Mechanical Properties of TiO_2 and WC Reinforced Epoxy Resin Composites

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Abstract— This paper deals with study of mechanical properties of titanium dioxide (TiO_2) and tungsten carbide (WC) reinforced epoxy based polymer matrix composite materials. Composite specimen's reinforcing Tio_2 and WC at three different weight percentage (0%, 5%, and 10%) were prepared by casting technology in wooden moulds. Tensile and flexural properties of both reinforced and unreinforced epoxy was checked. All tests were conducted as per ASTM standards. Tests were conducted at room temperature. From results it was found that there is increase in tensile and flexural strength for WC reinforced epoxy composites but TiO_2 reinforced results in decrease in tensile strength for both 5% and 10%.

Key words: WC Content, Epoxy Resin Composites

I. Introduction

An important characteristics of polymer composite material is its ability to improve the mechanical properties by filling different metal oxides and different ceramic fillers. Small percentage of reinforcement in polymer matrix results in significant improvement in different mechanical properties. Most of the modifications in mechanical properties are done by adding in organic fillers, metal particles and ceramic fillers in polymer matrix. Percentage of these fillers also has influence on material property. This property changes are measured by basic principles or by the experimentations. Effect of these different fillers on mechanical properties is largely depend upon the filler particle size, shape and degree of dispersion in polymer matrix. [1-3].

Among these various types of fillers TiO_2 metal oxides and WC ceramic fillers were attracted attention because of drastic change in mechanical properties when reinforced in polymer matrices. Now a days these fillers becoming popular because of low cost and extensive application in different areas. [4]

Many investigations are conducted on dispersion of particles in matrix materials. Dispersion characteristics mainly depend upon the method of manufacturing. [5]

Epoxy resins are popular and well known thermosetting resins for polymer matrix composites, they have series of good characteristics like good stiffness, dimensional stability and chemical resistance. They also has good adhesion properties with different types of reinforcements. Epoxy resins along with fiber reinforcement have higher strength to weight ratio compared to steel [6].

Nano particles has tendency to agglomerate under vendors walls forces. So inclusion of these nano particles reduces the interfacial interaction between resin and reinforcement. Dispersion of these nano particles in matrix phase also has influence on mechanical and thermal behavior of composites. Many fabrication methods were tried for uniform distribution of these nano particles into the matrix phase of polymer composites [7].

Aluminium matrix along with different ceramic reinforcements such as silicon carbide, aluminium oxide, boron carbide and tungsten carbide are proved as good wear resistance composite materials and also they possess good mechanical and thermal properties [10]. Epoxy matrix modified with Al_2O_3, TiO_2, and SiO_2 micro particles in glass fiber epoxy composites shows good mechanical properties but in case of Al_2O_3 agglomeration of particles is observed. [11]. Aluminium reinforced with silicon carbide and graphite carbide particles shows a good wear resistance properties hardness goes on increasing for SiC reinforced aluminium composites but graphite results in decrease in hardness. Wear rate of SiC is less compared to graphite reinforced aluminium.

Present work is focused on reinforcing the TiO_2 and WC in epoxy matrix no other reinforcement was used to clearly study the effect of these particulate fillers on epoxy resin. Samples with 0, 5 and 10 wt. % of TiO_2 and WC were fabricated and different mechanical properties such as tensile and flexural strength were checked.

II. Experimental

A. Materials

For present study epoxy Lapox T 22 resin and K6 hardener were selected as matrix system. It is supplied by Atul Ltd. Gujrat. The filler TiO_2 was obtained from Fisher Scientific, Mumbai. WC was obtained from Reliable Bearing Company, Mumbai.

B. Fabrication

Fillers such as TiO_2 and WC were added to the epoxy resin in two different weight (5 and 10%) and stirred in a glass beaker. Stirring is done manually and it was continued till the particles get dissolve in resin. After that K6 hardener was added to the mixture for curing. Hardener and epoxy ratio was 1:10. Hardener was added slowly by continue stirring. Following table shows different sample composition.

Sr. No.	Epoxy (Wt. %)	Titanium Dioxide (Wt. %)	Tungsten carbide (Wt. %)
1	100	-	-
2	95	5	-
3	90	10	-
4	95	-	5
5	90	-	10

Table 1: Specimen Composition

After adding hardener to the epoxy resin mixture is poured into the wooden moulds to which wax and release agents was applied. Curing time is 24 hr. at room temperature. After curing specimens were removed from molds and cut to the standard dimensions. Specimen dimensions were as per the ASTM standards. Following table- 2 shows ASTM standard for different tests.

