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Thermomechanical and Solid Particle Erosion Behaviour of $CaCO_3$ and SGF (Short Glass Fibre) Reinforced ABS/PA6 Composites

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In this study we have investigated thermomechanical and solid particle erosion behaviour of ABS/PA6 composites reinforced with $CaCO_3$ particles and SGF. ABS/PA6 composites were reinforced with $CaCO_3$ particles and SGF at different weight ratios (0, 10, 30, 15/15 wt.%). Composite materials were manufactured by twin screw extruder and injection molding machine. Thermomechanical properties were investigated by dynamic mechanical analysis (DMA) method. Moreover erosion wear behaviour was investigated on solid particle erosion test machine. Experimental results show that thermomechanical properties significantly depend on particle types and weight ratios. While storage modulus was found to be maximum for 30 wt.% SGF-reinforced samples, the loss modulus was found to be maximum for 15/15 wt.% hybrid samples. Moreover minimum loss factor values were found for hybrid samples, but glass transition temperature of samples were not effected significantly with $CaCO_3$ and SGF reinforcement. Erosion behaviour depends on particle impact angle, the type of reinforcing particles and their weight ratios. Maximum erosion rates were found at impingement angle of 30° for 30 wt.% $CaCO_3$-filled samples. According to experimental results both $CaCO_3$ and SGF reinforcement have positive influence on thermomechanical properties. However $CaCO_3$ and SGF reinforcement have reduced the solid particle erosion resistance of ABS/PA6 composites.

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1. Introduction

Engineering thermoplastics and their composites are finding increasing applications in nearly all industrial areas, due to their low cost, resistance to various chemicals, easy formability, recyclability, low electrical conductivity, ability to be transparent or to be coloured and light weight, compared to metals. Especially high the demand for lower density materials is in automotive and aerospace industries. Polymeric materials have replaced metals in such parts as air filter housings, resonators, timing gears, radiator fans/tanks, instrument panels and electronic modules [1–3].

High commercial interest is given to ABS/PA6 blends, viewed as high performance materials, because of their excellent potential for applications where super tough materials with high thermal stability are needed. On the other hand, the ease of processing and stability of the blend over wide processing conditions makes this blend suitable for engineering applications. Main application areas of the blend are automotive interior components, power tools, garden equipment, sport goods, medical equipment, and furniture [4–5].

Presence of the ABS in the PA6 matrix causes the reduction of modulus and tensile strength. For this reason short glass fiber (SGF) can be used to recover lost properties caused by the ABS. On the other hand, since cost is an important criterion for the usage of an engineering material, then $CaCO_3$ can be used to reduce the costs. Therefore, in this study SGF and $CaCO_3$ were used as reinforcement and cost reduction additives, respectively [6–8].

2. Experimental

2.1. Material and preparation of composite

The ABS/PA6 blend, known as Triax 1120 trademark, was provided in granule form from Lanxess. The reinforcement materials, glass fiber (PA1) and $CaCO_3$ were provided from Cam Elyaf A.Ş. and Omya A.Ş. respectively.

$CaCO_3$, SGFs and $CaCO_3$/SGF reinforced ABS/PA6 composites were prepared via melt blending in a twin-screw micro-compounder (15 ml, DSM Xplore, The Netherlands) at barrel temperature of 235 °C with a screw speed of 100 rpm. Compounding ratios of prepared composites are presented in Table I. Each composition was kept in the barrel for mixing period of 3 min. At the end of the mixing period, the melt was transferred to injection-molding device. The injection and holding pressures were set to 10 bars, and melt and mold temperatures were 235 °C and 80 °C, respectively.

2.2. Methods

In the current study, composite samples were eroded under impingement angles of 30° and 45° in an air jet-type erosion test rig. Garnet particles of 74–105 μm were used as erodent particles in erosion tests. Schematic illustration of the erosion test rig is shown in Fig. 1. Erodent

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TABLE I

Compounding ratios and sample codes of composites.

Matrix/ CaCo3/SGF	Composite type	Matrix [wt.%]	CaCO$_3$ [wt.%]	SGF [wt.%]
100/0/0	pure	100	0	0
90/10/0	Calcite-reinforced	90	10	0
70/30/0		70	30	0
90/0/10	SGF-reinforced	90	0	10
70/0/30		70	0	30
70/15/15	hybrid	70	15	15

particles were accelerated by a static pressure of 3 bars, along a 50 mm nozzle of 5 mm diameter. Before and after the erosion tests all samples were cleaned with air spraying. At the end eroded samples were weighed on an electronic balance with the accuracy of 60.1 mg. All samples were eroded for 10 s, and wear amounts were measured.

