STUDIES ON DRAWING OF POLYETHYLENE TEREPHTHALATE BY THE PROTOTYPE INCREMENTAL DRAWING PROCESS

By

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CERTIFICATE

This is to certify that the thesis entitled "STUDIES ON DRAWING OF POLYETHYLENE TEREPHTHALATE BY THE PROTOTYPE INCREMENTAL DRAWING PROCESS" being submitted by Mr.Anjan Kumar Mukhopadhyay, to the Indian Institute of Technology, Delhi, for the award of the degree of Doctor of Philosophy in the Centre for Materials Science and Technology, is a record of bonafide research work carried out by him. Mr. Anjan Kumar Mukhopadhyay has worked under our guidance and supervision and fulfilled the requirements for the submission of the thesis.

The results contained in this thesis have not been submitted, in part or in full, to any other University or Institute for the award of any degree or diploma.

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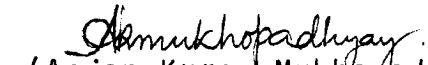

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ABSTRACT

The Incremental Drawing Process (IDP) is a novel technique where the molecular structure of spun fibres are oriented by incremental stretching over several successive steps. The synthetic fibre is drawn between two bodies, one or both of which have a continuously increasing diameter. Two different drawing body profiles have been used in the present investigation to get different drawing sequences.

Earlier work has shown that a significant improvement in the properties of Nylon-6 could be obtained by drawing at ambient temperatures. The latter phenomenon was ascribed to the better molecular alignment achieved by the IDP process as compared to the conventional drawing process (CDP) under identical processing conditions. The present work is an attempt towards exploring the potential of the IDP process for the drawing of PET spun at low as well as high speeds.

Since, the glass transition temperature (T_g) of PET is in the range of 70 -80 ^{0}C, it is necessary to draw PET fibre at elevated temperatures. As a first attempt, a chamber type of heating system with hot air blowing attachment was fabricated. Polyethylene Terephthalate partially oriented yarn (PET-POY) was successfully drawn by IDP at draw-ratios of 1.76, 1.84 and 2.00 with 12,13 and 15 steps respectively at a drawing speed of 300 m/min.

Correspondingly, PET-POY was also drawn by CDP at equivalent draw-ratios and speed. At an equivalent draw-ratio of 2.0, the tenacity and initial modulus values for IDP were 0.50 and 9.38 N/tex respectively as compared to 0.39 and 8.33 N/tex for CDP. This showed that IDP registered tenacity values higher than CDP by about 28%. The higher tenacity of the fibre drawn by IDP as compared to CDP can be attributed to the existence of highly oriented amorphous regions in IDP drawn fibres. A model has also been proposed to explain the significant improvement in properties in IDP as compared to CDP.

In order to study the development of orientation, the fibres were collected from selected steps and analysed. An advantage of using IDP for such a study is that the fibres obtained at different steps are part of the same continuous process and samples at different draw-ratios are obtained in one single experiment. In this study, PET-POY was drawn by IDP to a draw-ratio of 1.89 at a temperature of 85^{0}C maintained with a heated chamber coupled to a hot air blowing system. It was demonstrated that IDP is an excellent technique to follow and analyse the process of drawing. The structural development could be correlated with the development of mechanical properties.

The attainment of temperature above 120^{0}C was difficult in the chamber type of heating system whereas

high temperatures in the range of 200 ^{0}-250 ^{0}C was necessary for achieving high tenacity and high modulus fibre. Hence, a plate type heating system was used to attain the dual objectives. To achieve high tenacity fibre, PET filaments spun at different spinning speeds were drawn to equivalent draw-ratios with the two plate heaters with independent temperature control designed for IDP. PET-POY was drawn keeping the (a) first heater temperature at 90 ^{0}C and ranging the second heater temperature from 140 ^{0}C to 200 ^{0}C (b) first heater temperature at 85 ^{0}C and ranging the second heater temperature from 140 ^{0}C to 200 ^{0}C respectively. Similarly, low oriented PET was drawn with the first heater temperature at 85 ^{0}C and the second heater temperature varying from 140 ^{0}C to 200 ^{0}C. It was observed that pre-orientation of the parent material was responsible for the change in properties. Highest value of tenacity was obtained in low oriented PET samples drawn to a draw ratio of 5.2 with the temperature combination of 85 ^{0}C/200 ^{0}C. It registered a tenacity of 0.6 N/tex in IDP whereas tenacity of 0.49 N/tex was registered when drawn by the CDP under identical processing conditions. Thus an increase of 22% in tenacity value was evidenced.

Effect of drawing speed on the properties of PET-POY was also studied. The residence time in IDP is much higher than CDP and thus high speeds of drawing are possible by IDP. The multifilament PET-POY was drawn at 100, 200,

300, 500, 700 and 900 m/min at a draw ratio of 1.76 with the temperature of 80 ^{0}C. The properties increased upto a speed of 300 m/min, but no significant change was seen beyond 300 m/min. This was explained on the basis of rate of crystallisation and relaxation with respect to the residence time. It has been shown that IDP is capable of attaining high drawing speeds without affecting the properties or fibre breakage.

It has been clearly shown that the prototype system developed provides fibres with superior properties than those obtained by CDP. Furthermore, IDP can be used to prepare high strength fibres from commercially available conventional semi-crystalline polymers. It has also proved to be an excellent technique for following the process of structure development in oriented system. Hence it has excellent scope for commercial exploitation as well as a tool for scientific investigation.

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