

**SOME STUDIES ON INTER-RELATIONSHIPS
BETWEEN
PROCESSING, STRUCTURE AND PROPERTIES
IN ISOTACTIC POLYPROPYLENE FIBRES**

By

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TO
MY BELOVED
PARENTS

CERTIFICATE

This is to certify that the thesis entitled "**Some Studies on Inter-relationships between Processing, Structure and Properties in Isotactic Polypropylene Fibres**" being submitted by **Shri. Y.C.Bhuvanesh**, 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 record of bonafide research work carried out by him. Shri. Y.C.Bhuvanesh has worked under my guidance and supervision and fulfilled the requirements for the submission of this 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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A handwritten signature in black ink, consisting of a stylized 'Y' followed by 'C' and 'Bhuvanesh' in a cursive script.

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ABSTRACT

A mathematical model for carrying out process simulation of melt spinning of polypropylene fibres has been used to carry out predictions of filament velocity, temperature, diameter, stress, amorphous birefringence, total birefringence and crystallinity with the help of a computer program developed for the purpose. The predictions were compared with the density and crystallinity values of experimentally obtained as-spun samples. The experimentally obtained as-spun samples showed some unusual behaviour. The density of the samples spun at a temperature of 290°C and a constant throughput rate of 44.5 g min⁻¹ displayed a minimum in density at around a spinning speed of 800 m min⁻¹. When lower throughput rates of 13.5 and 17.5 were used at temperatures of 260 and 290°C, no change in density could be observed upto spinning speeds of 800 m min⁻¹. The phenomenon has been investigated in detail to identify the underlying factors which affect the spun fibre characteristics like crystallinity, crystal form and density. The predictions made by the mathematical model have been discussed and their relevance to the above mentioned density variations brought out.

The role of addition of small amounts of atactic polystyrene (2 to 8 percent by weight) during melt spinning of polypropylene yarns produces some distinct differences in the structure and properties of the as-spun polypropylene yarns. In the as-spun state, the blended samples were found to display an enhanced extensibility in comparison to the polypropylene yarn. The blended samples showed inferior mechanical properties upto a draw ratio of 3.7 when compared to polypropylene yarns of corresponding draw ratio, while at draw ratios of 4.4 and above, the blended polypropylene yarns containing 2 and 5 percent by weight of polystyrene showed superior mechanical properties and also improved creep and recovery behaviour. The

as-spun blended sample containing 5 weight percent of polystyrene showed a lower glass transition temperature corresponding to the polypropylene phase in comparison to the as-spun polypropylene yarn. When the samples of draw ratio 4.4 were compared, the situation was found to be quite opposite to that observed with the as-spun samples. An investigation has been carried out into the structural and morphological basis of the above mentioned observations. The effect of the processing conditions on the polystyrene phase and its effect on the properties of the yarns has also been investigated.

A detailed investigation into the stress and temperature dependence of the creep and recovery behaviour of as-drawn polypropylene and polypropylene blended with 5 weight percent of polystyrene has been carried out. Analysis of the creep behaviour of the samples has been attempted by using various techniques which include plotting of creep isochronals and Sherby-Dorn plots. Long-term prediction of creep has been achieved with the creep data obtained at various temperatures and stresses by using time-temperature superposition, stress-time superposition, combined stress-time-temperature superposition and the use of retardation spectra.

To investigate further into the viscoelastic nature of the as-drawn polypropylene yarn and polypropylene yarn blended with 5 weight percent of polystyrene, isothermal stress relaxation studies were made. An unusual observation has been made during stress relaxation experiment on the as-drawn yarns which had not been subjected to any conditioning treatment. At 0.5 percent pre-strain and at a temperature of 60°C and above, the stress, after an initial decrease registers an increase. This reverse relaxation is not seen for a pre-strain of 2 percent and for the annealed samples. A detailed investigation has been carried out on the as-drawn polypropylene yarn to gain an insight into the phenomenon. On the basis of the results presented, the occurrence

of inverse relaxation has been attributed to the generation of shrinkage stress, which is a manifestation of structural relaxation occurring in tandem with the viscoelastic relaxation process. The contribution due to the structural relaxation could be eliminated and time-temperature superposition carried out with both the as-drawn samples to construct master stress relaxation modulus plots which were used to obtain the relaxation spectra for both the samples.

The effect of spun fibre characteristics and spinning and drawing conditions on the stress generated during the drawing of as-spun samples of low oriented and partially oriented polypropylene yarns and the as-spun polypropylene yarn containing 5 percent by weight of polystyrene has been studied. The shrinkage characteristics (boiling water shrinkage and shrinkage stress generation) of the as-drawn samples have been studied further and the role played by the processing conditions and the subsequent structural characteristics of the as-drawn fibres have been highlighted. An attempt has been made to analyse the development of shrinkage stress in the as-drawn yarns on the basis of the linear stress-optical law and the resulting deviations from the predictions made by the rubber elasticity theory have been discussed.

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