For the determination of dynamic mechanical behavior of polymers the DMA testing method was widely used. DMA tests were applied to each sample in three-point bending mode, by calibrated TA Instruments Q800 equipment, at a heating rate of 5 °C/min in the temperature range from room temperature to 150 °C, under deformation frequency of 1 Hz and amplitude of 25 μm. Dynamic mechanical properties of CaCO$_3$ and/or SGF reinforced composites were measured by DMA. As a result storage modulus (E'), loss modulus (E''), loss factor ($\tan\delta$) (ratio of loss modulus to storage modulus), and the glass transition temperature (T_g) were obtained.

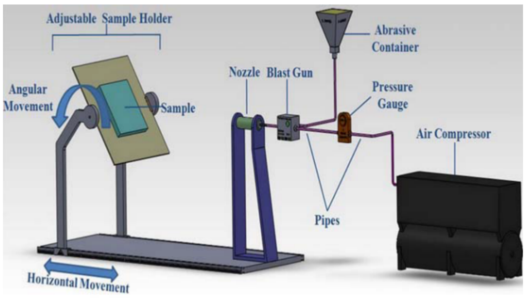

Fig. 1. Air jet-type erosion test rig.

3. Results and discussion

3.1. Dynamic mechanic properties (DMA)

Measurement of DMA associated with the reaction of a material to cyclic deformation as a function of temperature were carried out. The storage modulus (E'), corresponds to the elastic reaction to the deformation, loss modulus (E''), is connected with the energy lost in form of the heat due to friction related to internal motions, which reflects viscous behavior of material, loss factor ($\tan\delta$), referred as the internal damping, and the glass transition temperature (T_g), the temperature of peak damping, which refers to molecular mobility transition, were sequentially determined using the results of the test.

Storage modulus of CaCO$_3$- and/or SGF-reinforced ABS/PA6 composites at various weight ratios is shown in Fig. 2a. Investigation of Fig. 2a shows, that both of the reinforcement materials, CaCO$_3$ and SGF have increased the storage modulus of ABS/PA6. In comparison with CaCO$_3$, the SGF has improved more the storage modulus. Storage modulus value of the hybrid composite is located in between the ones of CaCO$_3$- and SGF-reinforced composites.

Results for loss modulus are shown in Fig. 2b. Both reinforcement materials have increased the loss modulus of the composite at each weight ratio. In comparison with the effect of CaCo$_3$, the effect of SGF on loss modulus of ABS/PA6 was more prominent. Values of loss modulus of hybrid composites are located between the values for CaCO$_3$- and SGF-reinforced composites, as it was in the case of the storage modulus.

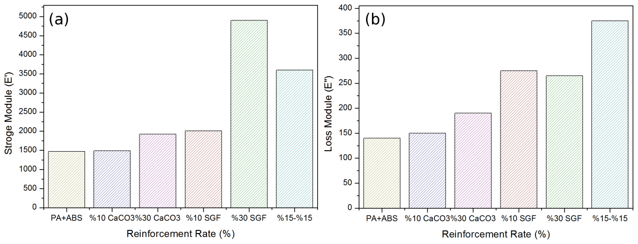

Fig. 2. Dynamic mechanical behavior of polymers: (a) storage modulus, (b) loss modulus.

Values of $\tan\delta$ of composites are given Fig. 3a. According to Fig. 3a, while reinforcement of ABS/PA6 with CaCO$_3$ has increased $\tan\delta$, reinforcement with SGF has decreased the value of $\tan\delta$. These results show that SGF reinforcement has stronger interfacial bonding to polymer matrix in comparison with the CaCO$_3$ reinforcement. The strongest interfacial bonding was obtained by hybrid composites.

Glass transition temperatures of composite samples are given Fig. 3b. Examination of the Fig. 3b shows, that CaCO$_3$ and/or SGF reinforcement have no significant effect on value of T_g of ABS/PA6.

