MECHANICAL PROPERTIES OF UN_REINFORCED AND SHORT GLASS FIBRE_REINFORCED POLYPROPYLENE

By

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T O M Y P A R E N T S

CERTIFICATE

This is to certify that the thesis entitled "Mechanical Properties of Un-reinforced and Short Glass Fibre-reinforced Polypropylene" being submitted by Shri S.N. Pandit to the Indian Institute of Technology, Delhi for the award of the degree of Doctor of Philosophy is a record of the bonafide research work carried out by him. He has worked under our guidance and supervision and has fulfilled the requirements for the submission of this thesis which, to our knowledge, has reached the requisite standard.

The thesis, or any part thereof, has not been submitted to any other University or Institute for the award of any degree or diploma.

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ABSTRACT

Polypropylene is one of the important thermoplastics in use today. In India, polypropylene production has recently commenced as a large tonnage material. To consume this large quantity it is necessary to diversify its applications. One of the most promising areas is to reinforce polypropylene with short-glass fibres so as to produce a material that would have engineering applications. The work presented in this thesis is an attempt to establish the technology of production of such a material and to investigate at length its behaviour under different kinds of loading.

Producing glass-fibre-reinforced polypropylene parts normally involves two operations viz., compounding and moulding. In the work reported in this thesis, compounding was done in a single-screw extruder and involved mixing glass fibre with polypropylene and a coupling agent which was used to improve the adhesion between the glass-fibres and the polymer matrix. The compounding operation parameters like temperature profile and screw speed were optimised to ensure that the dispersion of glass fibres in the polymer matrix was uniform.

Once the compounded material containing uniformly distributed glass fibres is available, it can be moulded into any desired shape with the help of an injection moulding machine. In moulding these articles, the process parameters (.e.g screw speed, temperature profile, injection pressure,

etc) were optimised.

Test samples of flat and tubular shapes were moulded from both un-reinforced and glass fibre reinforced polypropylene. In the latter case relatively higher moulding temperature were used. The reinforced mouldings were made from compounded material containing 10%, 20% and 30% (by weight) and also from standard commercial grades.

The samples were then tested at room temperature in torsion, tension and combined tension-torsion. Studies in tension were made under constant rate of strain and constant rate of loading. The other studies were made under constant rate of loading only.

Heat distortion tests were also conducted. Dynamic tests over a range of temperature in free vibration were made to study the viscoelasticity exhibited by the samples.

The mechanical results obtained for polypropylene homopolymer, which is a large deformation material, have been analysed in terms of generalised stress-generalised strain functions and it has been shown that such a treatment is possible for this material. For reinforced samples this treatment has limited applicability and the possible reasons for this are discussed.

The use of coupling agents for improving the bond strength between the fibre and the matrix is very essential in the case of the present system viz., glass-fibre-reinforced polypropylene because of the inert nature of the matrix.

Two coupling agents in monomeric and polymeric forms were incorporated and the results show that one of the polymeric coupling agents is relatively more effective in improving strength.

The strength characteristics of the composite system have been studied and reported in detail. The strength was measured under simple and complex loads. While incorporation of glass fibres improves the strength in tension, only limited gains are shown in strength under torsion and combined tension-torsion loads. Possible reasons for these are discussed. The fibre length distribution of different samples was measured by noting the lengths of 700 fibres in each case. The strength data have been analysed in terms of Bowyer and Bader's theory which explains the strength characteristics on the basis of fibre-length distribution. This has been found to explain the present results quite satisfactorily and has also allowed the calculation of the orientation factor. It is found that there is considerable breakage of fibres during processing and from a starting length of 6 mm, most of the fibres are below 0.4 mm in the moulded product. This is also the situation in the standard commercial product. The consequences of fibre length reduction are discussed in detail.

The moduli of the composite systems under different loadings have been presented and it is shown that under various loading systems the modulus shows 50-300% improvement.

The tension results have been analysed in detail in terms of some existing theories. This analysis also gives a method of calculating the orientation factor and it has been shown that the orientation factor compares reasonably well with that obtained from strength data analysis.

Some studies on dynamic mechanical measurements made over a range of temperature are also presented and these show that the incorporation of glass fibres changes the behaviour of polypropylene under dynamic torsional loads. It is noticed that the glass fibres suppress the viscoelasticity and this is manifested in the broadening of damping peak and reduction of its amplitude compared to that of polypropylene. The storage modulus increases with increasing glass-content. The results on the temperature dependence of storage modulus are also presented and discussed.

The toughness of such composite systems is relatively much less than that of the polymer itself. Some experiments were conducted to improve the toughness by the addition of small quantities of high density polyethylene polymer in the composite system. Considerable improvements in toughness were obtained by this method.

The heat distortion temperature studies show that in the reinforced samples the heat distortion temperature is almost doubled compared to the polymer.

Finally, from the experimental results and their analyses presented in this thesis, the importance of fibre/matrix adhesion and the fibre length in determining strength is clearly brought out and in this context, the following two observations can be made:

i) In the present set of samples, the bond strength appears to have a reasonable value but in view of the latest developments in the area of coupling agents, studies with the aim to bring about considerably larger improvements need to be carried out; and

ii) The average fibre-length in the final product is rather small and process parameters during extrusion compounding and injection need in-depth studies so that the fibre-lengths can be preserved to get higher improvements in properties.

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