room line. This is because usually 3–4 shades each of own dyed polyester and dope dyed viscose are used in one lot of 'market desired' shade. So we will have 4 weigh pan hopper feeders for the 4 shades of polyester and another 4 weigh pan hoppers for the 4 shades of dope dyed viscose. All the eight weigh pans have to be set to give desired percentage of each colour in the final shade. The weigh pans will drop different colours on the lattice moving below the weigh pans. At the end, there will be a vertical lattice that will take a cross-section of all the 8 shades and feed it to a hopper feeder. An automated spin finish spray system could be installed at this hopper feeder. The hopper feeder should then feed to a multimixer or a similar equipment to ensure an intimate mixing of all the 8 shades involved before feeding to a scutcher and on to chute fed cards.

From cards to ring frames

Beyond cards, we understand that robots are employed to carry full card cans to breaker drawing creel; the robots have a sliver piecer, so the robot pieces the sliver end from a new full can to another can in the creel at the breaker drawing. Similar robotic arrangement is provided to carry breaker-drawing cans to finisher drawing. Mechanical block creeling of cans at roving and transporting the doffed roving bobbins to the ring frames section by mechanical means are the next known stages of automation. Some of the fully automated spinning mills in Japan and Germany would have such fine tuned mechanical handling arrangements.

In such mills, humans—males or females—are required only to

- Attend to cards/draw frames/fly frames for piecing of sliver/roving
- Doff the roving bobbins and place them on conveyers
- Remove lappings from top/bottom rollers if occurs anywhere from cards to ring frames
- Replace exhausted/broken roving bobbins in the creel at ring frame and thread it through the top arm, etc.
- Attend to any mechanical/electrical/electronic stop motions when these act and stop the machine.

Since the breakage rates at cards, draw frames and fly frames are extremely rare in such mills, and since lapping tendency negligibly low; only a few multi-skilled workers are sufficient in each shift.

In India, use of robots does not appear meaningful technologically as well as economically. Therefore, the material transport would still be semi-automated in the ideal spinning mill spinning polyester and blends.

Indian spinning mills in near future

Here is a vision of tomorrow's spinning mill in India: a fully automated spinning operation with all spinning preparatory and ring frames working at speeds much higher than obtaining today. Such a fully automated (without robots) mill may take some time to settle down and to get going smoothly. But once it starts, it will run on its own; and high spindle speeds of 30000 rpm at ring frames will be standard items. These mills may not be very big in size, since only a pre-planned narrow set of counts would be spun in these mills. Each process flow would consist in about 15000–20000 spindles working on standard counts, using one single brand of PSF and VSF continuously. Only under such scenario would automated high speed spinning of polyester blends be a great success.

The pay back period for such investment is not expected to be attractive solely on the basis of labour saving in India. However, consider a mill that happens to lose about 2% of production during the year, as a daily average loss due to absenteeism at ring frames and winding. If this mill can eliminate the loss through automation, the pay back period would be likely to be less than 6–7 years. The advantage of low running costs can thereafter be reaped fully by the mill.

Editorial Note: The Textile Association (India) has encouraged Mr. S. Y. Nanal to write this book consolidating his expertise for the use of Indian textile industry with the hope that such a day dawns soon in India. TAI joins Mr. Nanal in his vision that many modern spinning mills in India move towards such automation and many new mills come up in this fully automated format.

So far we have

- covered the basic concept of high speed spinning of polyester blends,
- specified conditions that have to be met to make it a success, and
- shown that the economic advantage of high speed spinning is large.

A technical book would normally be considered complete with this coverage.

But frankly, it is one thing to describe what needs to be done, and quite another to implement it in mill practice. We have already mentioned earlier that several mills have indeed gone in for high speed spinning of polyester blends. How did they go about it? What prompted them to take this path? How did they manage to succeed in their task? Studying their case histories would certainly prove enlightening to the readers and users of this 'practical guide'. The success of some of the pioneering mills has therefore been brought out as live case studies in Chapter 7. We thank the management the four mills, 2 spinning grey yarns and 2 fibre-dyed yarns, for permitting us to present their cases in this book. We hope that these case illustrations will bring out the ingredients of success more vividly, and so will inspire many more mills to go in for high speed spinning, not just for polyester blends, but also for other fibres.

It is not an organisation like a mill, but it is always an individual that makes things happen. A leader needs to have a vision, a dream of achieving the highest level of performance. He needs to be prepared to take a great risk of treading boldly on an uncharted path. In each mill where high speed spinning of polyester blends has been achieved and sustained over years, some one had taken a lead. What kind of persons were these successful pioneers? And how did they manage to demolish the technological barriers that existed before they proved high speed spinning a success? We stand to learn from their example. Therefore, this practical guide on high speed spinning gives their career profile in Chapter 8. This way, we wish to salute the pioneers who have successfully spearheaded the movement towards super high spindle speeds.

Several other mills and several other individuals are also likely to have achieved such a success in high speed spinning. We

hope that their tribe will increase after using this practical guide on high speed spinning of textile staple fibres of all kinds.

We are grateful to the managements of the following mills for granting permission to write technical case study of high speed spinning of polyester viscose blend achieved successfully in their mills. Their willingness to share the details of technical specifications and parameters with all is praiseworthy.

Grey fibre spinning

- Priyadarshini Spinning Mills, Hyderabad, Andhra Pradesh
- RSWM Ltd, Banswara, Rajasthan

Dyed fibre spinning

- Sangam (India) Ltd, Bhilwara, Rajasthan
- Raymond Ltd, Chhindwada, Maharashtra

We place on record our great appreciation of the following leaders who pioneered the success of high speed spinning of polyester viscose blends in their mill.

V.K. Indrayan
R.N. Sharma
B. Shiva Reddy
S.M. Gupta
M.M. Biradar
Sanjay Sharma

7

Live Case Studies

We bring you here four live case studies—two from grey spinning and two from dyed fibre spinning—of blend spinning mills which run their ring frames successfully at spindle speeds higher than 20000 rpm. Readers will note the various steps taken by each of these mills to sort out problems that came up and finally to run their LR6 ring frames at the desired high speed with great success.

It is interesting to understand why and how these four spinning mills attempted high speed spinning. Priyadarshini did it because their CMD asked them; and they were willing even to take an outsider's help for it. RSWM Ltd did it because this idea emerged during a brain storming session. Brain storming is an excellent tool to motivate people to come up with new ideas and ideally every mill should do it regularly. Sangam did it because they heard that some other mill on dyed fibre was running their ring frames @ 20500 rpm. Raymonds did it only after an outside consultant told them that their mill meets all the conditions required to speed up ring frames. Only this realisation prodded them to increase the speed of 4 ring frames to 22000 rpm. And the working and yarn quality remained the same at high speeds. And of course there exist a few other mills that have tried half-heartedly to increase the spindle productivity, but have not succeeded.

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*(one interesting tail piece. In one company, they found that one mid-level executive never spoke and so did not really participate. On questioning, he reacted rather angrily that in his opinion, only those who get higher pay than him, should provide new ideas. He could not be convinced that salary and position has nothing to do with generation of ideas.)

Grey fibre spinning at high speeds

Priyadarshini Spinning Mills

Priyadarshini Spinning Mills is situated at Sadashivpet, about 75 km from Hyderabad on the Hyderabad–Mumbai highway. This mill, set up in 1983, today has 50428 ring spindles and produces 28 tons/day of blended yarn in polyester/viscose grey and fibre dyed, 100% polyester, polyester/cotton in fibre dyed, and other yarns in both single and doubled yarns, the count range being 24–76s.

When the mill was set up, Mr. C.K. Rao was the Chairman-cum-Managing Director. He being a spinning technologist himself gives more importance to technical excellence. Today his son, Mr. Harish Cherukeri, is the MD and Mr. Rao is always available to give his valuable advice. Mr. B. Shiva Reddy, as the President and Director, is the head of this spinning mill. Mr. Reddy is personally responsible for the success of several spinning achievements—running grey 60s PV at an unbelievable maximum speed of 24500 rpm, spinning dyed polyester/dyed cotton blends in solid shades, spinning of 14% real dark deep black—to name just a few.

This mill erected 14 Lakshmi's LR6 ring frames in 2000/2001. The frames have 960 spindles each with 36 mm ring diameter and a lift of 170 mm. When these ring frames were ordered, Mr. Rao told Mr. Reddy and the staff that he has ordered new ring frames designed to run at a maximum speed of 25000 rpm and expects these will be run at speeds close to this figure.

Mills intended to spin 60s and 76s PV on these ring frames using 1.0d × 44 mm polyester fibre from Reliance and 1.5d × 44 mm Gwalior viscose from Kharach plant. In due course the ring frames arrived, were erected and started on production. They started at 16000 rpm, working was OK, then they speeded to 18000, every thing was fine. Then they tried 20000 rpm and faced very high-end breaks of 10–12 per 100 spindle hours. The winding cuts tripled. The mills tried whatever they could think of, but to no avail. Then they decided to take outside consultant's help and invited Mr. SY Nanal to come and help them. Mr. Nanal was surprised and hesitated because such high speeds were not attempted any where in the world. But the mill management insisted, and he agreed to help the team in their task. He then recalled certain Indonesian spinning mills that run at 14000–16000 rpm but get an end breakage rate of 3–5 per 1000 spindle hours—one-tenth of what good Indian spinning mills get. Fortunately, he had the relevant technical information of these mills, and he scanned that information to identify six process targets in spinning preparatory that Priyadarshini Mills should achieve before they think of speeding up their ring frames again. Mr. Nanal then went to Sadashivpet and addressed the entire technical team. Thereafter, the team broke down each of the target, under guidance of Mr. Nanal, in terms of actions to be taken, and planned several trials. By the end of the 3rd month, mills could satisfactorily reach all the six set targets. Till then, the LR 6 ring frames were kept running at spindle speed of 18000 rpm. The ring frames were then speeded up in steps of 2000 rpm to reach the maximum speed (during doff) of 24500 rpm. It took full 6 months and one visit every month for a stay of 1 week every time by the consultant to achieve this extraordinary feat. As an outside consultant, Mr. Nanal says that the credit for this achievement on the shop floor goes to the mill team which worked steadfastly till it achieved the desired results, and to the mill management for setting high targets and simultaneously encouraging the team by giving all support.

