Mechanical Properties of Aluminium Nitride Particles Filled Epoxy Composites

Ankesh Soni
Department of Mechanical Engineering, Sagar Institute of Research and Technology-Excellence,
Bhopal-462041 (M.P.)

Alok Agrawal
Department of Mechanical Engineering, Sagar Institute of Research and Technology-Excellence,
Bhopal-462041 (M.P.)

Abstract*—In this investigation a class of polymer composites consisting of epoxy as a matrix material with a micro-size aluminium nitride as a filler material is developed. A set of composite specimen with filler content ranging upto 50 wt. % has been fabricated using simple hand lay-up technique. The effect of filler content on different mechanical property of the prepared sample is studied. The various mechanical property evaluated are tensile strength, compressive strength and hardness. From the experimental results, it is found that aluminium nitride filled epoxy composites possess high compressive strength and hardness. Through, tensile strength of the composite decreases with increase in filler content in the fabricated composites.

***Keywords*— Aluminium nitride, Epoxy, mechanical properties, Polymer matrix composites.**

I. INTRODUCTION

The most common matrix materials for composites are considered to be polymeric. The reasons for this are twofold. Firstly, in general the mechanical properties of polymers are inadequate for many structural purposes. In particular their strength and stiffness are low compared with other matrix materials i.e. metals and ceramics. This means that there is a considerable benefit to be gained by reinforcing polymers, and that the reinforcement does not have to have exceptional properties. Secondly, and most importantly, the processing of polymer matrix composites (PMCs) need not involve high pressures and does not require high temperatures. It follows that problems associated with the degradation of the reinforcement during manufacture are less significant for PMCs than for composites with other matrices. Also the equipment required for PMCs may be simpler.

The amount of filler that is incorporated inside the matrix is considered to be the most significant factor which can alter the performance of composite system. It has been shown by many researchers that dramatic improvement in mechanical properties can be achieved by incorporation of either micro or nano-particles, since rigid inorganic particles generally have a much higher stiffness than polymer matrices [1]. The effect of $CaCO_3$ volume fraction on the notched Izod impact toughness of high density polyethylene (HDPE)/$CaCO_3$ composites is shown by Liu et al. [2]. Cho et al. [3] underlined the interest of replacing micro-scale particles by its nano-scale counterparts smaller particle size yields higher fracture toughness.

As far as tribologicalbehaviour is concerned, it has been seen that the incorporation of certain particles enhances the wear resistance of polymers. Wetzel et al. [4] study the effect of micro and nano-sized ceramic particulates into an epoxy resin. They study the effect of SiC and TiO_2 particles for different particle loading and particle size as well as with surface modification of particles and observed that with increase in filler loading and decrease in particle size, the specific wear rate decreases whereas modification of particles has only a little effect on the wear performance. However, Zang et al. [5] reported that grafting of PAAM onto nano-silica increases the interfacial interaction between the particles and the matrix through chemical bonding. Antunes et al. [6] found that increasing average particle dimension tends to decrease the volume removed by wear in the composite and increase it in the antagonist body. Recently, Anjum et al. [7] studied specific wear rate of SiO_2 filled glass-epoxy composite. Likewise, the incorporation of hard particles i.e. SiC, ZrO, Ti_3SiC_2 has led to enhancement in wear resistance [8-10].

Many investigations are reported on optically transparent polymer composites because of their wide industrial applications, such as optical fiber sensors, packaging products and medical devices [11]. Other than difference in refractive indices of both the phases, supplementary parameters like filler concentration, particle size and affinity between filler-matrix also influence the composite transparency [12]. Zhou and Burkhart [13] studied the effect of inclusion of SiO_2 on three different polymers i.e. polycarbonate (PC), polystyrene (PS) and PMMA, which are all amorphous thermoplastics and are often used as an alternative to glass. Yuan et al. [14] studied the effect of particle size of LaB_6 particles on optical properties of LaB_6/ PMMA composites. They further reported that modification of LaB_6 by adding silane coupling agent enhanced the property to a great extent by increasing the light absorption strength of composites. Li et al. [15] evaluated dynamic mechanical properties of particulate composites using high-precision ultrasonic testing technology. Against this background, an attempt has been made in this research work to develop aluminium nitride based epoxy composites using simple hand lay-up technique and to study their mechanical behavior under controlled laboratory conditions