Sr. No.	Test	ASTM
1	Tensile Test	D 638-02a
2	Bending Test	D790

Table 2: ASTM standards

C. Tensile Properties

Tensile test is also known as tension test and it is a common mechanical test which we carry on materials. Tensile properties of fabricated specimens were checked. Tensile tests were carried out on universal testing machine model-TUE-C-400. By pulling material we can find its tensile strength and by measuring deformation at various loads we can plot stress strain curve, which will help to predict material behavior at various loads. Point of specimen failure is called as Ultimate tensile strength. From this test tensile strength, percentage elongation and young's modulus were calculated.

D. Flexural Properties

3-point bending test was performed on UTM machine to determine flexural properties of specimen. Specimen was supported on supports distance between supports is 70 mm. The 3-point bending test provides values for modulus of elasticity in bending, flexural stress and flexural modulus. The main advantage of a three point flexural test is the ease of the specimen preparation and testing. Specimen was fabricated in rectangular shape having constant cross section.

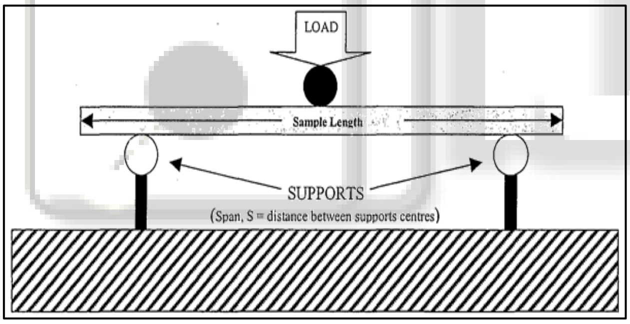

Fig. 1: 3 Point bending test

III. RESULTS AND DISCUSSION

A. Tensile Test

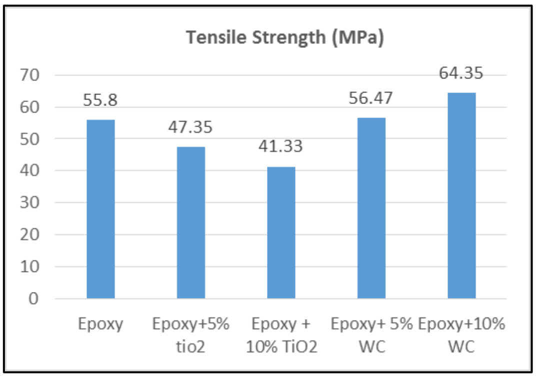

Fig. 2: Effect of fillers on tensile strength

As shown in Figure-2, it is observed that 10% of WC filled epoxy composites has a highest tensile strength of 64.35 MPa, 5% of WC filled epoxy has tensile strength of 56.47 MPa which shows slight increase in tensile strength compared to unfilled epoxy. 5% of TiO_2 filled epoxy shows decrease in tensile strength compared to pure epoxy. 10% of TiO_2 filled epoxy has lowest tensile strength of 41.33 MPa. Metal oxides effects strength in two ways one is weakening effect due to stress concentration and another is reinforcing effect. In this case weakening effect is predominant and hence composite strength is lower than matrix. In other case reinforcing effect is predominant so results in increase in tensile strength.

As shown in figure 3, WC filled epoxy results in more elongation compared to unfilled and TiO_2 filled epoxy composites, Elongation of 10% of WC filled epoxy increased by 1.9 % than neat epoxy. TiO_2 filled epoxy results in lower elongation compared to unfilled epoxy. TiO_2 reinforcement results in decrease in ductility of epoxy this shows that TiO_2 reinforcement in epoxy results in loss of ductility of epoxy.