The mills have been running their ring frames continuously for the last 7 years at maximum speed of 24500 rpm—the highest in the world for polyester blend spinning.

This mill runs this mixing as below:

- Viscose is pre-opened before blending with polyester.
- Polyester fibre is taken from 4 to 5 different trucks.
- Mills prepare a stack mixing of polyester and viscose.

They have installed a Unispray automatic spin finish spray system in the Hopper Bale Breaker. The spin finishes used are from Clariant – Leomin LS1 and CS. The percentage of spin finish put on is around 0.25%.

- They still use lap feed to Lakshmi's (LMW) C300 cards running @ 150 m/min.
- They use 8 × 8 doubling and drafting in drawing. The D02S runs @ 180 m/min while RSB 851 operates @ 650 m/min.
- Their roving frames are Lakshmi's LF1400 running @ 900 rpm.
- Their ring frames are Lakshmi's LR6 of 960 spindles each.

The spinning plan used is as follows:

	60s	76s
Card hank	0.160	0.195
Finisher drawing hank	0.165	0.200
Roving hank	1.80	2.20
TM	0.75	0.75
Ring count	60.0	76.0
TM	2.90	2.90

Performance data:

- Unevenness of finisher drawing sliver = U% 1.6–1.8
- CV% of finisher drawing wrapping of 6 m is around 0.25
- Spectrograms taken once a month for each RSB851; and no peak seen

- U% of roving is around 3.0–3.25
- CV% of 15 m wrapping of roving is 0.5
- Stretch between full and empty roving bobbin is less than 1%
- Ring count is full count—60s and 76s
- CV% of count is around 1.8–2.0

Other yarn properties:

	60s	76s
Actual count	60	76
Lea count variability CV%	1.8	2.0
Single yarn strength (g)	265	210
Elongation at break %	11.5	12.0
Single thread strength (km)	26.5	26.0
Uster U%	12.4	13.7
Thin* (–50)	48	118
Thick* (3)	80	174
Neps* (3)	125	119
Total	253	411

* per km

Their maintenance practices are:

At cards

- Full cleaning and full setting – every 15 days
- Checking wire conditions – every 6 months
- Replacing licker in wire – every 9 months
- Replacing fillet on stationary flats – every 6 months

At draw frames

- Top rollers buffed – every week
- Cleaning the frame – ——do——
- Autoleveller check – once a month

At fly frame

- Top roller buffing – once a month
- Cleaning the frame – ——do——
- Resetting bottom rollers – once every 6 months

At ring frames

- Top roller buffing – once a month
- Cleaning the frame – – –do– –
- Topping the spindle oil – – –do– –
- Resetting bottom rollers – once 6 months
- Traveler changed – every 10 days with Braecker travelers and every 4 days with LR travelers

Rings are Emperor rings from Lakshmi.

Routine QC checks are as follows: breakage rates at roving and ring; checking condition of cots and aprons and full yarn quality checks—count and frame rise.

One ring frame tenter looks after 3 slides (1440 spindles).

Their ring frame production is

- 60s – 13 g/ss
- 76s – 78 g/ss

Their cots are Precitex with shore hardness of 83° duroshore. Ring frame cots are ground lightly every 30 days and discarded after 10 buffings.

Mills tried a higher speed of 26000 rpm. The end breaks went up from 4 to 6/7; so tm had to be increased from 2.9 to 3.1 and the production came down from 113 to 110 g/ss. So the mills concluded that the maximum speed (during doff) of 24500 rpm was the optimum one under their conditions.

What is really creditable is the fact that mills have been running at this super high speed continuously for the last 7 years (years 2001–2008), and have maintained the performance of all machines from cards to ring frames at specified values. This is due to sincere efforts by all staff and workers; and the daily detailed rounds, daily meetings to discuss QC reports, religiously following maintenance practices and frequent inspections of critical parts like cots, aprons, spindles, etc and the devotion of all top technical personnel in the mills.

Mills have had no major breakdowns on the 14 LR 6 ring frames though these frames have been running at these super high speeds. Only a few nylon keys on the variator hubs had worn out. No other part has been replaced. There is no machine vibration even at spindle speeds of 24500 rpm. The mill is quite happy with the performance of their LR6 ring frames.

RSWM Limited

This mill, a unit of the mill group formerly known as Rajasthan Spinning and Weaving Mills Ltd, is situated about 5 km away from Banswara town on the Banswara–Dungarpur road. The mill has 88 000 ring spindles and 1680 rotors, and spins only grey yarns in 100% polyester, polyester/viscose, 100% cotton and other specialty blended yarns mostly with the best fibres from the world market. The Banswara unit makes up to **65** tons of blended yarns and **29** tons of cotton yarns daily. The count range is from 7s to 45s for polyester and blended yarns, and from 10s to 40s for cotton yarns.

This mill runs 30s 65/35 polyester/viscose yarn at a maximum spindle speed of 22 000 rpm on a modified Lakshmi's G 5/1 ring frames and obtains a production of 270 g/ss.

In order to make a success of this high speed spinning trial, the mills formed a joint team of persons from production, maintenance, engineering and quality control, which worked in a close coordination. They make extensive trials on one machine or on one group of machines. When a trial is successful, it is implemented on other machines working on the same count.

The following changes were effected:

1. Mills worked closely with both fibre producers to optimise (increase) the amount and the type of spin finishes they put on polyester and viscose staple fibres. This was done because mills had conclusively proved that over sprays (LV 40/2152P) do deteriorate the spinning performance and yarn quality. So at the end of all trials, mills could run the polyester/viscose blend with less over spray.
2. Mills also tried polyester staple fibres made in different plants of PSF/VSF supplier and settled on a fibre from certain plants and froze its specifications.
3. At the Rieter card, cylinder speed was increased from 450 to 480/500 rpm. Mills also tried different makes of card clothing and finally settled on imported make with 860 wire points per square inch. The number of stationary flats was increased from 3 to 8 to provide better carding action.
4. No major changes were made at draw and fly frames.
5. At ring frames, put 38–40 mm diameter imported rings, installed energy efficient spindles, and changed main driving electric motor to 34 kWh energy-efficient one. Mills also put a speed variator for fine adjustment of spindle speed. Mills also took trials with different rings and travelers and finally decided to use a combination of imported rings and travelers.
6. Mills took studies to relate spindle speed, end breaks and power consumed and played with the increase in spindle speed such that the end breaks and the power consumed reduced significantly. Two graphs illustrate these results: the first graph shows conditions as obtained and the second graph indicates the correction made. The table below states the results:

	Before	After
Average breakage rate	2.35	2.53
Average spindle speed	19010	19791
Max spindle speed	21200	22000
Average electrical load (Amp)	36.09	36.10
kWh	23.45	24.40
Average FRS (rpm)	380.5	391.5

The two figures A and B illustrate the full data in graphical format.

Every spinning mill keen to run ring frames at high speed should undertake such studies to keep the end breakage rates low and, more important, keep the increase in power consumption due to higher speeds to the minimum. Other details from the mills are:

Spinning plan organisation:	30s PV
Card sliver (hanks)	0.11
Finisher sliver (hanks)	0.11
Roving (hanks)	0.86
TM	0.83
Ring frame count	30.0
TM	2.92
Ring diameter 38/40 mm	

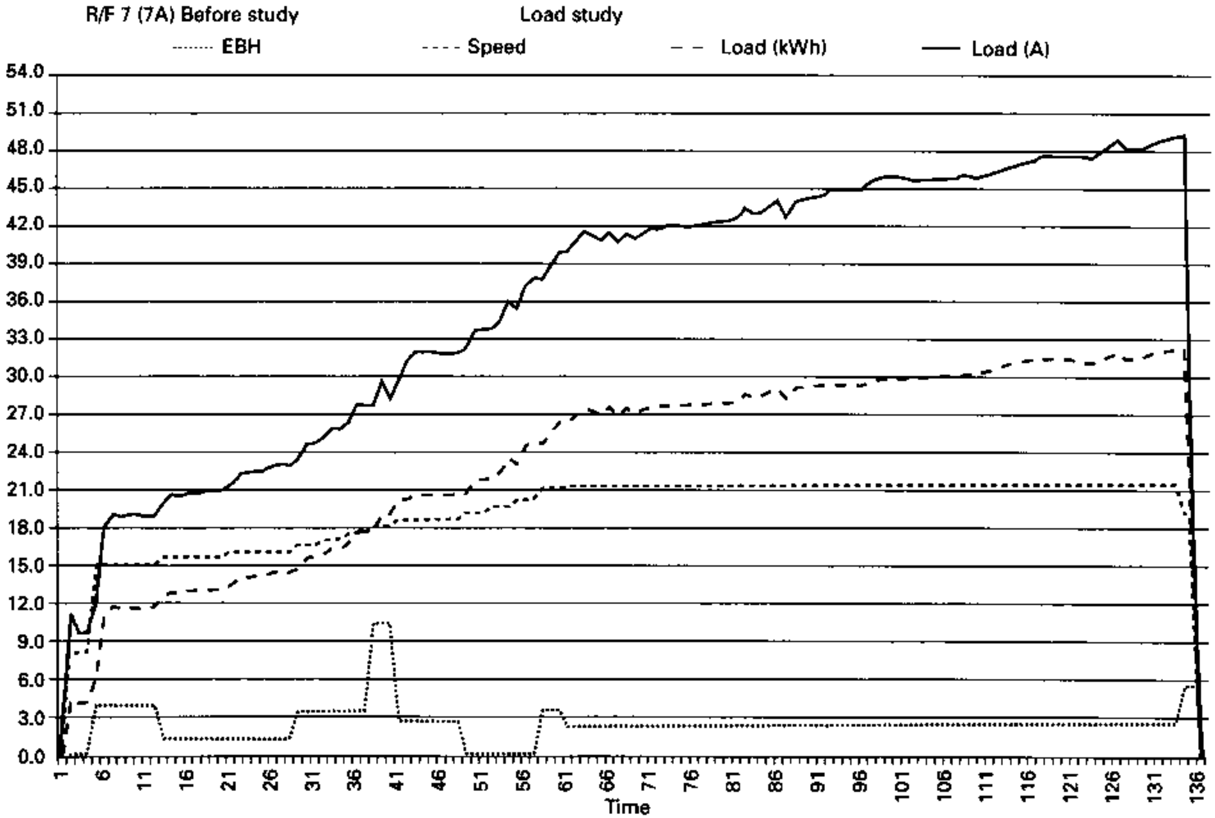
Quality parameters are as follows:

