STUDIES ON STRUCTURE - PROPERTIES OF POLYPROPYLENE TEXTURED YARNS

BY

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CERTIFICATE

Certified that the dissertation entitled "STUDIES ON STRUCTURE - PROPERTIES OF POLYPROPYLENE TEXTURED YARN", which is being submitted to the Indian Institute of Technology, Delhi, by Malesh Mukhopadhyay in fulfilment for the award of the Degree of DOCTOR OF PHILOSOPHY is a record of the student's own work carried out by him under our joint supervision and guidance. The matter embodied in this dissertation has not been submitted for the award of any Degree or Diploma.

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ABSTRACT

The way thermoplastic textured yarns have enveloped the textile arena today, can simply be termed as remarkable. Out of large amount of textured yarns produced today, polyester and nylon constitute the major portion. The ease of thermo-mechanical texturing coupled with high and stable bulk produced in nylon and polyester may be considered as the reason for their unassailable lead over the other fibres. It is, however, surprising that an important fibre like polypropylene has yet to get the proper attention of the texturing industry, though it has established itself firmly in several industrial applications. In fact, its total consumption for apparel end uses is very little. Absolute hydrophobicity, lack of reactive dye sites and high crystallinity are some of the adverse properties associated with this fibre. Nevertheless, it has various useful properties in addition to it being cheaper. This polymer, therefore, shows a great promise. Extensive work had been done on false twist texturing of nylon and polyester, however, research publications of texturing of polypropylene are rather scarce. It is, however, well known that this fibre is difficult to texture and dye. It is, therefore, of interest to examine this fibre from the point of texturizability and then to modify it suitably to meet the requirements of texturing and dyeing.

It was but pertinent, therefore, to first optimise the texturing process variables, i.e., temperature, time, twist and tension, on polypropylene multifilament yarn. In addition to texturing properties like crimp rigidity and crimp stability, mechanical and structural properties of polypropylene yarn, textured at different conditions, have been investigated and reported. Compared to polyester and nylons, a high residence time was found to be needed at the optimum conditions for developing satisfactory texture. Upon investigation, two basic drawbacks of this fibre were highlighted : they are very high parent yarn crystallinity ($\simeq$ 70%, X-ray) and poor thermal conductivity.

Thermal conductivity, which determines primarily the cooling time, can be effectively tackled on modern-day texturing machines which provide adequate cooling arrangements. High crystallinity has, therefore, been identified as a major hurdle from the point of view of texturing. Two different approaches were considered for effectively reducing the crystallinity of parent yarn,

(i) tension annealing, at temperature just below the temperature of maximum crystallisation rate, followed by quenching.

and (ii) melt blending polypropylene with small amounts of incompatible polymers; in our case polyester and polystyrene.

Our studies revealed that the crystallinity of textured polypropylene yarn reduced with the heating time. Taking a cue from this, tension annealing was considered as pre-treatment to texturing. Short tension annealing, particularly at 110°C, followed by quenching, reduced the crystallinity and consequently increased the texturizability of polypropylene. Various mechanical, structural and thermal properties of annealed and textured yarns have been analysed and presented.

From the practical point of view, the above process does not seem to have a commercial appeal, though it could establish the need for reduced crystallinity. On the other hand, melt blending is a simple and commercially viable alternative. Polyester and polystyrene (2-5%) were melt blended with polypropylene prior to spinning. These yarns were found to have substantially low crystallinity; polypropylene/polystyrene blend (95/5) having a crystallinity as low as 34%. This resulted in very high crimp rigidity, that too at very low residence time in the heater. The effect of melt blending on structural, mechanical, thermal and texturing properties has been investigated in detail. A small drop in mechanical properties, as a result of blending, is indeed outweighed by the substantial improvement in not only the texturizability but also the dyeability. A marked reduction in crystallinity was bound to help in the dyeing process, especially with disperse dyes. However, the crystallinity alone could not explain the dyeing behaviour of the blends, in that the polypropylene/polystyrene (95/5), though has the least crystallinity, showed

poor equilibrium dye uptake values. Other parameters, like amorphous volume per crystal, shrinkage and shrinkage rate of the blends have been studied in detail to throw some light on this atypical dyeing behaviour. Nevertheless, it was determined that polyester blends show a great deal of promise from the point of view of dyeing.

In order to further increase the dye diffusion, dyeings were carried out from solvent assisted aqueous medium. The solvent, a mixture of xylene and methanol (1:2 V/V), was used in small proportion (1.5%). The effect of solvent addition on disperse dye uptake, their wash fastness and light fastness has also been reported. Considerable improvement in equilibrium dye uptake is observed in the solvent assisted dyeings.

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