II. MATERIALS AND METHODS

A. *Material considered*

The presently used matrix is a thermoset polymer epoxy. The epoxy resin Lapox-12 is used in the present work which belongs to the epoxide family. Bisphenol-A-Diglycidyl-Ether (commonly abbreviated to DGEBA or BADGE) is the common name of the presently used epoxy resin. It provides a solvent free room temperature curing system when it is combined with the hardener tri-ethylene-tetramine (TETA) which is an aliphatic primary amine with commercial designation HY 951. The epoxy resin with its corresponding hardener is procured from M/s Atul Limited, Bhopal. It is a liquid, unmodified epoxy resin of medium viscosity which can be used with particular hardener for making composites. They are amorphous and highly cross linked polymers. Due to this structure it has high tensile strength and modulus, good thermal and chemical resistance.

Aluminium nitride is an aluminium based ceramic material is used as one of the filler material in present work. The used aluminium Nitride has been procured from Souvinier Chemical, Mumbai, India. The particle size analysis of the material provides the information that the average sizes of particles are about 60-70 microns. AlN with hexagonal structure is taken as filler material because it proivde best thermal conductivity among other structure of it. It also has low coeffcient of thermal expansion are are reasonably good strength. They are not very reactive substance and also shows good dieelctric properties. Figure 3.4 shows the pictorial microstructural view of aluminium nitride particles.

B. *Composite Fabrication*

Simple hand lay-up technique is used in the present investigation for fabrication of aluminium nitride particles in epoxy matrix. This method is considered as the simplest technique for composite fabrication. The fabrication of composite using hand lay-up method involves following steps:

1. The room temperature curing epoxy resin epoxy resin (Lapox-12) and corresponding hardener (HY 951) are mixed in a ratio 10:1 by weight as recommended.
2. Micro-size aluminium nitride particles were then added to the mixture of epoxy and hardener which is later mixed thoroughly by hand stirring.
3. A coating of silicon spray is mandatory over the mould before pouring the epoxy/hardener/aluminium nitride mixture into it, a silicon spray is done over the mold so that it will easy to remove the composite after curing. The uniformly mixed dough is then slowly poured into the mould.
4. The cast is than cured for 8 hours before it was taken from the mould.

Composites were fabricated with different weight fraction of filler ranging from 0 wt. filler i.e. neat epoxy to 50 wt. % filler. The composite fabricated under the investigation is given in table 1

TABLE I

EPOXY COMPOSITES FILLED WITH ALUMINIUM NITRIDE

S.No.	Composition
1	Neat Epoxy
2	Epoxy + 10 wt % Aluminium Nitride
3	Epoxy + 20 wt % Aluminium Nitride
4	Epoxy + 30 wt % Aluminium Nitride
5	Epoxy + 40 wt % Aluminium Nitride
6	Epoxy + 50 wt % Aluminium Nitride

C. *Mechanucal Characterization*

The tensile strength of the composites is measured with a computerized Tinius Olsen universal testing machine in accordance with ASTM D638 procedure by applying uni-axial load through both the ends at a cross head speed of 0.5 mm/min. Static uniaxial compression tests and flexural test on specimens are carried out using the same computerized Tinius Olsen universal testing machine. The method by which the compression test is conducted is in accordance with ASTM D695. Affri LD250 hardness measuring instrument is used to determine the micro-hardness of the fabricated composite. The tests are in accordance with ASTM E384.

III. RESULTS AND DISCUSSION

A. *Micro-hardness*

Figure 1 shows the variation in the value of hardness of the composite material for different content of aluminium nitride in epoxy matrix. It can be seen from the figure that incorporation of aluminium nitride particles impart interesting changes in the value of hardness of the epoxy matrix. It is evident from the figure that with addition of fillers, micro-hardness of the composites improved and this improvement is mainly a function of the filler content. The increment is is obvious because of high hardness value of AlN as compared to epoxy matrix. Increased filler content resulted in increase in modulus of the composite, leading to a corresponding increase in the hardness of the composite. For application like microelectronics, improved hardness is required to overcome the wear during the installation of different component over the chip. Also high hardness is required to protect the delicate component from foreign attack. For 50 wt. % AlN content, hardness of the composite body increases form 0.087 GPa for virgin epoxy to 1.116 GPa which is around thirteen times that of neat epoxy. The increment is considered to be the great achievement in the presently fabricated samples.