	Uster U%	CV% of wrappings	Wrapping length (m)
Card sliver	3.95	2.90	10
Finisher drawing sliver	1.91	0.40	5
Roving	2.96	0.79	15
Ring yarn	9.80	1.21	120

Mills monitor and control spectrograms of every finisher drawing delivery daily. Mills use cots of shore hardness 83° for front rollers and 90° for back rollers; grind them after every 30 days and discard them after 2 mm reduction in diameter.

Mills Maintenance Schedule:

Cards
full setting – 3 months
full cleaning – 1 month
Replacing licker in wire 7/8 months


R/F 7 (7A) Before study
Load study
EBH
Speed
Load (kWh)
Load (A)
54.0
51.0
48.0
45.0
42.0
39.0
36.0
33.0
30.0
27.0
24.0
21.0
18.0
15.0
12.0
9.0
6.0
3.0
0.0
1
6
11
16
21
26
31
36
41
46
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56
61
66
71
76
81
86
91
96
101
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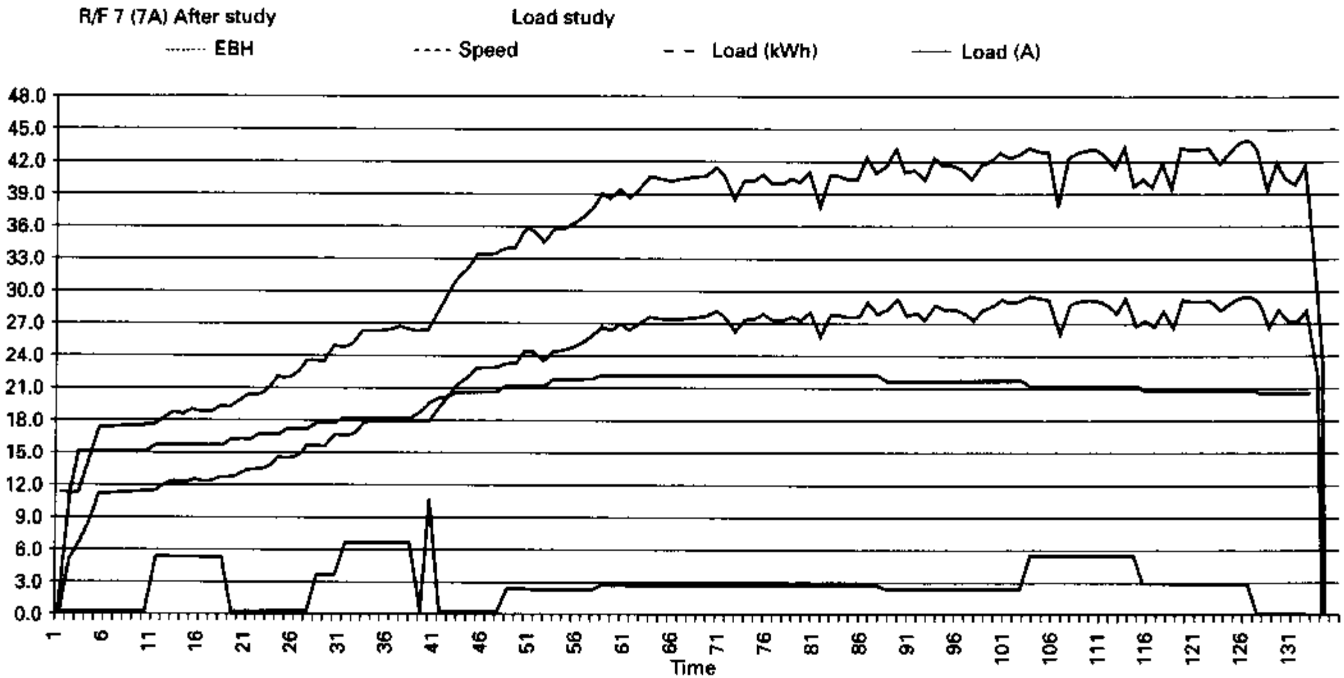
111
116
121
126
131
136
Time



R/F 7 (7A) After study
Load study
EBH
Speed
Load (kWh)
Load (A)
48.0
45.0
42.0
39.0
36.0
33.0
30.0
27.0
24.0
21.0
18.0
15.0
12.0
9.0
6.0
3.0
0.0
1
6
11
16
21
26
31
36
41
46
51
56
61
66
71
76
81
86
91
96
101
106
111
116
121
126
131
Time

Replacing fillet on stationary flats
back along with L-in 7/8 months
front along with cyl. doffer in 2 years

Draw frames cleaning – 10 days
Resetting bottom rolls O hauling – 3 years
Rechecking autolevellers – 15 days
Calibration of electronic autoleveller components – 3 years from LMW

Roving
full cleaning – 20 days
full setting – 6 months
cot buffing – 3 months
checking % stretch – every new lot

Ring frame
full cleaning – 1 month
resetting bottom roll – 1 year
semi-overhauling – 3 years
cot buffing – 1 month
traveler change – 10 days

Mills believes in online quality control over offline quality control. The mill believes more in using process observations than the QC test reports for noticing the need for control or improvement. They have linked their SQC instruments and autoconer to a central computer equipped with software developed in-house to analyse the reports with short-/long-term data easily. Since the automatic winding machines are also linked to this system, most of the abnormal drums are attended to and corrected within 24 h. This is a major quality advantage to their customers in that the drums giving fewer/ more cuts than standard are eliminated quickly, giving ultimately a much better yarn quality.

This mill is a rare example of a spinning mill which modified existing ring frames in good mechanical condition to run at a maximum speed of 22000 rpm, which is 2000 rpm higher than the designed speed of G 5/1 frame. This is creditable. And what has the mill changed? Only spindles, rings and travelers—all are consumables that need to be replaced periodically. The only major non-consumables expense was a new electric motor with speed variator, the payback of which comes in less than 2 years. This entire package is quite cost effective.

That the RSWM could make fibre suppliers alter their spin finishes so that their spinning units can reduce over-pray is a great achievement. That the mills have taken trials to optimise card clothing, rings, travelers, etc, shows a very systematic and scientific approach to make high speeds spinning of polyester blends a success.

Mr. Sanjay Sharma, Chief Operating Officer, who masterminded the trials of high speed spinning is grateful to Mr. J.C. Laddha, Chief Executive (Yarns) who provided guidance and encouragement, and thanks Mr. Sukesh Sharma, Sr. General Manager—technical, and Mr. R.K. Gagrani, Asstt General Manager (QC), for their involvement and support.

Dyed fibre spinning at high speeds

Sangam (India) Ltd

Sangam India Ltd has two spinning units in Bhilwara—spinning division I is at Biliya Kalan with capacity of 100000 spindles exclusively on dyed fibre spinning in polyester/viscose blends, and spinning division II at Sareri with capacity of 100000 spindles on both dyed fibre spinning in polyester/viscose blend and cotton spinning. Together, the two divisions produce 120 tons of fibre dyed spun yarn and 20 tons of cotton yarn per day. So this is India's biggest fibre-dyed yarn spinning mill—and as the dyed fibre spinning of short fibres is an Indian phenomenon—this mill would be the world's biggest spinning unit for dyed fibre spinning. Mill's major counts are 15s, 18s, 30s, 40s and 50s. This mill probably records the highest productivity in grammes per spindle shift for 15s and 18s in India. All the spun yarns are doubled because these are used for suitings.

Let us look at two of their major counts: 18s as it is their strong product and 30s which is a very common count.

Let us take a quick look at this mill. They have chute feed to 43 cards. Surprisingly, in their recent expansion, this mill went in for finisher scutchers and the new cards are lap fed. The mills took this step because they found that the chutes need to be cleaned often, about once in 15 days. A fair amount of oligomers, un-reacted dye stuff and other chemicals get deposited and obstruct the smooth flow of fibres. Moreover, during the transfer of fibres from blowroom to cards, the fibres (especially, when they are wet in rainy season) get entangled, thereby causing more neps and objectionable faults. They have Lakshmi's and Trumac blowroom lines.

They have Lakshmi's LC300 A, 300 AV-3 and C1/3 and Trumac's DK 780/DK 800 cards. They run Lakshmi's LC 1/3 cards @ 130 m/min; while all other cards are run @ 170 m/min. Card hanks are 0.115 for 18s and 0.130 for 30s. They use D06 as breaker and run it @ 350 m/min; while the finisher draw frame RSB 851 is run @ 750 m/min. The finisher sliver hank is slightly coarser: for 18s, it is 0.112 and for 30s, it is 0.120.

