A CHARACTERIZATION OF GLASS MAT THERMOPLASTIC COMPOSITES FOR AUTOMOTIVE APPLICATIONS

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The effect of varying stamping temperature on the morphology and subsequent fracture properties of a stampable glass fibre reinforced polypropylene composite has been examined in detail. The experimental data indicate that stamping the composites at higher temperatures results in improved energy-absorption characteristics particularly under conditions of localized impact loading. It is believed that stamping in a lower temperature mould leads to flow-induced damage to the glass fibres as well as higher residual stresses.

INTRODUCTION

Stampable glass mat thermoplastics (GMT) such as glass fibre reinforced polypropylene are presently being considered for a number of applications most particularly within the automotive industry. GMT's can be manufactured by stacking pre-heated blanks in a mould and stamping under precisely defined processing conditions. Since the blanks are often significantly smaller than the overall size of the mould, the forming process involves considerable flow. The flow characteristics of the material are therefore likely to depend strongly upon the temperature of the stamping mould. To date, little work has been published regarding the influence of moulding temperature on the subsequent mechanical properties of GMT's. Rossi and Molina (1) used two mould temperatures, 85 and 95°C, and observed little or no influence on the strength characteristics of a glass fibre/polypropylene

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GMT. The work presented here examines a wider range of mould temperatures than those used by Rossi and Molina and considers morphological effects as well as mechanical property characterization.

EXPERIMENTAL PROCEDURE

The material studied in this research program was a glass fibre reinforced polypropylene GMT. The isotactic polypropylene matrix was reinforced with approximately 30% by weight random glass fibres. The stamped part took the form of a circular plate with a diameter of approximately 380mm and nominal thickness 2.6mm. Three stamping conditions were examined in this study, details of which are given in table 1.

TABLE 1. Summary of the mold temperatures examined in this study.

MATERIAL DESIGNATION	LOWER MOLD TEMPERATURE	UPPER MOLD TEMPERATURE	AVERAGE TEMPERATURE
A	40°C	45°C	42.5°C
B	70°C	75°C	72.5°C
C	100°C	105°C	102.5°C

The mechanical properties of the panels were assessed by undertaking a series of tension, single edge notch bending (SENB) and impact tests. Tensile testing was undertaken on ASTM D638-72 type specimens using a Schenck Trebel testing machine at a crosshead speed of 2mm/minute. The longitudinal strain was measured with the aid of a mechanical extensometer and the threshold for acoustic emission activity using a Dunegan ENDEVCO apparatus with a 50-175 kHz sensor.

Single edge notch bend tests were conducted on specimens with dimensions 75mm x 14mm x thickness supported on semi-cylindrical rollers positioned 56mm apart. A pre-crack was machined at the mid-span of each specimen and sharpened using a fresh razor blade. The length of the pre-crack was chosen to be between 30 and 50% of the specimen depth. Here again testing was undertaken at a crosshead speed of 2mm/minute.

Charpy impact tests on a Frank pendulum were undertaken on the above specimen geometry. For purposes of continuity, the specimens were again supported on two rollers placed 56mm apart. Finally, the low velocity impact response of the material was evaluated through a series of drop-weight impact tests. Here, a 470 gram tup with a 14mm diameter hemi-spherical head was released from varying heights in order to yield impact energies in the range of 1 to 5 Joules. The 80 x 80mm square plates were supported on a 55mm diameter ring.

RESULTS AND DISCUSSION

DSC scans of the three stamped materials showed that neither the degree of crystallinity or the melting temperature of the PP matrix were dependent upon the stamping temperature with the level of crystallinity being approximately 50% and the melting temperature being approximately 165°C in all cases. The scans obtained from the 102.5°C stamped material (material C) exhibited a second smaller endothermic peak at a temperature some 15°C below the principal melting peak. Previous work by Davies et al (2) showed that the presence of this peak was associated with a distinct transcrystalline zone extending up to fifty microns into the matrix. It is generally believed that the presence of such transcrystalline zones in these materials is related to shear-induced crystallization .

Initiation of damage during tensile testing was determined by acoustic emission. Here, the threshold was defined as being the applied stress at which the number of emissions exceeded 10,000, this corresponding approximately to one per cent of the total number of emissions recorded in a complete test to failure. Figure 1 presents the variation of the damage threshold stress with average mould temperature, T_{mould}. From the figure a slight increase in the threshold stress is apparent with increasing T_{mould}. However, no such temperature dependency is apparent in the tensile strength data with failure occurring in all cases at an applied stress of around 60 MPa, Figure 1. Similarly, no distinct mould temperature dependency was apparent in the Young's modulus data.

The results of the Charpy impact tests and the single edge notch bend tests are presented in figure 2. The data suggest that stamping at higher temperatures results in superior toughness and energy-absorbing characteristics with the data corresponding to the 102.5°C material being significantly higher than those of it's 42.5°C counterpart.