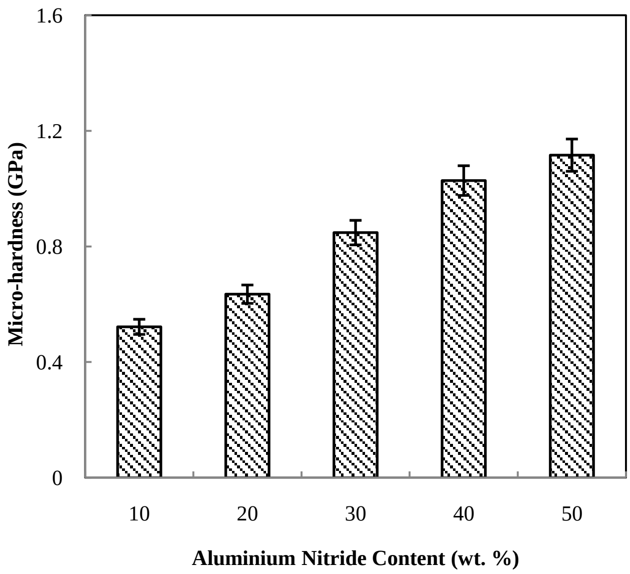

Fig. 1 Micro-hardness of epoxy/aluminium nitride composites

B. *Tensile Strength*

The variation in the value of tensile strength with varying content of aluminium nitride in epoxy based composite is shown in figure 2. From the figure it is clear that with increase in the content of aluminium nitride in epoxy matrix, tensile strength of the combination decreases. The tensile strength of neat epoxy is 40.5 MPa which decreases to 38.5 MPa at a loading of 10 wt. % of micro size AlN which is an decrement of 4.9 %. The rate of decrement increases with increase in filler content and for maximum filler loading of

50 wt. %, the tensile strength of composites decreased to 25.1 MPa. This decrement is attributed to 38 %.

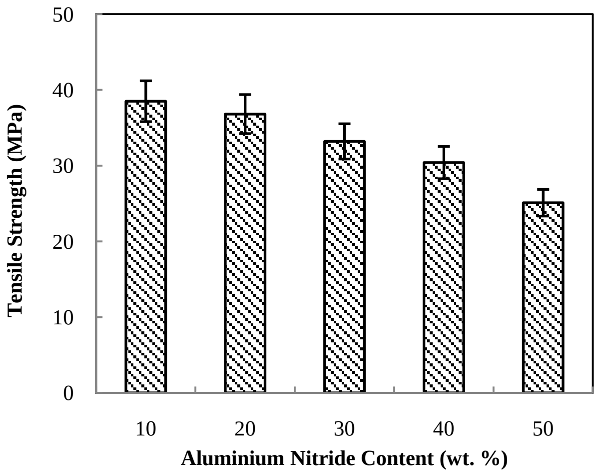

Fig. 2 Tensile strength of epoxy/ aluminium nitride composites

C. Compressive Strength

The dependence of compressive strength of epoxy composites filled with aluminium nitride with different filler content shown in figure 3.

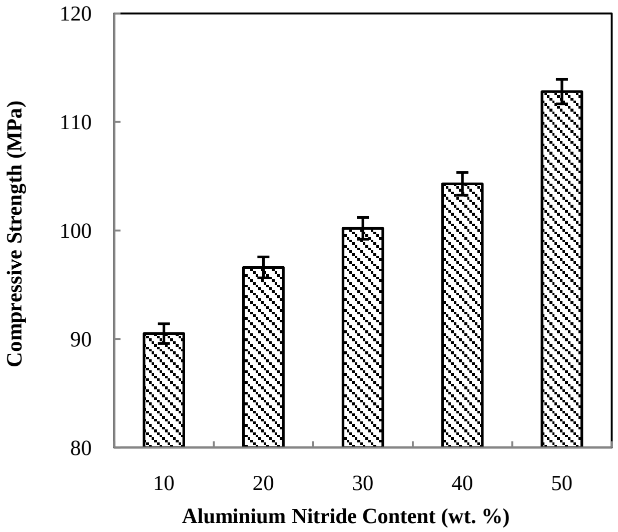

Fig. 3 Compressive strength of epoxy/ aluminium nitride composites

It can be seen from the seen that with increase in AlN content, compressive strength of the composites increases. The increasing behavior is obvious as AlN has very high compressive strength as compared to epoxy matrix and hence the combination delivers higher compressive strength. The compressive strength of neat epoxy is 85 MPa which increases to 96.6 MPa at a loading of 10 wt% of micro size AlN. This is an appreciable increment of 13.76 %. This increment further increases when higher loading of AlN is used in epoxy matrix. With 50 wt. % of AlN, the combination delivers compressive strength of 112.8 MPa which is an increment of 32.7 %