They have Lakshmi's 1400A, 1465 and 1660 fly frames and Zinser 681 fly frames. The roving hank is 0.72 for 18s and 1.05 for 30s; they use a higher TM of 0.85 for both 18s and 30s. Fly frame speeds are 900 rpm for 18s and 1050 rpm for 30s.

Mills have both Lakshmi's G5/1 and LR6 ring frames.

	18s	30s
Average spindle speed rpm	15012	18937
Maximum spindle speed	15600	19720
TM	2.95	3.07
Production in g/ss	440	249

G5/1 ring frames have 576 spindles per frame; ring diameter used is 38–42 mm; lift is 180–210 mm. The LR6 ring frames also have 576 spindles per frame, ring diameter 38 mm and lift is 170 mm. Number of spindles allotted per tenters are 1152 (2 sides) for 18s and 1728 (3 sides) for 30s.

Mills have Autoconer 338 and Savio Orion Cone winders. They wind 18s @ 1600 m/min while 30s is run @ 1500 m/min. The yarn cleaners are Loepfe YM800 I.

Mills have Vijay Lakshmi two-for-one twisters running @ 10500 rpm for 18s and 11000 rpm for 30s.

Their quality parameters are as follows:

	18s	30s
Card:		
Neps/g of sliver	——— below 1.33 ———	
Uster U%	4.12	4.05
CV% of 6 m wrapping	2.54	2.65
Total card waste	1.15	1.40
Finisher sliver:		
Uster U%	1.83	1.88
UV% of 6 m wrapping	0.24	0.28
Roving:		
Roving U%	3.35	3.45
CV% of 15 m wrappings	0.88	0.92
Breaks/100 spindle hours	——— below 1 ————	
% Stretch empty to full bobbins	0.2	0.3
Ring:		
Actual count	18 ± 0.2	30 ± 0.3
CV% of count (120 m lea)	1.65	1.68
Uster U%	8.24	10.46
Thick places	0.06	7.08
Thick places	5.62	16.50

Neps	23.45	83.28
Total imperfections	29.13	86.86
Yarn hairiness	3.33	3.58

Classimat–objectionable faults: checks on Autoconer, which has online Classimat on every drum

Avgerage breaks/100 spindle hours	2.5	2.8

Winding:		
Cuts/100 km	40–60	80–100
Yarn hairiness on winding	3.5 to 4.5	3.5 to 4.8

Imperfections after winding 30% higher than ring yarn

Mill's maintenance practices are as follows:

		Semi-HP cards	HP cards
Card –	cleaning	every 15 days	every 10 days
	Full setting	every 30 days	every 20 days
Drawing –	cleaning	8–12 days	
	Top roller buffing	10–15 days	
	Cleaning of bottom rolls	Every lot change	
Roving –	Buffing frequency for cots	3–4 months	
	Bottom roller resetting	2.5–3.5 months	
	Cleaning of flyer legs/aprons	12–18 days	
Ring –	Buffing frequency for cots	2.5–3.5 months	
	Cleaning of aprons	10–12 days	
	Cleaning of bottom rolls	10–12 days	
	Resetting of bottom rollers	5–7 months	
	Traveler change schedule	4 days	
	% Pneumafil waste	1.1 %	
General –	Lot size	2–25 tons	

RH maintained – in card room in different seasons 45 to 50% round the year

– in ring spinning in different seasons —do— — — — —

Dry bulb 96 to 98 °F

% over spray for semi-dull –	% LV40 0.44 and % 2152P 0.02
– Water	2 to 2.5% depending upon season
% over spray for trilobal –	LV 40 0.35% and 2152P 0.30
– Water	2 to 2.5% depending upon season

for dark/extra dark shades — same as for trilobal

Moisture accepted in dyed polyester, in semi-dull: 3–4%, in trilobal: 5–6%, in dope-dyed viscose: 11–13%

The mill has reserved a few cards to pre-card viscose in case the shade of viscose has a contrast with that of polyester; also, if raw white viscose is blended with black polyester in mélange shade. Viscose is pre-carded also when viscose of many shades are mixed.

Incidentally, Sangam runs all their spinning preparatory machines at much higher speed than other mills. They run RSB 851 draw frames at 700–750 m/min on dyed fibre mixings; while most other mills run this machine at 450–550 m/min. Sangam just cannot speed up their ring frames further because they are short in preparatory.

Special efforts are put in to tackle certain 'difficult' shades that give poor performance at every machine and yield high values of unevenness and imperfections. They check the static charge of every lot; and if need be, take corrective action. Appearance boards of card web are made and observed. If the web is not OK, certain specific actions are taken. The SQC department makes a summary of data on every lot run in the month. If a shade has worked badly — and if the bad working is due to the viscose component, the complaint goes to Gwalior Rayon; they help to solve the problem. If the problem is polyester based, then the mill checks the combination of dyes used and tries changing dyes. More problems are faced in dark and extra dark shades.

The quality of water in Bhilwara is satisfactory in terms of TDS (Total Dissolved Solids); it is unsatisfactory during the summer months of April and May. Over the year, the TDS remains below 300 ppm. The mill has plans to install a RO (Reverse Osmosis) plant to ensure a TDS of near zero through out the year.

In the tribal belt in which this mill is located, quite some worker shortage is experienced by all the mills in the area. This shortage is also because a large number of industrial units have come up in this region. In the month of May, the problem becomes acute since workers from Orissa, Uttar Pradesh and Bihar take long leave to go to their native places.

Raymond Ltd

Raymond Ltd. has a composite textile mill at Boregaon in Chhindwara district of Madhya Pradesh, about 75 km from Nagpur on the Nagpur–Chhindwara road. Here Raymonds have put up polyester/viscose (PV) spinning unit, polyester/wool spinning unit using the worsted system; weaving and full range of wet processing for both polyester/viscose and polyester/wool suitings. This unit makes about 40000–45000 m per day of suitings for which Raymonds are famous.

The PV unit has today 10 848 ring spindles. It spins only own dyed polyester/dope dyed viscose in 65/35 blend using 1.4d × 44 mm PSF from Reliance and 1.5d × 38/44 mm viscose staple from Gwalior Rayons from Nagda. The unit produces about 5.5 tons of yarn per day. Major counts are 15s, 20s, 33s, 40s, and 50s. Most of the single yarn is doubled on TFO twisters and a small proportion is used as single weft with doubled warp in weaving. Spinning of reverse twist yarn in all counts is a regular phenomenon in Raymond.

The PV unit produces dyed PV yarns. Each shade has 3 or 4 differently coloured polyester fibres and also 3–4 differently coloured dope-dyed viscose fibres. Many shades have either one dark coloured viscose shade blended with other light coloured shades or vice versa. The dark or the light coloured viscose component forms neps, which become objectionable at finished fabric inspection. Cloth menders remove the neps that look bad. Pre-carding of these specific shades of viscose fibres gives good results in terms of eliminating such neps. Also, mills do frequently play with deniers of polyester and viscose—1.2, 1.3, 1.4, and 1.5 and cut lengths of 38 and 44 mm to control not only neps but other yarn faults like slubs etc. In small spindleage of 10 848, they run light/medium/dark shades in all count combinations at a time, taking utmost precautions to ensure no mix-ups. Some of the normal work practices are: use of small lot sizes of even less than 200 kg, 6 different counts with their respective derivatives of reverse twist, frequent changes in count run on ring frames (about 4 per month), consequent changes in preparatory and in post-spinning areas. Such practices are rarely found in other mills.

They have 3 blowroom lines to run 18–25 lots every day; the average lot size is around 200–300 kg (or even smaller). To avoid contamination, blowroom has to be stopped after every lot and has to be thoroughly cleaned up. Therefore, one would see their blowroom stopped for much longer period in a day. The same is true in rest of the spinning sections—especially, in the preparatory sections—where the machine cleaning time is often more than the production time. Mills have both lap fed and chute fed cards. Cards are Lakshmi's C1/3 and LC 300A-V3 cards running @ 100–120 m/min. The chute has to be cleaned every 15 days.

They have Lakshmi's DO6 draw frames running @ 250–300 m/min as breaker and Lakshmi's RSB 851 as finisher running @ 500–550 m/min. This mill has a service contract with Voltas to maintain their autolevelers. Its impact is seen in very low values of CV% of 6 m wrapping, which are around 0.146–0.152. Other mills get these values @ around 0.20–0.25. It is really rare to see such good values. The U% of finisher sliver is also around 1.6–1.7; so the mill has ensured that their finisher drawing sliver is as even and as uniform as can be made; thereby laying a good foundation for high speed spinning.

The mill has Lakshmi's LF 1400 and LFS 1660 fly frames running at 900 to 1000 rpm. Their U% of roving is 3.16; CV% of 15 m wrapping is 0.35 (other mills get 0.5) The stretch on the roving, measured by the difference in wrappings of full and empty bobbins, is well controlled at 0.36% and their breakage rate is around 0.75 breaks per 100 spindle hours.

Mills have 8 Lakshmi's LR6 ring frames and 14 Kirloskar Toyota RX1 240 ring frames of 480 spindles each and 2 Lakshmi's G5/1 ring frames of 544 spindles each with 40 mm ring diameter and lift of 175 mm. They work with all these ring frames at an average speed of 17 500, the maximum speed being 19 000 and the production is 190 g/ss for 33s and 100 g/ss for 50s. These figures are lower than those of other mills because the twist multiplier used by Raymond is 3.53; whereas other mills using 44 mm fibre would use 2.9–3.0. Raymonds have found that with higher than normal twist, the fabric appearance and feel is improved significantly. Fabric appearance as well as the feel and the texture are important to a 'high value' suiting manufacturer like Raymond.