The dynamic characteristics of the materials were further assessed by conducting drop-weight impact tests on a series of 80 x 80mm square plates supported on a 55 mm diameter ring. Here, the material was characterized by determining the size of the damage zone as detected by an ultrasonic C-scan. As a result of material limitations, only two specimens were used per impact condition. The variation of damage area with impact energy for the three stamping temperatures is shown in figure 3. From the figure it is clear that a strong mould temperature dependency exists with the average damage area in the 42.5°C panels being some three times greater than that of the highest stamping temperature.

From the results presented above it is believed that the more rapid cooling associated with stamping in a lower temperature mould results in the generation of greater residual stresses within the composite. It is also possible that the poorer flow characteristics associated with the material stamped at lower temperatures may result in damage to the load-bearing glass fibres.

REFERENCES

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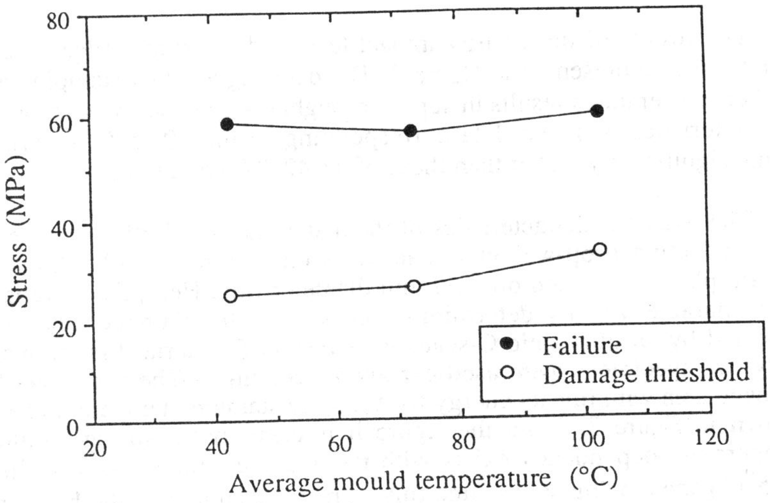

Figure 1 Variation of damage threshold stress and failure stress with average mould temperature

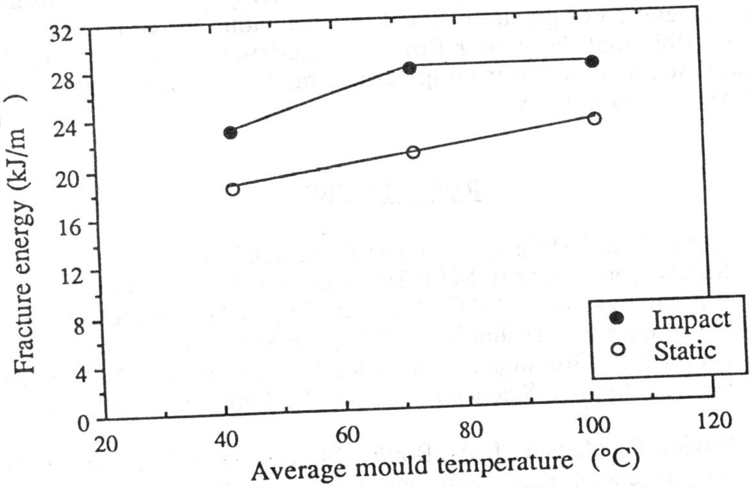

Figure 2 Variation of static and impact fracture energy with average mold temperature

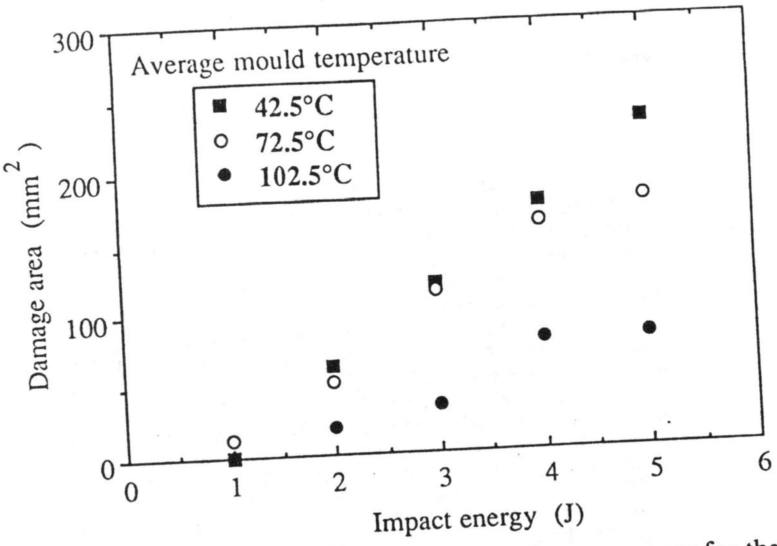

Figure 3 The variation of damage area with impact energy for the three stamping conditions