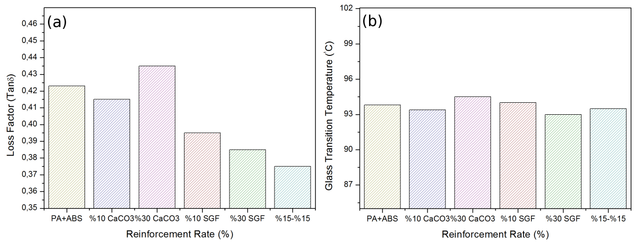

Fig. 3. Dynamic mechanical behavior of polymers (a) loss factor ($\tan\delta$), (b) glass transition temperature (T_g).

3.2. Erosion behaviour

Samples were eroded at particle impingement angles of 30° and 45° to investigate the effect of particle impingement angle on solid particle erosion behaviour of composite samples. Since, polymer composites show semi-ductile erosion behaviour, the selected particle impingement angles were 30° and 45°.

The effects of particle impingement angle on erosion behaviour of $CaCO_3$ and/or SGF reinforced ABS/PA6 are given Fig. 4a. As can be seen in Fig. 4a, ABS/PA6 and all reinforced samples are eroded more at particle impingement angle of 30°.

Effect of reinforcement-type and of the weight ratio on solid particle erosion behavior of $CaCO_3$ and/or SGF reinforced ABS/PA6 composites is given in Fig. 4b. Incorporation of $CaCO_3$ and/or SGF into ABS/PA6 matrix caused a reduction of solid particle erosion resistance of ABS/PA6 at both values of impingement angle. SGF reinforcement reduces the erosion resistance of composite less than the reinforcement with $CaCO_3$.

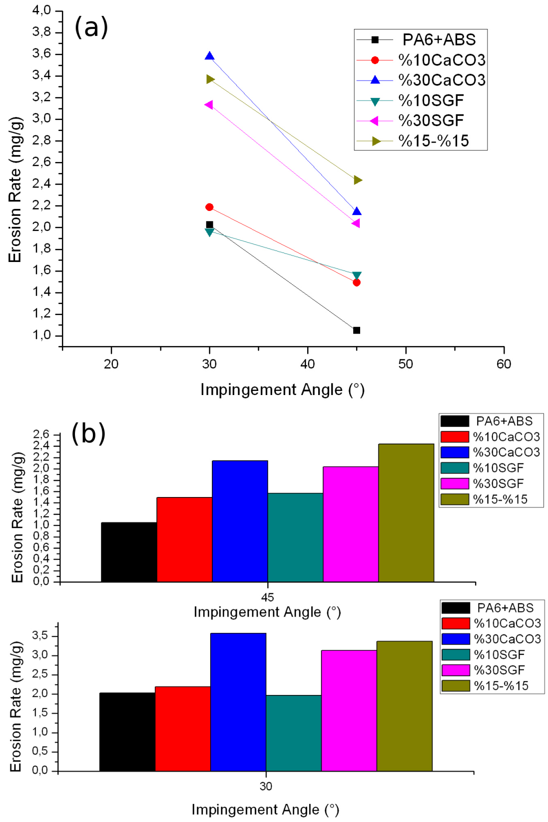

Fig. 4. Erosion test results: (a) effect of impingement angle, (b) effect of reinforcement type and ratio on the erosion behaviour of ABS/PA6 composite.

4. Conclusions

1. $CaCO_3$- or SGF-reinforcement has increased the storage modulus and loss modulus of ABS/PA6 polymer. Moreover SGF reinforcement has increased the DMA parameters more than the $CaCO_3$ reinforcement. Storage modulus and loss modulus values of hybrid composites are located between the ones of the $CaCO_3$- and SGF-reinforced composites.

2. Though reinforcement with SGF has decreased the value of $\tan\delta$, reinforcement with $CaCO_3$ has increased it. On the other hand hybrid composites showed the smallest value of $\tan\delta$ and best interfacial bonding properties. Glass transition temperature of ABS/PA6 was not effected significantly by $CaCO_3$ or/and SGF reinforcement.

3. ABS/PA6 is eroded more at particle impingement angle of 30° than at 45°, and all reinforced samples have similar behaviour. Moreover, addition of $CaCO_3$ and/or SGF into the ABS/PA6 matrix has reduced the solid particle erosion resistance of ABS/PA6 for both values of impingement angle. Reinforcement with SGF has reduced the erosion resistance of composite less than reinforcement with $CaCO_3$.

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