Mr. Nanal had responded to the invitation of the mill to undertake an audit of their blend spinning operations. In the course of his checking, he found that the mills satisfied all the requirements needed for successful high speed spinning. He suggested that one LR 6 ring frame be speeded up to run at 22 000 rpm. This was done and mills found working alright. Then they speeded up 3 other ring frames to 22 000 rpm and the end breakage rate continued to remain around 1.0–1.2 breaks per 100 spindle hours; U% and imperfections were at the same level as before and winding cuts were also unchanged. The high roving twist multiplier of 0.8 and high yarn TM of 3.53 were possibly responsible for the breakage rate remaining the same at higher speeds. At this stage, the worker's union intervened and stopped speeding up other ring frames until the wages of the ring frame workers are suitably increased by way of share in the increased profitability of the mill. Otherwise, at the technical level, the mill could have raised spindle speed even to 24 500 rpm.

The mill is now running some of the LR6 ring frames at the maximum speed of 22 000 rpm, the average speed being 19 500 rpm. Production has gone up to 212 g/ss for 33s (an improvement of 11.6%) and 108 g/ss for 50s—an increase of 8% in productivity. Surprisingly, the breakage rate has remained steady at 1.0–1.2 breaks/100 spindle hours at the higher speed. Also winding cuts did not go up at all with higher ring frame speed. The probable reasons would be the excellent preparatory quality and the higher than normal twist in roving and yarn.

In India, so far the highest speed for dyed fibre spinning has been 20 500 with Sangam, Rajasthan Spinning & Weaving Mills, Gulabpura and Priyadarshini. Therefore, Raymonds have now set a new record with the maximum speed of 22 000 rpm.

Mills have 5 autoconers 338 with Loepfe optical clearers and equipped with Mill Master Easy, winding at 1400–1600 m/min with winding cuts at 37 per 100 km. Mills have 33 TFOs, the makes being Star Volkman, Murata and Prerana—all running at 10 500 rpm and one Fadis (Italian) assembly winding machine running at 800–1300 m/min and rest 4 are Peass Mettler running at 350–450 m/min.

The average spun yarn properties are:

Count	33s	50s	
Uster U%	10.7	12.7	12.1*
Thin places	8	73	52
Thick places	4.6	135	65
Neps	120	539	148
Total	174	757	278
Hairiness	2.6	2.0	

(*with 1.2d × 38 mm polyester and 1.3d × 38 mm viscose)

Mill's maintenance practices are:

All old Lakshmi's C1/3 cards are provided with C-factors for better quality of sliver. Cards and other machines—all parts that come in contact with fibres—are cleaned with petrol after every lot change as considerable quantities of oligomers, un-reacted dyestuffs and other chemicals get accumulated. All cards are fully set every 20 days.

Cot grinding: draw frame cots are ground every week, fly and ring frame cots are ground every 2 weeks. All flyer tops are cleaned with soap every 2 months.

Life of Bracker travelers is 3–4 days. All top and bottom aprons of ring frame and speed frame are washed with soap every 2 months. All bottom rollers, coilers of draw frame and coiler of cards are scoured with brush and petrol after every lot change.

The mill uses cots of 35 mm diameter and 90° shore hardness on all ring frames. Life of Braecker travelers is 3–4 days.

Another important point is that mills buy all their spares from the original machine suppliers only. This is the best practice and only quality conscious mills are doing this. This practice not only enhances the life of machines, but also helps in delivering consistent good quality of product.

Mills go for the best available accessories. They have opted for Titan solid rings and Bracker travelers which contribute a lot to high speed spinning. Only a few quality conscious mills are using such ring and traveler combinations.

The mill has also given annual maintenance service contract for autolevelers of cards running with chute feed system which turns out to be a very wise decision.

For this comparatively small mill size of around 11 000 ring spindles, the mills have a staff of 15 technically qualified people in spinning PV. A difference here is that many of the QC activities are carried out by mill's production staff. The staff is comparatively young and enthusiastic, and was very much involved in speeding up the ring frames from the earlier maximum spindle speed of 17 500–22 000 rpm.

At Raymond, the PV spun at high speeds is treated like a family treats a new born baby. Every body takes care to ensure that everything is done right in day-to-day working. For them, quality and productivity are like two sides of the same coin; both are equally important for them to make the product not only quality competitive, but also cost effective.

Raymond's look forward to keeping their leadership in high speed spinning of dyed polyester blends by trying to run ring frames at 24 500 rpm in due course. And that too with 1 break/100 spindle hours and around 37 cuts per 100 km at autoconer. The PV unit also is trying to reduce yarn imperfections to the bare minimum, so that no mending is needed at the final stage of finished fabric.

Learning: ingredients of successful implementation

- Management keen and insistent on achieving targets that need 'stretching'; and willing to support the efforts of the technical staff.
- Staff enthusiastic about trying new ideas and willing to pick up good ideas from all sources.
- Perseverance after initial failures, if any. Willing to try out different approaches till success gets achieved.
- Different sections like production, quality control, maintenance work together for the set goal.
- Management appreciates sustained improvement and rewards concerned staff appropriately.

8

Saluting the Pioneers

At the time when blend spinners all over the world were happy in running polyester blends at spindle speeds of 14000 to 16000 rpm on their ring frames, a few spinners in India dreamt of 'high speeds of 20000 rpm plus' for polyester blends. Their vision, perseverance, hard work and risks taking attitude, made it happen. These spinners are:

1. Mr. V. K. Indrayan now as CMD of Indian Yarn Ltd, Chandigarh
2. Mr. R. N. Sharma now with Reliance Chemotex Industries Ltd, Udaipur
3. Mr. B. Shiva Reddy, Director (Technical) at Priyadarshini Spinning Mills Ltd, Sadashivpet, Hyderabad
4. Mr. S. M. Gupta, President (Works), Sangam (India) Ltd, Bhilwara
5. Mr. M. M. Biradar Senior Manager, P.V. Spinning, Raymond Ltd, Chhindwara and
6. Mr. Sanjay Sharma Rajasthan Spinning & Weaving Mills Ltd, Banswara

These six pioneers have laid a strong foundation for high-speed spinning of polyester blends in India. It is due to the efforts of these pioneers from India that high speed spinning of polyester blends has become a solely Indian phenomenon. All in the Indian textile industry should be proud of these pioneers who have shown the way to manage high speed spinning successfully.

We hope that not only other spinners in India but also those in other countries will follow suit and make a success of high speed spinning of polyester blends soon.

V. K. Indrayan

Mr. V. K. Indrayan is today the Chairman and Managing Director of Indian Yarn Ltd, his own spinning mill of 27000 ring spindles, situated at Lalru in Punjab near Chandigarh.

Mr. Indrayan hails from Meerut in UP and completed his schooling there in 1959. He took his B. Text degree from Government Central Textile Institute in Kanpur in 1964.

He started his career in textile industry by working in Modi Spinning & Weaving Mills, Modinagar and at TIT at Bhiwani, which were among the first few mills in India to work polyester and acrylic staple fibres. In 1972, he joined Bhilwara Spinners, Bhilwara, as Spinning Master. He established dyed fibre spinning there. He then shifted to Kiran Spinning Mills in Thane. He established dyed fibre spinning there also and improved their productivity. In 1980, he joined Reliance Chemotex at Udaipur as a Technical Manager; and he set new norms of quality in polyester blended yarns.

In 1984, he joined Pasupati Spinning & Weaving Mills at Dharuhera in Haryana as Chief Executive; and he made it one of the highest profitable spinning mill. In 1987, he was invited to join Priyadarshini Spinning Mills in Hyderabad as President. This mill was then only 4 years old and was losing money. He turned this mill around by putting the entire mill on polyester–viscose blends in grey and fibre-dyed qualities. At present, Priyadarshini is the only mill in South India to do dyed fibre spinning in a big way. Also, it has the finest reputation for the highest productivity and quality. Mr. Indrayan set the foundation for this. He ventured into high speed spinning here by speeding Lakshmi's G5/1 ring frames from 14000–15000 to 18000 rpm.

In 1995, he realized his ambition to become a mill owner (as achieved by a few technicians—R. L. Toshniwal, B. K. Ladia and C. K. Rao) by putting up Indian Yarn Ltd at Lalru in Punjab. This mill has 27000 ring spindles, specialises in acrylic spun yarns for which the market is close by, at Ludhiana.

The bio data above describes only his journey from a shift assistant in Modi's mill to CMD of Indian Yarn Ltd in 32 years. That does not really tell us much about Mr. Indrayan as a spinner. It was in Priyadarshini in early 1990s—20 years back—that he visualized not only high speed spinning of polyester blends but he knew he would make a success of it. He was a true visionary. In 1990s, as he puts it, he applied the fundamentals of spinning to manage high quality and productivity. Proper amount of over spray, gentle opening of the fibres, perfect carding, very even drawing sliver with lowest CV%, roving with U% less than 3.5 were ensured. Also ensured was good maintenance of all machines; particularly of drafting systems—cots and aprons—to make a success of high speed spinning. He and Mr. Shiva Reddy increased spindle speeds of G5/1 ring frames by 1000 per month only after ensuring well-blended feed at blow room, very tight settings between inclined spiked lattice and evener roller so that the lumps move up and down in the hopper getting opened up gently, checking U% of every roving bobbin/frame every month to ensure that no roving bobbin with a U% higher than 3.5 is sent to ring frames—and this way in late 1980s they reached 18000 rpm on 60s PV. This was very near to the upper limit of spindle speed for G5/1 ring frames. This was a record then.

