

**STRUCTURAL DYNAMICS OF SPUN
YARNS DURING EXTENSION**

by

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Dedicated

to

*My parents, wife, Prakhar
and Shivangi*

CERTIFICATE

This is to certify that the thesis entitled “**STRUCTURAL DYNAMICS OF SPUN YARNS DURING EXTENSION**” being submitted by **Mr. Alok Kumar** to the Indian Institute of Technology Delhi, for the award of the degree of **Doctor of Philosophy** is a bonafide research work carried out by him. Mr. Alok Kumar has worked under our 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

An attempt has been made to study the progressive deformation mechanism and related dynamics of ring yarn structure during extension. Hence an image processing system called "Microcontroller based 3-D yarn structure analyser" has been designed and developed to characterize and visualize the configuration of fibres in two orthogonal planes at required levels of yarn extension.

Automatic scanning and data acquisition software has been developed to locate the position of coloured fibres and yarn boundary from the images of yarn in two orthogonal planes. The boundary of the yarn is located on the principle of thresholding. On the other hand tracer fibres of different colours are located using hue, saturation and colour space and sequential technique. Accordingly suitable program has been written in C language, run on Linux.

The image processing system along with multi-coloured tracer fibre technique has been used for quantitative analysis of changes in the internal structure of ring yarn on extension. Data relating to position of yarn boundary, and tracer fibre is extracted with image acquisition software at every 0.05 mm distance along the yarn axis. Accordingly 3-D Cartesian co-ordinates are obtained and plotted to give 3-D path of the fibre. The three dimensional trajectory of different coloured tracer fibre exhibits typical characteristics of a fibre in yarn. It is observed that leading, middle, and trailing portions of the fibre show different structural changes along the length of the fibre on yarn extension and found to be non uniform along the length of the fibre. Hence fibre extent of each fibre is divided into ten equal segments and structural parameters are calculated for

each segment. Front portion of the fibre as coming out from front roller of drafting system of ring frame is considered as leading portion and the back portion as trailing portion. To calculate the radial parameters in the cross-section of yarn, it is divided into 20 annular concentric cylindrical zones of equal radial width of 0.01 mm each. Different internal structure parameters in these zones are calculated at different yarn extension levels.

A detailed study has been carried out to assess the fibre migration parameters in terms of mean fibre position (MFP), mean migration intensity (MMI) and root mean square deviation (RSMD). It has been observed that the MFP, MMI and RSMD are significantly influenced by yarn extension. It has been observed that the MFP increases slightly upto 4% of yarn extension and then decreases upto 8% extension but slightly increases on further yarn extension to 12%. But it is observed that the value of MMI and RSMD decrease with the increase in yarn extension.

The fibre straightening, straining and slippage of fibre in yarn during progressive yarn deformation has been quantified and further fibre overlap in the yarn at different extension level is measured. With yarn extension from 0% to 4% the fibre straightening is found to be maximum and percentage of the fibre slippage is minimum with moderate fibre strain. But during yarn extension from 4% to 8% maximum fibre slippage is noticed with moderate percentage of fibre straightening and least percentage of fibre straining. With further increase of yarn extension from 8% to 12% maximum fibre straining is observed with minimum fibre straightening and moderate fibre slippage. Fibre straining percentage along the length of fibres in different segment is not uniform and this trend is applicable for all level of yarn extension. Fibre-pair-overlap length

(FPO) increases almost linearly with yarn extension. But percentage increase in FPO depicts a declining trend with different interval of yarn extension. Contrary to this, fibre-overlap index (FOI) almost remains constant at all the level of yarn extension.

The angular orientation of fibres in the yarn has been visualised in terms of migration angle, helix angle, spatial orientation angle and three other angles defined on the basis of 3-D path of the fibre. Effort has also been made to assess the influence of progressive axial yarn extension on these angles. It is observed that average value of migration angle α , helix angle β and spatial orientation κ continuously decreases with the increase in yarn extension but angles γ and χ responds differently to yarn extension. Both the angles first increase with yarn extension from 0% to 4%, latter decrease on further yarn extension from 4% to 8% and finally marginally decline with yarn extension from 8% to 12%. Value of angle θ hovers around 90^0 at all yarn extension levels. It is observed from the cross-sectional distribution of these angles that at 0% yarn extension level the value of angles α , β and κ increases from yarn core to yarn surface up to certain level of radial distance from the yarn axis and angles γ and χ decreases. But angle θ remains constant. In the subsequent zones angles do not show any regular pattern. The trend is noticed at all levels of yarn extension. The study of different angles along the length of fibre with yarn extension reveals that the values of angles α , β , κ and γ decrease and angle χ increase from leading end of the fibre up to 4th to 5th segment. Subsequently angle α , β , κ and γ increase and angle χ decrease up to the trailing end of the fibre. This trend is valid for all the levels of yarn extension. But angle θ remains moreover constant along the length of fibre with all the levels of yarn extension.

A detailed study on effect of progressive yarn extension on helix twist of fibre has been carried out. It was noticed that helix twist of the fibre decreases with yarn extension. Maximum decrease in helix twist is observed in 4% to 8% yarn extension stage followed by 0% to 4% and 8% to 12% yarn extension. Helix twist of yarn is found to be marginally higher than machine twist. Helix twist of the fibre increases from 1st zone to attain maximum value in the 4th zone and in the subsequent zones it shows declining trend at all yarn extension levels. It is further noticed that helix twist decreases in respective zones up to 10th zone with yarn extension. In order to understand the effect of yarn extension on helix twist the yarn cross-section is divided into three zones, i.e. core, intermediate and surface. The results reveal that at all the levels of yarn extension helix twist is found to be maximum in the core zone of yarn and followed by intermediate zone and surface zone. It is further noticed that machine twist remains in the intermediate zone. Core zone has higher and surface zone lower helix twist as compared to machine twist.

Finally impact of progressive yarn extension on diameter, overall packing fraction, radial packing density and partial packing fraction in different segments along the length of a fibre has been studied in detail. It has been observed that with the increase of yarn extension, yarn diameter continuously decreases but at different yarn extension intervals, the percentage decrease in the value of yarn diameter is different. The packing density of yarn does not follow the exact trend of yarn diameter with the increase in extension of yarn. The yarn packing density initially increases at very high rate, then at very low rate and finally the packing density of yarn rather slightly decreases with the increase in yarn extension. The radial packing density of the yarn is not uniform across

the cross-section of the yarn and it is maximum at half the yarn radius. The location of maximum radial packing densities of yarn is shifted toward yarn axis with yarn extension. The change in yarn packing density with yarn extension is not uniformly distributed over the three zones of the yarn. Packing density of fibres in the core zone of the yarn increases up to 8% yarn extension and with further yarn extension to 12% of a slight dip in core packing density is observed. The behaviour shown by intermediate zone is somewhat different. As yarn is extended from 0% to 4% and 8% to 12% fibres are more closely packed in the intermediate layers but on yarn extension to 4% to 8% it remains constant. Thus changes in the packing density of fibres in the intermediate zone of the yarn with yarn extension are more pronounced than core zone of the fibres. The partial packing density along the length of yarn is not uniform and the results are equally applicable for all levels of yarn extension.

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