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CHARACTERISTICS OF EPOXY MATRIX BASED COMPOSITES WITH VARIOUS NANO-PARTICLES

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ABSTRACT

In metal-forming process, friction plays a significant role in determining the life of the tool, the formability of the work material and the quality of the finished products. The nano-particles can serve as matrix reinforcement as well as change the mechanical behavior of these materials. The effective dispersion of anisotropic particle such as short fibers, whiskers and platelets can substantially improve the reinforcement of the polymer matrix. The dispersion of single layer highly depends on the processing techniques, such as solution blending, in-situ polymerization and melt compounding. The improvement of compressing and wear mechanism can be effectively achieved by the inclusion of nano-inorganic particles into polymer-based composites. This paper presents the results of experimental investigations on various nano-particle filled epoxy matrix based composites. The effect of exfoliated nano-particles in the epoxy matrix is studied based on the improvement of compressing and wear mechanism. Numerous experiments of lubricated compression tests were conducted to determine the tribological properties. Studies have shown that epoxy composites containing nano-particles exhibited remarkably improved mechanical and wear properties.

Keywords: Epoxy matrix, Nano-particles, Polymer based composite

1. INTRODUCTION

In metal-forming process, friction plays a significant role in determining the life of the tool, the formability of the work material and the quality of the finished products. The nano-particles can serve as matrix reinforcement as well as change the mechanical behavior of these materials. The effective dispersion of anisotropic particle such as short fibers, whiskers and platelets can substantially improve the reinforcement of the polymer matrix (Kazt and Mike 1997). The dispersion of single layer highly depends on the processing techniques, such as solution blending, in-situ polymerization and melt compounding Okada et al. 1993; Akelah et al. 1995; Akelah et al. 1994; Giannelis 1996; Durand et al. 1995). The improvement of compressing and wear mechanism can be effectively achieved by the inclusion of nano-inorganic particles into polymer-based composites. Recent studies have shown that nano-composites containing only a small amount of ceramic nano-particles exhibited remarkably improved mechanical and wear properties. Durand et al. (1995) revealed that the addition of ceramic particles extremely decreased the wear coefficient and large particle were found to protect the polymer matrix better than small particles. It is important to study the role of these particles in the wear behavior and the dynamic rheology properties of polymer based nano-composites. This paper presents the results of experimental investigations on various nano-particle filled epoxy matrix based composites. The effect of exfoliated nano-particles in the epoxy matrix is studied based on the improvement of compressing and wear mechanism. Numerous experiments of lubricated compression tests were conducted to determine the tribological properties.

2. MATERIALS, MANUFACTURING PROCEDURE AND EXPERIMENTAL TECHNIQUES

Two different kinds of ceramic filler nano-particles were applied into the unsaturated polyester epoxy matrix. Organically treated Na-montmorillonite (cloisite® 30B) and inorganically treated titanium dioxide were used as fillers. The filler content was varied from 0 to 10 vol%. The epoxy matrix and nano-particles were mixed for 1 hour by using a spex mill. The filler elements were dried in an oven at 70 ^{o}C for 1.5 hours. In order to lower the resin viscosity and to get a better wetting of particles, the epoxy matrix was also preheated to the same temperature. After the filler elements were compounded with the resin matrix, the mixture was hot pressed in a vacuum to distribute the particles homogeneously. Finally the mixture was poured into a mold. During the heating process, the mold containing mixed powders was pressed up to 180 MPa and holding at 150 ^{o}C for 1 hour to promote degassing from the particle compact.

The experimental set-up was arranged in a 80 ton hydraulic press as shown in Fig.1. To confine the material flow to plane strain, two platens are placed on the both ends of the test specimen (with moving platen on upper side and fixed platen on bottom side). To decrease the barreling on the specimen surfaces, the frictional drag between the platen and specimen interface was reduced by spraying the platen with Teflon. The compression tests were conducted according to ASTM D790-92 standards by an Instron 8562 testing machine with a constant rate of 0.1 mm/sec at room temperature.

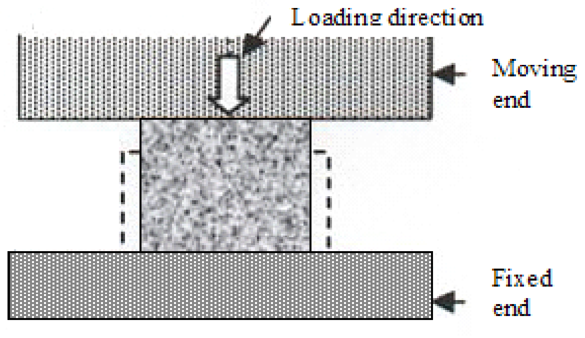

Fig 1. Experimental set-up for compression testing of cylindrical specimens

4. RESULTS AND DISCUSSION

The x-ray diffraction measurements for both nanostructure matrix contained cloisite⊗ 30B and titanium dioxide, respectively and pure epoxy matrix are given in Fig. 2. It is broader and less intensive before peak of the pure matrix, which indicates that the system is mainly exfoliated and only a small part remain not exfoliated. The trace peak is shifted to 6.0^{o} after mixing with nano- powder of cloisite⊗ 30B. For the matrix filled with titanium dioxide powders at ambient temperature, the trace peak is further shifted to the left and is broaden slightly. These x-ray patterns denote that the nano-particles have extremely high intercalated or exfoliated in nano-composites.