In Pasupati, Mr. Indrayan repeated the Priyadarshini experiment. Here he had ring frames of earlier vintage—Lakshmi's DJ5—to work with. He and Mr. R. N. Sharma modified these ring frames and put pulley drive after removing tin rollers, changed spindles, rings etc and then ran them on 60s PV at 20000 rpm.

No wonder we call Mr. Indrayan the 'father of high speed spinning of polyester blends in India'. His two disciples—Mr. Shiva Reddy and Mr. RN Sharma—have continued his traditions. Mr. Shiva Reddy of Priyadarshini Spinning Mills runs LR6 ring frames on 60s PV at 245000 rpm and Mr. Sharma at Reliance Chemotex runs 100% Dope Dyed black at 22500 rpm also on LR6 ring Frames.

R. N. Sharma

Born and brought-up at Bhiwani where the Technological Institute of Textiles is located. He passed from TIT in the year 1970. Mr. Sharma started his career from the Synthetic Spinning section of TIT Mills.

- TIT Mills was one among the very few to start synthetic spinning in those days. No expertise and no prior experience was available and each step in the direction of processing these fibres was a hit and trial. And whosoever hit well in that period, has risen to the level of President (of a mill) today.

  After 2 years of working with TIT, Sharma joined DCM Group's Hissar Textile Mills and got a further chance to work in synthetic spinning.
- P/V blends used to fetch very good profits to the mills. The main complaint from weavers was of *patta* (stripes or bars) formation due

to blend variation. He was nominated a member of the team formed to tackle this problem. The present day system of stack layering and vertical cutting of mixing was actually developed and introduced during that period.

After 4 years of working with DCM, Mr. Sharma joined Rajasthan Spinning & Weaving Mills (RSWM), Gulabpura.

- RSWM could easily be termed as 'mother industry' of synthetic spinning. He did a lot and achieved a lot during the working for 6 years at Gulabpura. What so ever system were designed, devised and practiced at Gulabpura in the period 1975–1980, became the Rule-Book of synthetic spinning in coming years. After being for 6 years with RSWM, he worked as Technical Manager with Reliance Chemotex Industries, Udaipur and Siddhartha Super Spinning, Nalagarh for a period of 5 years and then joined Pasupati Spinning, Dharuhera in the year 1987.
- He headed Pasupati for 12 years and a considerable amount of innovative work, particularly in fibre dyed yarn, was done under his leadership. It was at Pasupati Spinning that DJ-5 ring frame were made to run at a spindle speed of 20 000 rpm after almost re-building them. Since 1999, he is at Reliance Chemotex Industries Ltd, Udaipur.

He has been with the industry for more than 38 years now. 'A lot has been done but a lot more still remains to be done. However, life is really too short to complete any work so well, that nothing more is left to do.'

B. Shiva Reddy

Mr. B. Shiva Reddy is currently the Director (Technical) at Priyadarshini Spinning Mills, Sadashivpet about 75 kms from Hyderabad on the Hyderabad–Sholapur highway. Mr Shiva Reddy's is a unique case of a person joining a mill as a Spinning Manager and slowly but steadily climbing up to a position of a Director on the Board of Management. This credit is to both; the management who recognized the potential talent in Mr. Shiva Reddy and went on giving him more and more responsibilities, and to Mr. Shiva Reddy who could come up to the management's expectations at every promotion.

Born on 4th June 1948, Mr Shiva Reddy did his diploma in Textiles, with distinction, from the Government Polytechnic at Guntur.

Mr. Shiva Reddy started his career with Azamjahi Mills at Warangal. This was a composite textile mill with 42 000 spindles, 1000 looms and full processing with fibre dyeing. He started as an assistant in spinning and then was promoted as Assistant Spinning Manager. He worked here for 9 years.

He then joined Vijay Spinning Mills (70000 spindles) at Vijaywada. Here he became Spinning Manager. He worked here for 5 years.

In 1983, he joined Priyadarshini Spinning Mills as a Spinning Manager just as mills were staring up their production. He made significant contributions here. His biggest achievement is running 14 (LR 6) ring frames on 60s and 76s PV at the highest speed of 24 500 rpm—**highest in the whole world**—for the last 7 years. He has made a success with dyed polyester/dyed cotton blends, that too in solid shades. He may be the only spinner to run this blend on a large scale. He ran real deep black of 14% shade at normal speeds. He could speed up the most difficult shade—navy blue—to 18000 rpm. from the earlier value of 14000 rpm.

He is soft spoken and unassuming. Even at the age of 60, he spends at least 6 hours a day in the department. Nothing that has gone wrong eludes him, howsoever small it may be. He invariable notices such items and gets them corrected or eliminated. It is only because of his detailed daily rounds that he has been able to run LR 6 ring frames at 24500 rpm with just 4 breaks per 100 spindle hours steadily for the last 7 years. It is not easy to maintain such good working over such long years.

He was one of the first to run flame-retardant fibres in a fairly big way. However, lack of market within the country led to stoppage of this fibre in the mill. He has spun 120s in 100% polyester counts from the Super Microdenier 0.5d × 38 mm fibres at good speeds. Very few spinners would attempt such a super fine count in polyester.

He is an excellent team builder and knows how to handle labour. There has hardly been any labour problem in his mills.

Mr. Shiva Reddy today is prepared to take any challenge in spinning of polyester blends—grey, dyed and specialty—which is the mark of a real great spinner.

S. M. Gupta

Mr. S. M. Gupta is today the President (Works) at Sangam Spinners Ltd, Bhilwara. Sangam has 200000 ring spindles working exclusively on fibre dyed qualities. This is a record of sorts. It is not an easy job to run 200000 spindles on dyed fibres. This is the biggest unit of its kind in India, and in the world.

Mr. S. M. Gupta was born on India's Independence Day—15th August—in 1953. He did his B.Sc. from University of Rajasthan in 1973; and then took his B. Text from TIT Bhiwani in 1977.

He now has a rich experience of 31 years in the blend spinning industry. He started his textile career with Rajasthan Spinning & Weaving group and learnt the basics of dyed fibre spinning there. He later worked at Mahaveer Spinning Mills, Hoshiarpur; Rama Fibres, Bhiwani; Super Syncotex, Gulabpura; and Shri Rajasthan Syntex, Dungarpur.

He joined Sangam in 1995 when Sangam was being established and was in the process of installing machinery. He was selected for Sangam because he had an excellent experience in running dyed fibres and Sangam had planned to run only dyed fibres. Sangam has grown now to 200000 ring spindles making 120 tons of dyed fibre yarn daily.

Mr. Gupta is one of the few spinners who keep themselves up to date by reading textile magazines and other publications regularly; and he takes great interest in discussing finer points of dyed fibre spinning with different visitors.

Mr. Gupta has really understood the various changes take place during HTHP dyeing in the physical properties of polyester staple fibre and knows how to optimize spin finish and other parameters like twist multiplier etc. to ensure that the dyed fibre works well on all spinning equipment. He is therefore able to run C1/3 cards at 130 m/min, LC300 and DK 780 cards at 170 m/min. The mill operates RSB 851 draw frames at speeds between 700 and 750 m/min. And at the same time, he ensures that all spun yarn properties like evenness, CV% of wrappings, breakage rates, etc. are kept well under control. He excels in spinning of 15s and 18s—gets the highest spindle productivity (g/ss) in the country. He feels that running of 30s and 40s could be further speeded up; but there is limitation in the preparatory.

Another plus point Mr. Gupta has is in his handling of people working under him. He has a way with people and has built up a strong technical team in Sangam. His labour relations are equally good; and Sangam has had no labour problems at all though they have 4000 workers on roll.

Mr. Gupta is a distinguished technocrat, and will surely go places in time to come.

M. M. Biradar

Mr. Malkappa Biradar works as Senior Manager and Head of Department at polyester–viscose spinning unit of Raymond Ltd., at Boregaon about 75 kms from Nagpur on the Nagpur–Chhindwara road in Madhya Pradesh. The PV spinning unit has today 10 848 ring spindles producing about 5.5 tons of fibre dyed yarns per day. Their main counts are 15s, 20s 33s, 40s and 50s; the blend is 65/35; polyester 1.4d × 44 mm is from Reliance. It is dyed at the unit, while the viscose 1.5d × 44 mm is dope dyed from Gwalior Rayon.

Mr. Biradar completed his diploma in textiles from Government Polytechnic, Solapur in 1986; he stood first in the state and won a gold medal. He then took his textile degree from DKTE's Textile and Engineering Institute at Ichalkaranji in 1989 where he stood third in order of merit in Kolhapur University. He is a fellow of Institution of Engineers and also a fellow of the Textile Association (India), which he secured in 2006. He is also a member of All India Management Association and Indian Society for Training and Development, Quality Circle Forum of India, Precitex Spinners Association. He is a Chartered Engineer in textile discipline and Vice Chairman, Vidarbha Unit of the Textile Association (India). He is also on the committee for revision of curriculum set up by Government Polytechnic, Nagpur.

He started his textile career in 1990 with Raymond in polyester/wool and in 100% wool spinning in their worsted spinning department. Raymond then was putting up a brand new mill at Boregaon and Mr. Biradar was recruited for this new venture. For sometime, Mr. Biradar was looking after both, polyester–wool and polyester–viscose spinning. Then in 2004, when the management decided to fully modernize the PV section, he was put in full charge of the PV unit. He is fully conversant with both short- and long-fibre spinning, having spent over 12 years in worsted spinning and now 6 years in PV spinning.

PV spinning at Raymond is complex. Every month, they spin 60–70 shades—each shade has 4 or 5 colours each of polyester and viscose in proportions suggested by their Design & Development department. Some of these shades have a small proportion of dark-coloured viscose while all other shades are light in colour; while some other shades have light coloured viscose with all other shades being dark. This small proportion of viscose fibres forms neps that have to be removed during mending. Certain shades have so many neps that it is not possible physically to remove them during mending; such fabrics have then to be over dyed, putting mills to a considerable loss. Mr. Biradar has tried pre-carding of these small proportions of viscose to solve this tricky problem.