IV. CONCLUSIONS

This experimental investigation has led to the following specific conclusions:

1) With the increase in the content of aluminiumnitride in epoxy matrix, hardness of the composites increases and reaches its maximum value of 1.116GPa for 50 wt. % of filler loading.
2) Tensile strength of composite decreases with increase in filler content. The minimum tensile strength among the various fabricated samples was of sample with 50 wt. % of aluminium nitride. Its values were reported to be of 25.1 MPa.
3) Compressive strength of epoxy increases and this improvement is found to be more for increased filler content. The maximum value obtained is 112.8 MPa for 50 wt. % of filler.

REFERENCES

[1] Fu SY, Feng XQ, Lauke B, Mai YW (2008). Effects of particle size, particle/matrix interface adhesion and particle loading on mechanical properties of particulate–polymer composites. Composites: Part B: Engineering, 39: 933–961.

[2] Liu ZH, Kwok KW, Li RKY, Choy CL (2002). Effects of coupling agent and morphology on the impact strength of high density polyethylene/CaCO3 composites. Polymer, 43: 2501–2506.

[3] Cho J, Joshi MS, Sun CT (2006). Effect of inclusion size on mechanical properties of polymeric composites with micro and nano particles. Composites Science and Technology, 66: 1941–1952.

[4] Wetzel B, Haupert F, Friedrich K, Zhang MQ, Rong MZ (2001). Mechanical and tribological properties of microparticulate and nanoparticulate reinforced polymer composites. Proceedings of the ICCM-13, Wan Fang Digital Electronic Publisher, Beijing, ID 1021.

[5] Zhang MQ, Rong MZ, Yu SL, Wetzel B, Friedrich K (2002). Effect of particle surface treatment on the tribological performance of epoxy based nanocomposites. Wear, 253: 1086–1093.

[6] Antunes PV, Ramalho A, Carrilho EVP (2014). Mechanical and wear behaviours of nano and microfilled polymeric composite: Effect of filler fraction and size. Materials and Design, 61: 50–56.

[7] Anjum N, Prasad SLA, Suresha B (2013). Role of silicon dioxide filler on mechanical and dry sliding wear behaviour of glass-epoxy composites. Advances in Tribology, 2013: Article ID 324952.

[8] Patnaik A, Satapathy A, Mahapatra SS, and Dash RR (2007). Implementation of Taguchi design for erosion of fiber-reinforced polyester composite systems with SiC filler. Journal of Reinforced Plastics and Composites, 27: 1093–1111.

[9] Akinci A, Sen S, Sen U (2014). Friction and wear behavior of zirconium oxide reinforced PMMA composites. Composites Part B: Engineering, 56: 42-47.

[10] Xu J, Yan H, Gu D (2014). Friction and wear behavior of polytetrafluoroethene composites filled with Ti3SiC2. Materials and Design, 61: 270-274.

[11] Beecroft LL, Ober CK (1997). Nanocomposite Materials for optical applications. Chemistry of Materials, 9: 1302–1317.

[12] Maruhashi Y. Iida S (2001). Transparency of polymer blends. Polymer Engineering & Science, 41: 1987-1995.

[13] Zhou RJ, Burkhart T (2010). Optical properties of particle-filled polycarbonate, polystyrene and Poly(methyl methacrylate) Composites. Journal of Applied Polymer Science, 115: 1866–1872.

[14] Yuan Y, Zhang L Hu L, Wang W, Min G (2011). Size effect of added LaB6 particles on optical properties of LaB6/Polymer composites. Journal of Solid State Chemistry, 184: 3364–3367.

[15] Li R, Xia H, Xu ZZ, Ni QQ, Fu Y (2017). U-DMA measurement and dynamic analysis of ultrasonic wave propagation in particulate composites. Composites Science and Technology, 151: 174-183.

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