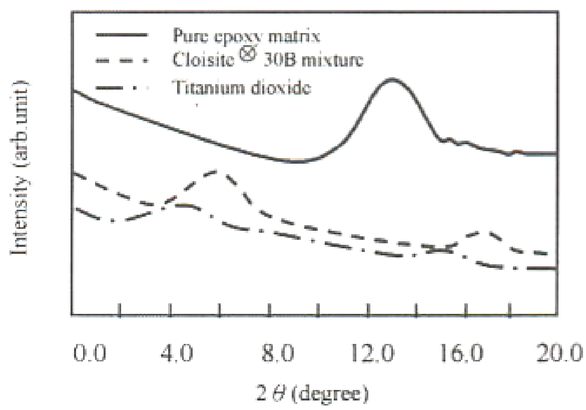

Fig 2. X-ray diffraction measurements for nano-composites and pure epoxy matrix

The compression strength of the epoxy nano-composites with various volume fractions of filler contents is presented in Fig. 3. The compression strength of the titanium dioxide nano-composites is higher than that of the cloisite⊗ 30B nano-composites owing to higher degree of exfoliation and better adhesion at the particle-resin interface. Furthermore, the compression strength for cloisite⊗ 30B composite starts to decrease gradually beyond a filler content of 5 vol%. It indicates that there is a lower degree of nano-particle-polymer interaction at higher filler contents.

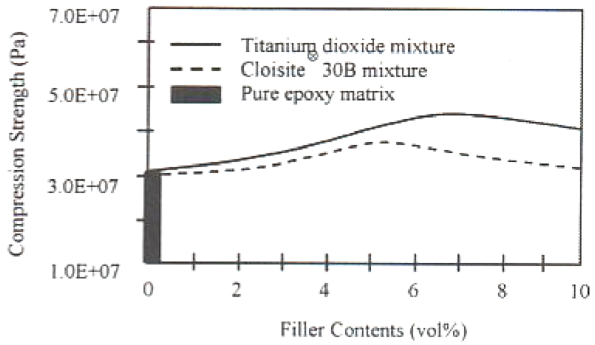

Fig 3. Compression strength of nano-composites as a function of filler content

From the SEM nanographs of specimen surface given in Fig. 4, the particle agglomerates for filler content of cloisite⊗ 30B is found to be larger. This is an indication of lower nano-particle-polymer surface interaction that results in lower compression strength.

(a). 5 vol% of cloisite⊗ 30B

(b). 7 vol% of titanium dioxide

Fig 4. SEM nanograph of the specimen surface

Figure 5 shows the compressive stress-strain curves for both matrix containing 5 vol% of cloisite⊗ 30B and 7 vol% of titanium dioxide, respectively and pure epoxy matrix. The mechanical properties derived from the compressive tests for three specific materials are summarized in Table 1. The compressive tests for cloisite ⊗ 30B based matrix exhibits an ultimate stress of 2.41 GPa, an elastic strain of 1.28% and a yield stress of 1.60 GPa. For nano-composites with titanium dioxide, ultimate stress, elastic strain and yield stress are 2.65 GPa,1.32% and 1.88 GPa, respectively. Pure epoxy matrix shows lower ultimate stress, elastic strain, yield stress and Young's modulus compared to nano-composites.

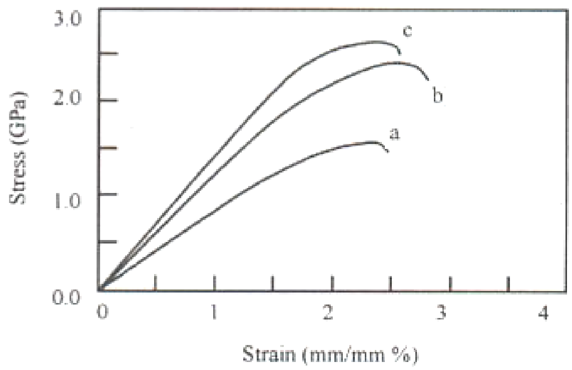

Fig 5. Comparison of compressive stress-strain curves at room temperature: (a) pure epoxy matrix, (b) nano-composites with cloisite ⊗ 30B and (c) nano-composites with titanium dioxide

Table 1: Mechanical properties of pure epoxy matrix and nano-composites

Composites	Yield stress GPa	Elastic strain %	Ultimate stress GPa	Young's modulus GPa
Pure epoxy matrix	1.05	1.21	1.48	87.1
Nano-composites with cloisite ⊗ 30B	1.60	1.28	2.41	125.3
Nano-composites with titanium dioxide	1.88	1.32	2.65	143.5

5. CONCLUSIONS

The compression strength of the titanium dioxide nano-composites is higher than that of the cloisite ⊗ 30B nano-composites owing to higher degree of exfoliation and better adhesion at the particle-resin interface. The compressive stress-strain curves showed that the fracture strength and young's modulus for both reinforced nano-composites are much higher than that of pure epoxy matrix which is attributed to the vein shape and the ductile dentritic phase occurred in the matrix during the compressive deformation.

6. REFERENCES

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