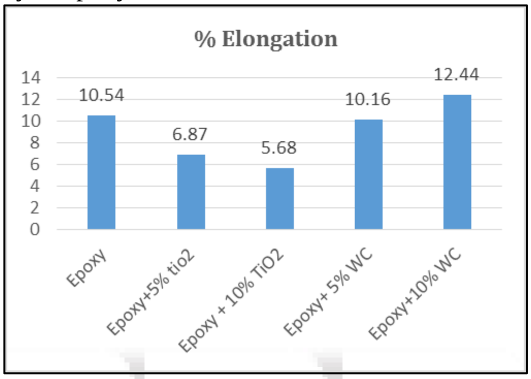

Fig. 3: Effect of fillers on % elongation

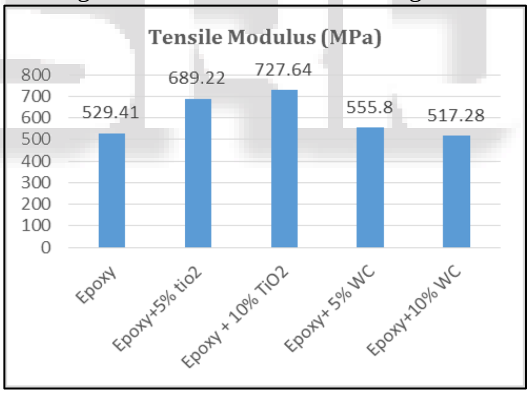

Fig. 4: Effect of fillers on tensile modulus

As shown in figure 4, tensile modulus is high for both TiO_2 filled epoxy compared to unfilled and WC filled epoxy. It indicate that TiO_2 reinforcement makes the epoxy stiffer than WC filled epoxy, WC filled epoxy also has more stiffness compared to neat epoxy.

B. Flexural Test

Flexural strength shows the ability of material to withstand forces which are applied perpendicular to its longitudinal axis. As shown in figure 5, TiO_2 fillers in epoxy matrix results in slight increase in flexural strength. 10% WC filled epoxy has higher flexural strength of 103.83 MPa. 10% of TiO_2 filled epoxy has lower flexural strength than 5 % of TiO_2. Main reason behind this is interfacial adhesion between TiO_2 and epoxy is weak compared to intermolecular forces of epoxy matrix. Porosity in the specimen increase with TiO_2 filler content. This is reason behind decrease in flexural strength of 10% of TiO_2 filled epoxy.

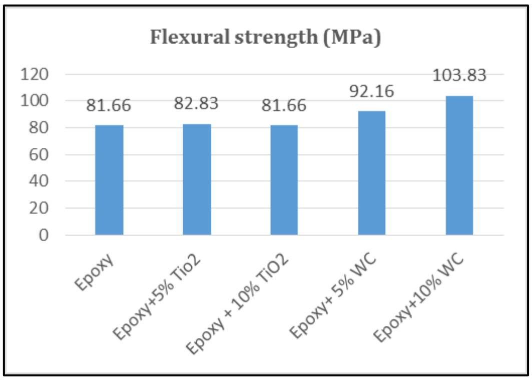

Fig. 5: Effect of fillers on flexural strength

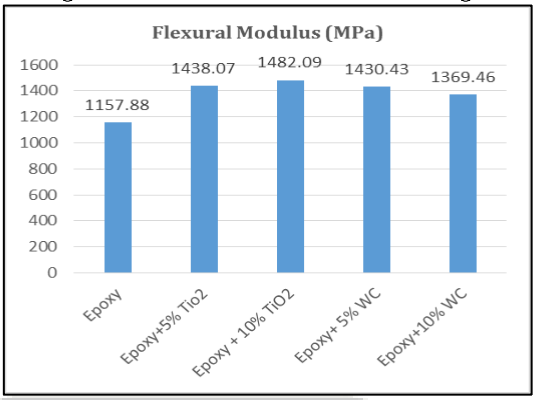

Fig. 5: Effect of fillers on flexural modulus

As shown in figure 5, flexural modulus is high for both TiO_2 and WC reinforced epoxy composites compared to neat epoxy, In case of 10% of Tio2 filled epoxy flexural modulus is high compared to other combinations. For 10% WC filled epoxy flexural modulus is decreased compared to 5% WC this is because of higher particles compatibility between polymer matrix and filler particles going to decrease and results in reduced flexural strength.

IV. CONCLUSIONS

Effects of TiO_2 and WC content on epoxy resin system was studied. Relation between filler percentage and mechanical properties was studied experimentally and following conclusion were drawn.

- 10% of WC filled epoxy shows high tensile strength of 64.35 MPa. 10% of TiO_2 filled epoxy has lower tensile strength 41.33 MPa compared to 5% of Tio_2 filled epoxy 47.35 MPa. TiO_2 content in epoxy system reduces the tensile strength compared to neat epoxy.
- Percentage of elongation is 12.44% for 10% of WC filled epoxy. Addition of WC results in increase in ductility compared to neat epoxy.
- Tensile modulus is 689.22 MPa for 5% of TiO_2 filled epoxy. Compared to other combination this indicate addition of TiO_2 in epoxy makes it stiffer compared to other combination of fillers and neat epoxy.
- Flexural strength is high (103.83 MPa) for 10% WC filled epoxy compared to other combinations.
- WC reinforcement in epoxy resin system increases tensile and flexural strength. WC reinforcement makes epoxy ductile than neat epoxy.
- TiO_2 reinforcement makes epoxy stiffer. Porosity is more in TiO_2 reinforced epoxy composites. Method of stirring also has influence on mechanical properties.

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