EFFECT OF DRAFTS AT DIFFERENT STAGES OF SPINNING PROCESS ON FIBRE ORIENTATION AND YARN PROPERTIES

by

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Dedicated to

My Parents

CERTIFICATE

This is to certify that the thesis entitled "**Effect of Drafts at Different Stages of Spinning Process on Fibre Orientation and Yarn Properties**" being submitted by **Mr. Akshay Kumar** to the Indian Institute of Technology, Delhi, for the award of the degree of **Doctor of Philosophy** in the department of Textile Technology, is a bonafide research work carried out by him. Mr. Akshay kumar has worked under our joint guidance and supervision and fulfilled the requirements for submission of the thesis.

The results contained in this thesis have not been submitted, in part or full, to any other University or Institute for the award of any degree or diploma.

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ABSTRACT

The effect of drafts at different stages of spinning process on fibre orientation and properties of sliver, roving and yarn has been studied by using Taguchi Method, ANOVA technique and Regression Model with the objective to figure out the effect of individual machines and simultaneous change in drafts at different machines in the spinning process. The L8 mixed orthogonal array was used to work out eight different slivers and rovings. Two different lap hanks, four different card drafts and two different draft/doublings at breaker and finisher were selected for the study. Eight finisher slivers of different linear densities were processed into two different types of rovings and 24^s Ne rotor and air-jet yarns. For roving-type I, the draft at speed frame was kept constant in all the samples while for roving-type II, the draft at speed frame was changed in such a way so as to produce same roving hank for all the eight samples. These rovings were processed into two types of ring yarns-type I and II in such a way so as to produce 24^s Ne yarn. The effect of uncontrollable variables such as, spindle to spindle variation and doff position was duly taken in to consideration.

The fibre orientation in sliver and roving was studied using both direct and indirect techniques. The modified Lindsley device was used for indirectly measuring fibre orientation parameters. The effect of change in process variables on various fibre orientation parameters (indirectly measured) in sliver and roving was statistically analyzed. Among all the fibre orientation parameters analyzed the 'coefficient of relative fibre parallelization (K_{rp})' has been seen to be influenced the maximum with change in process variables. The equation used for calculation of K_{rp} was critically analyzed and modified for a better explanation of fibre orientation. The modified index was named 'modified coefficient of relative fibre parallelization (K_{rpm})'. The effect of process variables on proportion of curved fibre end (ρ) has been analyzed to study the trends of

change in number and extent of hooks due to drafting. The fibre orientation in sliver and roving was also studied, directly, in terms of a new index of measurement of fibre straightness along the length, called Fibre Straightening Index (FSI).

It is observed that increase in lap hank and card draft increases ρ and decreases K_{rpm} in card and breaker sliver. However, the improvement in K_{rpm} is seen to be higher in finisher sliver and roving produced by finer lap hank and higher card draft in subsequent processes. High draft/ doublings marginally increase values of K_{rpm} in slivers and rovings. High speed frame draft reduces ρ marginally. Increase in lap hank, card draft and draft/doublings decrease the FSI in slivers. The lower speed frame draft tends to decrease FSI of roving.

The fibre orientation in slivers has also been studied using fibrograph length measurements in terms of 2.5 %, 50 % and 66.7 % span lengths. The 50% span length (SL) and 66.7% SL gives an indication of fibre hooks in the sliver. These span lengths in card sliver first decrease and then increase with drafting at breaker and finisher sliver due to removal of hooks. A combination of K_{rpm}, ρ and FSI is seen to decide the strength of slivers. Amongst the slivers the breaker sliver is the strongest and finisher sliver the weakest. It is observed that a stronger finisher sliver produces a stronger roving. The increase in K_{rpm} of card and breaker sliver increases sliver tenacity but decreases that of finisher sliver. A lower speed frame draft leads to a weaker roving.

The fibre orientation in ring yarn-type I and II, rotor and air-jet yarn has been studied using tracer fibre technique. The following fibre orientation parameters have been studied: fibre extent (along with number of hooks and their extent), migration parameters, and packing density. Two newly defined indices for studying the fibre overlapping length in yarns have also been proposed. These indices are: Fibre-pair-overalp length (FPO) and Fibre-overlap Index (FOI). Ring yarn is seen to have the highest fibre extent, FPO and

FOI and rotor yarn the least. The rotor yarn having high disorder and buckled fibre configuration, due to technological reasons, has the least fibre extent and fibre overlapping indices. A medium (101 or 114) card draft and a corresponding medium ring or speed frame draft give highest fibre extent in ring yarns.

