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Material properties

Effect of temperature on weldline integrity of injection moulded short glass fibre and glass bead filled ABS hybrids

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ABSTRACT

The present study investigated the effect of temperature on weldline strength of injection moulded ABS polymer reinforced with both short glass fibres (GF) and spherical glass beads (GB) over the temperature range 25 to 100 °C. It was noted that weld and non-weld tensile strength of ABS/GF/GB hybrids increased as the concentration of total glass in the hybrids increased. A linear increase in both weld and non-weld tensile strength was found with increasing the hybrid ratio of the glass fibre, χ. Results indicated that weld and non-weld tensile strength for the hybrid at a given temperature can be estimated from the rule of hybrid mixtures. Weld and non-weld tensile strength of the hybrid system decreased with increasing temperature in a linear manner. The rate at which weld and non-weld tensile strengths decreased with temperature was dependent upon the hybrid ratio of the glass fibre, χ, and the total concentration of glass in the hybrids. Weldline integrity factor for the hybrids decreased non-linearly with increasing χ, but increased linearly with increasing temperature.

1. Introduction

It is well recognised that the mechanical properties of polymer composites such as strength and modulus are derived from a combination of the filler and matrix properties and the ability to transfer stresses across the interface between the two constituents. These properties, however, are affected by a number of parameters, such as the concentration of the filler, geometrical shape and the aspect ratio of filler and the degree of interfacial adhesion between the filler and the matrix [1–9]. For example, whilst addition of short fibres to polymers matrices enhances strength, addition of spherical shaped particles (e.g. glass beads) cause deterioration. On the other hand, spherical particles with aspect ratio of unity provide isotropic mouldings whereas short glass fibres having aspect ratio much greater than unity provide anisotropic mouldings. Although fibre composites are strong and stiff when loaded longitudinally (along the length of the fibres) they are quite weak and less stiff when loaded transversely (normal to the fibres).

Hybridisation provides other dimensions to the potential versatility of composite materials. For example, by incorporating glass fibres and glass beads in the same matrix, one may obtain a moulding which may not be as stiff as the fibre reinforced system but is stronger than the glass bead system [10,11].

The study by Philips [12] raised the issue surrounding the possible synergistic hybrid effects, in which the properties of the hybrid composite might not follow from a direct consideration of the independent properties of the individual components. A positive or negative hybrid effect was then defined as a positive or negative deviation of a certain mechanical property from the rule of mixtures behaviour. In general, tensile strength of hybrid systems does conform to the rule of mixtures [10,11]. However, the majority of hybrid studies have been conducted using a single-gated mould cavity. Indeed, little is known on the effect of weldline on tensile strength of hybrid systems and its temperature dependence. To this end, this work was undertaken to study the effect of weldline and

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Table 1
Formulation for composites and hybrids.

	ABS/Glass Composites			
	Total Glass	GF	GB	Hybrid ratio, χ
	wt%	wt%	wt%	–
ABS/GB	10	0	10	0
	20	0	20	0
	30	0	30	0
ABS/GF	10	10	0	1
	20	20	0	1
	30	30	0	1
Hybrids	10	5	5	0.50
	20	5	15	0.25
	20	10	10	0.50
	20	15	5	0.75
	30	10	20	0.33
	30	15	15	0.50
	30	20	10	0.67

temperature on tensile strength of ABS polymer filled with short glass fibre and glass bead particles (i.e., ABS/GF/GB hybrid) over the temperature range 25 to 100 °C. To examine the applicability of the rule of hybrid mixtures, tensile properties of ABS/GF and ABS/GB composites were also studied under the same conditions as the hybrid composites.

2. Experimental details

2.1. Materials

Owens Corning chopped E-glass fibres (GF) of approximately 6.0 mm in length and 10 μm in diameter, and Potters solid spheriglass CP-3000 spherical glass beads (GB) of approximately 12–26 μm in diameter were used as reinforcing fillers for Acrylonitrile Butadiene Styrene (ABS) copolymer received from Bayer (Novodut P2H-AT). The ABS and the reinforcing fillers were used to produce a series of ABS/GB and ABS/GF composites with nominal glass contents of 10, 20 and 30% w/w and a series of ABS/GB/GF hybrids with total glass contents of 10, 20 and 30% w/w with different hybrid ratios. The hybrid ratio is defined here as

$$\chi = \frac{W_f}{W_g} \tag{1}$$

where W_g is the weight of the total glass and W_f is the weight of the short glass fibers in the hybrid.

2.2. Compounding

The materials listed in Table 1 were first mixed to the desired glass content and then dried in an oven at 80 °C for 4 h. After drying, each formulation was passed through a Leistritz micro 18GL-7R co-rotating twin-screw extruder at an average screw speed of 60 rpm to produce a homogeneous dispersion of bead and/or fibre throughout the matrix. The extruder temperature profile was 203/232/232/235 °C and the die diameter was 4 mm. The extrudates emerging from the die exit was continuously cooled in a water bath and fed through a granulator to produce pellets for injection moulding process. Pellets were dried in an oven at 80 °C for 4 h before being injection moulded into test specimens.

2.3. Specimen preparation

BS EN ISO-527 dumbbell shaped tensile bars were produced using a Negri Bossi NB60 injection-moulding machine at the processing conditions listed in Table 2. The mould used consisted of a single and double-gated cavity as shown in Fig. 1, each 1.7 mm in depth. In the latter, a weldline was formed as the two opposing melt fronts met mid-way along the gauge length of the specimen. The dimensions of weldline free (WF) specimens and specimens with weldline (WL) are depicted in Fig. 1.

2.4. Filler concentration measurements

The concentration of total glass in each material was determined from the glass residue remaining after burning at 550 °C three weighed samples that were cut from the gauge length of the moulded specimens. After cooling, the ash of glass residue was weighed and the exact weight fraction of glass (w_g) was determined. The w_g values were subsequently converted into glass volume fractions ϕ_g using the following relationship:

$$\phi_g = \left[1 + \frac{\rho_g}{\rho_m}\left(\frac{1}{w_g} - 1\right)\right]^{-1} \tag{2}$$

Taking the density of the matrix (ρ_m) as 1.12 kg m^{-3} and density of glass (ρ_g) as 2.54 kg m^{-3} gave average glass fibre concentration values of 4.4%, 9.5% and 15.5% v/v in GF composites and average glass bead concentration values of 4.2%, 9.1% and 14% v/v in GB composite.

Table 2
Injection moulding processing conditions.

Processing condition	100% ABS matrix	Composites & Hybrids with 10%total filler	Composites& Hybrids with 20% total filler	Composites & Hybrids with 30% total filler
Barrel temperature (°C)				
Zone 1	230	230	230	230
Zone 2	230	230	232	232
Zone 3	232	232	235	235
Mould temperature (°C)	70.00	70.00	80.00	80.00
Injection pressure (MPa)	8.50	8.50	9.00	9.00
Holding pressure (MPa)	3.00	3.00	3.00	3.00
Cooling time (s)	30.00	30.00	30.00	30.00
Cycle time (s)	33.00	33.00	33.00	33.00
Shot weight (g)	27.00	28.00	28.00	29.00