Mr. Biradar has excellent control on short- and long-term unevenness in spinning preparatory. He has given a service contract for autolevellers with Voltas. Net result is that CV% of 6 m wrappings of finisher sliver is as low as 0.146—a value so good it is not generally seen in other mills. His U% of sliver and roving is well under control being 1.8 and 3.2 respectively. And these good values have enabled him to speed up his LR6 ring frames on 33s, 40s and 50s to a maximum speed of 20000 rpm from the earlier speed of a maximum of 17000 rpm. This probably the highest speed seen in dyed fibre spinning in India, and in the world.

Mr. Biradar has a young qualified team; and he has motivated each one of the team so well, that they whole-heartedly take trials under his guidance to improve product quality and productivity. Work keeps Mr Biradar busy leaving him very little time for recreation. He spends his free time in reading textile magazines and books.

Mr. Biradar has written several articles, which have been published in Indian Textile Journal, Manmade Textiles, and in the Journal of the Textile Association. He has also presented papers at technical conferences and seminars. He keeps close contact with academic field. He is faculty-cum-coordinator for continuing education programme in textiles organized by Raymond and Government Polytechnic, Nagpur. He is a member at State Level Course Committee of Maharashtra State Board of Technical Education and Board of Studies of ATA and GMTA of the Textile Association (India).

Mr. Biradar, 42, now looks forward to breaking more records: not necessarily in further speeding up the ring frames but in reducing objectionable yarn faults to the minimum so that the costly suitings that Raymond produces need not be mended and still give a high packing performance of 'A' grade.

Sanjay Sharma

Mr. Sanjay Sharma is currently the Chief Operating Officer at RSWM Limited (Formerly Rajasthan Spinning and Weaving Mills Ltd.) Banswara. The mills have 88 000 spindles and 1680 OE rotors. The Banswara units produce polyester, polyester/viscose and pure cotton yarns totaling 90 tons per day.

Mr. Sanjay Sharma was born in Delhi on 7th June 1957. He completed his B. Textiles (Spinning) from Technological Institute of Textiles, Bhiwani, in 1978.

He started his industrial career as a technical trainee with Vardhaman Spinning in Ludhiana. He then moved over to Mayur Syntex at Sikandarabad in UP as Maintainence-in-Charge and then joined Arihant Spinning, Maler Kotla, in Punjab as Maintainence Engineer.

The next step was at Deepak Spinners in Baddi where he worked as Spinning Master (Maintenance) and was involved in over all planning and commissioning of the unit. Here he was elevated to the post of Vice President (Technical). Thereafter, he was transferred to their Guna unit as Vice President (Technical) only. He headed the Guna unit as coordinator and handled the planning, erection and commissioning of the new plant, starting from scratch. He worked with Deepak Spinners for 10 years.

Moving on, he joined Indo Rama Textiles at Pithampur as Head (Operations) and later he was transferred to their Butibori unit near Nagpur. He was with Indo Rama for 7.5 years.

Today he is with RSWM Limited at Banswara as Chief Operating Officer. Here, he led the mills in modifying Lakshmi's G 5/1 riung frames to run at a maximum speed of 22 000 rpm in a cost effective manner.

Mr. Sanjay Sharma is a strong believer in team working. He says, "Team motivation is my main motto, since that helps in achieving most of the targets of the organization". Mr. Sharma has put into practice a team-based approach under the guidance of seniors, blended with the concept of ownership in an innovative way.

He says "In our unit, managers talk mainly in terms of money and not in units of kg, percentage etc."

Mr. Sharma takes keen interest in professional activities. He has been an active member of the Textile Association (India) at Indore and Nagpur and now Rajasthan. He played a major role in organising Joint Technical Conference in Nagpur as Head of the Advertising Committee. He is mainly instrumental in starting TITOBA at Indore and Nagpur. He always remains in touch with his industry friends.

Learning: Characteristics of successful technology leaders

- The technical qualification—level and college—is less important than practical experience of achieving improvements on the shop floor.
- One learns to perform well under different circumstances by spending several years at a time in each mill during career progress. (Too fast changes or no change at all are less likely to help the person grow.)
- Having positive attitude to new ideas and willing to try them out sincerely.
- Skill of creating/joining teams and working with them for success.
- Ability to see and understand the management point of view, mainly in terms of financial implications of technical actions/improvements.

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No references are cited in the text since this book is meant to be a practical guide to practitioners. A good idea on spindle speeds, considered good in the industry, can be had from the norms books from SITRA and from the other produced jointly by all CTRA's for use in composite mills at one time. These books of norms give excellent information on quality and productivity starting from fibre properties and ending up with the final stage of fabric processing. The book references and the article references are given for those who wish to study and understand much more than needed for industrial practice of what is proposed in this book.

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Appendix 1: Vital Components in High Speed Spinning: Spindles, Rings, Travelers and Drive Motors

The highest mechanically possible spindle speed on ring frames is governed by the design capability of the spindle. If the design is such that the spindle can run free of vibration at 25 000 rpm and the metallurgy permits working at this speed for years together with almost no wear and tear, then it is possible to speed up the ring frame to this level.

This is permissible because any modern ring frame is sturdy enough to permit driving the spindle wharves at such high speeds without any machine vibration setting in. The other component of the ring frame that is directly affected is the drafting system. Any increase in front roller speed, even up to 50% (corresponding to the increase in spindle speed from say 16 000 rpm to 24 000 rpm) is within the design capability of the bottom and the top rollers, and of the weighting system using springs or pneumatic pressure.

The other important limitation to increase in spindle speed is the capability of the ring–traveler combination. This combination should be capable of giving a low breakage rate throughout the doff, when new and well run in. The service life of travelers in days, and that of rings in years at such high speeds of rotation become the crucial factors. Excellent quality rings and travelers are now available, and mills seem to choose them on two different bases: high prices and longer service life, or lower prices and shorter service life.

Ring frames of earlier vintage (say models up to about 1995) were equipped with spindles and rings that would be able to run at the maximum permissible spindle speed of about 18 000 rpm. Spindles and rings are available now for increasing this limit to 25 000 rpm. In a few years time this limit may increase up to 30000 rpm, thanks to the continual R&D efforts by manufacturers.

Consequently, it is worthwhile to replace existing spindles and rings on the old vintage ring frames to increase productivity. However, one more change is often needed to manage this; the drive motor needs to be replaced by a motor of higher capacity (and higher energy efficiency) to take up the higher load generated by the higher spindle speed.

The economics of this modernisation is as follows. Taking the prices of spindles, rings and motors as Rs 1000, 250 and 30000 respectively, the capital cost of converting a ring frame of 576 spindles works out to be (1250 × 576 + 30000 =) Rs 0.75 millions. If we consider that this modernisation helps to go from 18000 rpm to 24000 rpm, then the increase in spindle productivity is 33%. The additional production per spindle shift for 40s PV yarn would be about 50 g/ss (from 150 to 200 g/ss), i.e. 86 kg per day per frame. At a contribution of Rs 50 per kg, the additional daily contribution is Rs 4300 i.e. Rs 1.55 million per year; **an excellent return on investment.** Even for an increase in productivity of just 10%, the return of investment is in less than 2 years; one does not need to wait for the service life of the existing spindles, generally of about 12–15 years, to be over before considering replacement by the high speed spindles.

Appendix 2: Down the Memory Lane

BY R. N. SHARMA

(Editor: Mr. Nanal was agreeably surprised to receive this write-up from Mr. R. N. Sharma. We decided to reproduce this as an Appendix, because it gives a brief overview of how things changed in the field of polyester blend spinning from as a 'first person story'. Readers can see the parallel between this write-up and the historical perspective given in Chapter 2. We are sure that many senior technicians from the industry would have had a similar experience.)

In the year 1970 when I started my career, synthetic spinning was very new to the industry. The doffer rpm used to be around 5; and mills working with spindle speeds of even 7200 rpm at ring frames were earning a name and rising to fame! The productivity was not that important; all the 'innovations' on the shop floor were centered on how to produce synthetic yarn (polyester viscose blends) without any troubles in working at cards, draw frames and ring frames. The main problems were smooth working without any lapping of fibres and consequent stoppage of machines and spoiling of quality. 'Do what so ever, mange how so ever, but get these fibres to work smoothly and produce a decent yarn quality' was the way all technicians operated in every synthetic mill.

The biggest problem at that time was unwanted generation of static charge. Thus, started the concept of over spray and conditioning. Even steam pipes were installed in blow room and carding sections. No original machines suitable for synthetics were available so all the machines were being changed over from cotton to synthetic and were generally of poor mechanical condition. But the technical staff in synthetic spinning section had started realising that for producing acceptable quality yarn, the mechanical condition of the machines should be better. The motivation for improving the mechanical conditions was good, since each change in process (parameters) or in machine (condition) was resulting in quick response in terms of improvement in quality and also in productivity.

During the later part of 1960s, Japan had promoted the concept of large package spinning, and in many mills ring diameter at ring frame was even up to 2 in. (50 mm). This was done mainly to reduce the cost at winding, and because the ring frame productivity in terms of grammes per spindle shift was less important than in terms of least labour compliment for piecing, etc. Early 1970s started the idea of reducing ring diameter to achieve higher spindle productivity. Automatic winding machines were making their way into the synthetic spinning mills already. Therefore, the machine efficiency at winding was not reduced much even with smaller package sizes at ring frames. By 1975 the synthetic spinning mills had learnt well to run their spinning machines satisfactorily on PV blends. So, from 1975 to 1985 there was a smooth change in productivity at ring frame. Good mills had started touching 15000 rpm.

