ABSTRACT

Structure-property relationship of different types of polyester industrial yarns at different stages of its processing for specific applications

The present work deals with four major types of polyester industrial yarns viz. (a) high modulus low shrinkage (HMLS), (b) high tenacity (HT), (c) low shrinkage (LS) and super low shrinkage (SLS). Properties of each of these yarns are significantly different from one another, each one of which is tailor made to meet the requirements for specific end use applications. For example, HMLS polyester yarns are mostly used for reinforcement of high speed passenger radial tyres, whereas one of the major applications of HT polyester yarns is for reinforcement of conveyor belt. LS / SLS polyester yarns are largely used for manufacturing of various products under the coated fabric segment.

All these yarns have been produced using the same high molecular weight polyester chips (intrinsic viscosity of around 0.90) in commercial spin draw machines with specific set of process parameters. The objectives of the present work are summarized as under.

- To develop structure-property relationship of four major types of polyester industrial yarns and to illustrate their structural differences.
- To develop a relationship between the structural changes that occur in the downstream processes and the key properties of the parent yarns.
- To investigate on how the key properties of the parent yarns / cords are changed during accelerated performance tests of the final products in laboratory and its linkages with the structural parameters.

A deeper understanding on structure-property relationship is likely to help for developing new variants of polyester yarns and new products.

Various experimentations involve

- Preparation of the fully drawn yarns along with the corresponding undrawn yarns which have been especially made in the spin draw machine by wrapping the yarn on 1st godet roll.
- Processing of the yarns (HMLS) in pilot machines (viz. pilot twister and single cord dipping machine) to produce intermediate products.
- Preparation of intermediate/final products in the commercial production machines.
First part of the present work is focused towards establishing structure-property relationship of these four types of polyester yarns. Efforts have been made to understand structural transformation from undrawn yarn to drawn yarn and their linkages with the properties achieved. Various characterizations concerning structure and morphology of the yarns include crystallinity, crystal size, birefringence, crystallite orientation amorphous orientation and tie molecules. Physical, mechanical, thermal, static and dynamic properties of these yarns have been characterized and attempt has been made to establish the structure-property relationship.

The second part of the work involves studies on the changes in structure / morphology of the yarns in the downstream processes and their relationship with various properties. Yarns / cords have been extracted from the intermediate and final products which have been characterized to study the changes in molecular weight, structure and properties, and thereby to establish a structure-property relationship in the downstream processes. Special efforts have been made to set the test parameters for few properties (like dynamic, fatigue and hysteresis) considering the service conditions of the end products where these yarns are used.

Interesting observations have been noted with respect to the structural transformation from undrawn yarn to drawn yarn where HMLS yarn has been found to be significantly different than that of the other yarns. Amongst various structural characteristics, amorphous orientation and tie molecule fraction are found to be the two key parameters which have tremendous influence on most of the important yarn properties. A postulated morphology of these four types of polyester yarns has been depicted through a diagram to elucidate the relative differences.

Interesting observation on fatigue characterization of HMLS and HT polyester yarns has been noted, where cords (HT polyester yarn) pertaining to the bottom ply has been found to have lower strength retention after fatigue with respect to that of upper ply. Degradation of the basic polymer at different stages of its processing and strength retention of the yarn in the downstream processes have been discussed elaborately in the present work.