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

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THESIS SUBMITTED
IN FULFILMENT OF THE REQUIREMENT
OF THE DEGREE OF

DOCTOR OF PHILOSOPHY

to the

INDIAN INSTITUTE OF TECHNOLOGY, DELHI

JULY, 1995

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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ACKNOWLEDGEMENTS

I express my profound sense of gratitude and indebtedness to Prof. V.B.Gupta for his exceptional guidance with an extraordinary sense of dedication towards the task throughout the course of this research work. I have immensely benefited from this invaluable interaction that has played a momentous role in shaping up my research ethos which in my personal opinion is crucial to be able to carry out meaningful research.

I am extremely grateful to Prof.N.C.Nigam, Department of Civil Engineering, Prof. V.Raju, Director, Indian Institute of Technology, Delhi and Prof. K.R.Salhotra, Head, Department of Textile Technology, for the help rendered during my most trying times.

I express my gratitude to Prof. (Ms) Pushpa Bajaj, for her assistance and encouragement during the course of my research work.

I wish to acknowledge the help offered by Dr. C.Ramesh, Laboratory for Polymer Research, KUL, Lueven, Belgium, for carrying out crystalline index studies on one of my samples.

I am thankful to Dr. Kushal Sen for carrying out Fourier Transform Infrared studies on some of my samples.

I would like to place on record my gratefulness to Dr. E.Hairer and Dr. G.Wanner, Section de Mathematiques, Universite de Geneve, Case postale 240, CH-1211, Geneve 24, Switzerland, for allowing me to use one of their subroutines which was crucial in developing a highly complex computer program worth 4500 lines of source code necessary for obtaining numerical predictions based on a mathematical model for process simulation of melt spinning of polypropylene fibres.

I wish to express my gratitude to the distinguished faculty of the Department of Textile Technology, Prof. V.K.Kothari, Prof. P.K.Hari, Prof.Bhaskar Dutta, Prof.

M.L.Gulrajani, Prof. A.K.Mukherjee, Prof. R.B.Chavan, Prof. P.K.Bannerjee, Prof. B.L.Deopura, Mr. V.K.Agarwal, Dr.S.M.Ishtiaque, Dr.Ravi Chattopadhyay and Dr. B.K.Behera for their help and encouragement.

I express my gratitude to Mr. Harish Chowdhury, Department of Management and Systems, for being a great friend and offering support when I needed it most.

The co-operation provided by the laboratory assistants and technicians cannot be ignored and I take this oppurtunity to thank everyone associated with the Fibre Science and Fibre Production Labs. I would like to specially mention the names of Mr. Ashok Kumar Tanwar of the Fibre Production Lab. and Mr. D.C. Sharma of the Scanning Electron Microscopy Lab. for their selfless assistance rendered during the course of my research work. I would also like to thank Messers. V.K.Kala, R.Khattar, Amarjeet, Patilal, Om Prakash, Biswal, Jeetendra and Pasi.

The constant encouragement and cooperation given by my closest friends which are too numerous to be mentioned here. I would like to specially mention the names of Messers. Sriram Hegde, Praveen Kumar, Hajir Behrami and Joydeep Sensarma.

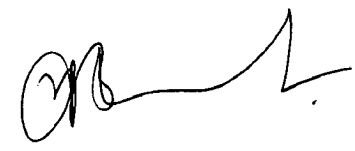
Words fail me in expressing my deep sense of gratitude to my wife, Sheila, for her constant inspiration and limitless love even during some of the most testing of times.

No amount of gratitude is enough to convey my indebtedness, regards and love to my parents for doing everything so selflessly and wholeheartedly and have been my prime source of motivation to embark upon this task.

I am indebted to my grandparents for their love, affection and support rendered during the course of this research work.

I would also like to place on record the names of my brothers, Mayur and Hoysala for their love and affection.

I would like to specially mention the names of my in-laws Mrs. & Mr. Dr. B.I.Uppin, Dr. Nina and Dr. Rajan Revankar for their love, encouragement, advise and more than anything else being immensely supportive during the course of my reserach work.



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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 precent 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 carrried out into the structural and morphological basis of the above mer tioned 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 generatiion) 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.

CONTENTS