At Pasupati Spinning, we were working PV blend at 16000 rpm by 1988 and during this time around, the spindle manufacturers started new innovations. M/S Kunal came out with the concept of smaller wharve diameter to reduce the weight of the spindle assembly and to get higher speeds with the same diameter of the tin roller/pulley drive to spindles. Kunal also came out with good quality PVC (poly vinyl chloride) bobbins which were soon replaced by PP (poly propylene). With this combination of lighter PP bobbins, wharve diameter of 20.5 mm and ring diameter of 42 mm, good mills started touching 17000 rpm of spindle speed.

During this period, Reliance introduced 1.0d polyester staple fibre and everybody in the industry started speaking of even higher productivity. We were a bit faster than others to touch 20000 rpm on DJ5 (on 60s PV, to start with) ring frames by year 1991. To achieve this speed, some of the important points implemented were as follows:

1. Thorough cleaning of mixing blender, particularly the area around disc beater and the mouth piece from where the opened fibre was delivered to the delivery pipes.
2. Conditioning of mixing for 24 h.
3. Buffing of calendar rolls of the scutchers in the blow room
4. Incorporation of all sorts of attachments available in the market during that period on Card C1/2 machine for getting optimum opening of the fibre.
5. Checking individual card's sliver on Baer Sorter for short fibre percentage and taking corrective steps, if needed, to achieve a short fibre content

of less than 3% in the sliver. This action was mainly to avoid any fibre breakage, especially of viscose, during carding.

6. On the basis of the card web appearance and its flow from doffer to table calendar rolls, the amount of spin finish was adjusted in the mixing department.
7. Thorough checking of draw frame DO2. I always found the 20 mm bottom roll to be the hidden culprit. Actually, there should be zero lateral movement in this small roll.
8. Draw frame top roller buffing, followed by acid treatment, was first done weekly and then for quite sometimes was done on a daily basis.
9. Checking of roving unevenness on individual spindles at Simplex (fly frame) GS. Initially for many months, this was done weekly. General problem was found to be the top arm disturbance; only sometimes it was a fault of draw frame. I do remember that strict follow-up of can numbering system was very useful in pin- pointing where the problem got generated.

   The impact of using good quality false twisters and its timely replacement was found delivering really good results. If false twister is not good enough then we need to increase the twist in the roving, leading to a drop in productivity at Simplex.
10. On DJ5 ring frame, the maximum gain was achieved by re-leveling the complete machine and also by eliminating vibrations in the ring rail while in motion.
11. The tin rolls in DJ5 were replaced with drum pulley drive, but only if vibration occurred with tin rolls.
12. Application of Liquimix after cot buffing also helped a lot in initial stages of the movement. After some time, when the spin finish got well adjusted, there remained no major role for Liquimix.
13. By the time Lakshmi Machine Works introduced G5/1 and then LR6 ring frames, the over all working environment had changed because of lot of improvement in the polyester staple fibre itself. Also, a substantial change had come about in the concepts used on the preparatory machines.

In the present circumstances, it is easily possible for mill technical staff to manage in such a way that almost no breakage (of sliver or roving) takes place at carding, at draw frames or to some extent even in Simplex. And if these machines are maintained well, then achieving super high speeds in the new generation LR-6 ring frame is not at all difficult. But one will have to abide by and follow strictly the basic rules of spinning and take guidance extended by experienced consultants, research workers and senior colleagues. Paying good attention to the ideas available through various papers published and talks delivered helps the technologists perform better at their mill jobs.

Editor: This book is a manifestation of the important last paragraph that advocates using the expertise of many for achieving good results. Here, we have summarised the "expertise of many for use by all".

Appendix 3: Rings and Travelers: Key Components in High Speed Spinning

Introduction

When processing polyester fibres, special attention to the fibre properties is essential. Compared to cotton or viscose fibres, polyester fibres can get damaged at relatively lower temperatures. Fibre fusing can lead to reduced yarn tenacity as well as to poor appearance of dyed fabrics because of the fused fibres getting dyed to deeper shades. The fibre finishes used currently on polyester fibres help to reduce the problem somewhat. However, this problem of heat generation cannot be neglected when spinning at high spindle speeds. In this context, rings and travelers become crucially important components in the success of high speed spinning; selection of the right quality of rings and of travelers is of the highest importance.

Heat generation at ring and traveler

The task of the traveler is to carry the yarn and rotate around the ring to impart twist, to provide sufficient tension to the ballooning yarn and to wind the twisted yarn on to the bobbin. To do this task well, the traveler has to stabilise the yarn balloon. With increasing spindle speeds, the spinning tension increases and the traveler friction with the ring also increases proportionately. This spinning tension created through the traveler rotating the yarn in a balloon form transforms the dynamical energy into heat. With higher speeds, the friction between the ring and the traveler increases. The larger the balloon size in terms of length and width, the greater is the spinning tension, the traveler-ring friction and the consequent heat generation.

Therefore, small ring diameters and short tube lengths (height of the spindle) are recommended to keep the balloon small and the spinning tension low. The smaller cop size is no more a disadvantage (as it was in the past) because the modern automatic winders have automatic yarn piecing units at every spindle position and the yarns are spliced together to avoid thick knots. The ratio of ring diameter to tube length should not exceed 1:5 so as to ensure an optimum balloon size.

Another means used on modern ring frames to keep the balloon tension low is the balloon control ring or the anti-balloon ring. This anti-balloon ring is placed approximately midway between the thread guide and the ring–traveler position, and the ballooning yarn is constrained by it. Thus, the anti-balloon ring splits one big balloon in two smaller ones, resulting in lower tension and lower frictional force at the traveler. Use of anti-balloon rings helps to keep the traveler weight low. Hence the temperature generated is also lower.

Traveler forces and heat

The traveler forces and the heat generated depend on the weight, the linear speed and the coefficient of friction of the traveler. The linear speed is determined by the ring radius and the spindle speed. With polyester and blends, the coefficient of friction between the yarn and the traveler is lower compared to with 100% cotton. This has to be compensated by higher traveler weight. The centrifugal force acting on the traveler can be calculated accurately but the coefficient of friction is only an estimate. Ring-traveler friction is not only difficult to measure, but is also influenced considerably by the quality of fibre finish and the amount applied to fibres. Therefore, the coefficient of friction can vary from one supplier to another as well between lots of the same supplier.

Good dissipation of heat generated at the traveler contact point with the ring is necessary to prevent travelers from getting overheated. In high speed spinning of polyester and blends, this aspect becomes crucial. The ring as well as the traveler must be selected in such a way that the traveler temperature is kept low to ensure good yarn quality and long life for travelers and rings. A larger contact area between the traveler and the ring during spinning ensures that the heat is dissipated from the traveler adequately.

Traveler selection

Four factors govern traveler selection.

1. Shape

Adapted to the flange of the ring-shape T-Flange 1 or 2 respectively ORBIT. Yarn clearance as low as possible but wide enough to avoid contact between fibres and ring (if fibres get in contact with the ring they touch at high traveler speeds and this could produce fused fibres or neps)

2. Wire cross section

- For regular blends: wide half-round cross section -- udr
- For delicate fibre: half-round cross section -- dr

3. Weight (number)

Most important! Since spinning tension is not measurable, the balloon shape is the best indicator of the rightness of the traveler weight. The tension must be high enough to stabilize the balloon in its full length. Avoid double ballooning, this causes end breaks. The hairiness is much influenced by the spinning tension.

4. Finish

STARLET finish when working with aggressive fibre finish or atmosphere. SAPHIR finish for normal condition.

Traveler shapes with medium to low yarn clearance, adapted to the yarn count, give the best quality of yarn and a low breakage rate. The wide half-round wire section (udr) combines smooth yarn passage for good yarn quality and good contact to the ring running track.

Travelers with STARLET finish provide excellent corrosion resistance. This property is an important factor when aggressive fibres finishes are applied. SAPHIR travelers can be used when no extra rust or corrosion protection is required.

The applied fibre finish is of great importance. Changing of one of the components may have an influence on the traveler lubrication and hence, on the spinning tension. In such cases, a different traveler needs to be selected. In most case, only the traveler weight needs to be optimised.

Practical experience shows that highest linear speeds are achievable with polyester-cotton blends. The speeds are somewhat lower with polyester-viscose blends.

Ring shapes and finish

The most used ring shape for high speed spinning is the T-Flange of size 1; and the traveler used with it is C-shaped. For the medium count range (Ne 30 to 50) Braecker ORBIT travelers and SFB rings give outstanding performance and quality results. The large contact area with this ring-traveler system dissipates the heat and ensures stable traveler running. The long inner leg of the travelers allows excellent heat transfer to the ring and keeps the yarn path at low temperatures. The Braecker TITAN rings are the benchmark for high speed spinning frames. The TITAN finish can be applied on all Braecker ring shapes.

Productivity

Modern ring spinning machines have up to 1600 spindles. Several workers need to be assigned simultaneously to ensure that the machine downtime at traveler changes is kept to the minimum. A well proven solution in industrialized countries is the use of magazined travelers. With the Braecker RAPID BOY inserting tool and AP Travelers, the machine downtime is reduced and productivity increased, while saving on labour cost.

Pre-conditions for high speed spinning

High speed spinning needs excellent standards to be achieved in quality of roving, in machinery maintenance and in house keeping. In the context of ring and travelers, the following points are of highest importance.

- Rings with smooth traveler running track
- Accurate centering of spindles in rings
- Accurately centered yarn guide elements (pigtail, anti-balloon ring)
- Smooth moving and leveled ring rails.

Conclusion

Mills which follow these guidelines on traveler-ring selection will be able to work their ring frames successfully at the highest speeds for which their spindles and ring frames are designed.

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