The effect of fibre parallelization in finisher sliver is retained in respect of fibre extent and FPO in rotor and air-jet yarns. A higher card draft and correspondingly lower air-jet draft give higher fibre extent and FPO in air-jet yarn. The fibre extent improves, overlapping indices reduces and trailing hooks extent and number of hooks decrease in air-jet yarns with feed finisher sliver of lower draft/doublings. The trailing hook extent is less than that of leading hook in ring, rotor and air-jet yarns due to greater chances of removal of trailing hooks during drafting. The trends of trailing hook extent, leading hook extent and their average values in rotor yarns are similar to those of proportion of curved fibre ends in forward & reverse direction and their average values in finisher sliver. The number of trailing hooks is lower than the number of leading hooks if draft is increased at ring and rotor spinning machine while reverse happens if the draft is changed at speed frame or air-jet spinning machines. Higher speed frame draft reduces leading hooks along with the trailing hooks. In case of rotor spinning total number of hooks does not depend on the draft given on the rotor machine.

FOI in ring yarn (type I and II) is directly related to K_{rpm} in respective rovings. The trends of FOI are opposite to those of fibre extent in ring yarn-type I but same in ring yarn-type II. A lower ring frame or rotor or air-jet draft increases FOI in all those yarns, decreases fibre extent in ring and rotor yarn and increases fibre extent in air-jet yarn. The changes in FOI are influenced the most by change in process variables in all type of yarns due to the consideration of both fibre extent and fibre overlapping length in calculation of FOI. Trends of K_{rpm} in finisher sliver with change in lap hank and draft/doublings are similar to those of FOI in rotor and air-jet yarns. The FOI emerges out to be a better measure of fibre overlapping than FPO due to its greater dependence on process variables.

The migration in yarn was studied in terms of three parameters, mean fibre position (MFP), mean migration intensity (MMI) and root mean square deviation (RMSD). The trends of migration parameters in ring yarn-type I are opposite to those of ring yarn-type II. The ring yarn has the highest mean fibre position and least MMI. The rotor yarn has the lowest MFP and RMSD. The air-jet yarn has the highest MMI and RMSD.

Increase in card draft increases MMI and RMSD of rotor yarn and decreases MMI of air-jet yarn. However, it tends to increase RMSD of ring yarn-type II, rotor yarn and air-jet yarn. A high draft/doublings at draw frame increases MFP in ring yarn-type II, rotor and air-jet yarns. A decrease in ring frame / air-jet draft or increase in speed frame draft decreases MFP in these yarns. All the migration parameters follow almost the same trends with change in process variables in rotor yarns which are similar to the trends of FOI of rotor yarn.

The trends of change in packing density with process variables are opposite to those of yarn diameter & helix angle but similar to those of migration parameters (especially MMI and RMS deviation) of various yarns studied. The packing density is found to be the highest in air-jet yarn and the least in rotor yarn. Increase in air-jet and decrease in rotor draft increases packing density of the respective yarns.

In regard to yarn properties, the ring yarn is seen to have the highest tensile properties, whereas, air-jet yarns the least. The low elastic recovery of viscose fibres is the cause of weaker air-jet yarns. The ring yarn is highly even and has the least number of thin places and neps but thick places are the least in rotor yarn. The air-jet yarn is the least even and has the highest number of thin places, thick places and neps. The trends of S/N ratio of U %, thin places, thick places and neps show that these parameters are correlated with each other in all three yarns. The total hairiness is the least in rotor yarn and number of hairs ≥ 3 mm (S3) the least in ring yarn. In air-jet yarn the total hairiness and S3 are the highest. Overall, the ring yarn is the best in terms of properties and air-jet yarn the worst. S3 in all three types of yarns decreases with reduction of MFP and increase of packing density of yarn.

The finer lap hank and higher card draft in preparatory process produces ring and rotor yarns of better properties. However, the higher speed frame draft improves the properties of yarn produced from coarser lap hank and lower card draft. Lower ring frame, rotor and high air-jet draft improves the properties of the respective yarns. Both hairiness index and S3 in ring yarn reduces with increase in lap hank (marginally), card draft, and speed frame draft. Increase in ring/air-jet draft increases S3. The effect of change in lap hank and card draft on changes in breaking elongation %, unevenness %, thick places, thin places, neps, hairiness index and S3 is significant at 90 or 95 % confidence level.

Overall, Taguchi ranking and ANOVA table show that the effect of change in card draft followed by lap hank are the two major factors influencing the fibre orientation and properties of sliver, roving and all three types of yarns.

Finally, it has been revealed that it is not the draft at individual machine in spinning process which decides the properties of these yarns, but it is the combination of drafts especially carding and yarn manufacturing machine.

In all the results the changes in the responses as assessed by ANOVA technique and Taguchi Method are almost in agreement with each other.

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