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Study of Mechanical properties of Epoxy composites filled with Graphite & TiO_2

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ABSTRACT

Epoxy Based Resin filled with Graphite particle & TiO_2 particle were made by hand layup technique. Tensile strength, Flexural strength, Impact, hardness & density were determined as per ASTMD 256, ASTMD 792, and ASTMD 2240. Composite containing 3 wt % of graphite particle exhibits the optimum mechanical & wears performances. A further increase in the graphite content increases the specific wear rate & deteriorates the mechanical performance. The performance of composites can further be improved by adding TiO_2 filler in polymer. The present work includes the processing & mechanical characterization of the composite. The experimental results showed that as TiO_2 increases (upto 4 to 5 wt %) density, hardness, Tensile strength & Flexural strength also increases & Impact strength decreases after increase in TiO_2. The systematic experimentation leads to determination of significant process parameters & material variables that predominantly influence the mechanical properties.

***Keywords* -** Epoxy, Graphite, TiO_2, Mechanical Properties.

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I. INTRODUCTION

Epoxy Resin is one of the most versatile polymers. Epoxies are most widely used family of thermoset large portion of them has been used for applications that do not require it to be reinforced (adhesives, paints, etc) the major application of reinforced epoxies is in circuit boards. Many advanced composites use epoxies because of their high thermal stability, adhesion & mechanical properties. It can be used for the aerospace structures, organic coating & common adhesives for domestic application. Mechanical test methods were used to investigate the mechanical properties of epoxy resin system. These tests are made to evaluate general performance & behavior of the epoxy resin system. Numerous researchers have modified wear resistance by lowering coefficient of friction of thermoplastic / thermoset resins with suitable solid lubricants. The influences of graphite content on mechanical properties of these composites were examined.

Polymer based composite have been extensively used in tribological applications because of their light weight, ease of fabrication, excellent specific strength, corrosion resistance, design flexibility, etc. Fiber reinforced polymer composites have been extensively used in automotive & aerospace application for making components such as gears, cams, Wheels, brakes, bearing liners, rollers, seals, clutches & bushing. Polymer composites with fibers or solid lubricants have been used in case of components where external lubrication is practically not feasible, some solid lubricants such as polytetreafluroethylene (PTFE), molybdenum disulphide (MoS2) & Graphite (Gr) have excellent wear resistance & anti friction abilities & commonly used in environment where fluid lubricants are ineffective.

(Basavarajppa & Ellangovan 2012) have studied the effect of adding fillers namely Gr into epoxy composite systems. They reported that addition of Gr has considerably reduced the specific wear rate of epoxy composites. (Shivamurthy) have mentioned that 3 wt % Gr into epoxy/glass multilayered laminates has led to the enhancement of both mechanical & dry sliding wear performance of laminates. However Gr beyond 3 wt % deteriorated both mechanical & dry sliding wear properties. The formation of clusters of Gr at higher filler content was cited as main reason for deterioration in properties of epoxy/glass laminates. Incorporation of solid lubricant (Gr) as secondary filler resulted in improvement of both mechanical & tribological properties of composites.

TiO_2 is a conventional filler material & is used extensively for developing new materials. It has strong potential as coating material with linear coefficient of thermal expansion & elastic modulus. TiO_2 has been used in combination with hydroxyapatite for developing biomaterial for implants because of its favorable biological effects & improved corrosion resistance. Mechanical properties of epoxy resin toughened with two different submicron particles of TiO_2 A small amount of TiO_2 submicron particle improves flexural, abrasion & pull of strength while amounts upto 5 wt % significantly enhance the Tensile properties. TiO_2 is used as white pigment due to its brightness.

II. MATERIALS & METHODS

2.1 Material

The matrix material used was epoxy resin (AW-106) & room temp curing polymer hardener (HV-953 U). The reinforcement material employed was TiO_2 the solid lubricant that has been used is Graphite (Gr)

2.2 Method

2.2.1 Composite Specimen Preparation

Hand lay-up is the simplest & oldest open molding method of the composite fabrication process. It is a low volume, labor intensive method suited especially for large components. A hand lay-up technique was used to prepare the epoxy composites with TiO_2 & solid lubricant (Graphite) as filler material. The specimen prepared has a size 200 mm in length, 25 mm in width & 8 mm in thickness as shown in fig. To prepare specimen epoxy resin (AW-106) & hardener (HV-953U) are mixed in same ratio by volume. Then the solid lubricant (Graphite) as a filler material constant 3 wt % & TiO_2 different wt % is mixed in the epoxy resin. The mixed composite is stirred gently into the liquid resin & try to avoid the introduction of air bubbles & even dispersion of the filler. And ensure the homogenous mixing of epoxy composite. The mixture is then poured into a metallic mold cavity coated with silicon based release agent (Spray Mould supplied by Dipa Enterprises, Ahmednagar) so as to get specimen as shown in fig. The mould is placed in an electric oven & heated at constant temp of 100°C for 1 hr. In such a way several different composites are made such as bare, 1 wt %, 2 wt %, 3 wt %, etc

Fig 2.1 Metallic Die Used for Specimen Preparation

Fig 2.2 Composite Specimen for Mechanical Testing filled with Graphite & TiO_2

III. EXPERIMENTATION

3.1 Experimental Procedure

3.1.1 Details of sample prepare

Specimen	Epoxy Matrix (%)	Reinforcement (%)	Graphite (%)	TiO_2 (%)
C1	50	50	3	0
C2	49	50	3	1
C4	47	50	3	3
C5	46	50	3	4
C6	45	50	3	5
C7	44	50	3	6
C8	43	50	3	7

3.2 Experimental Results

3.2.1 Effect of filler loading on Density

The density of the specimen is taken randomly through the length of the specimen. It is evident from Table 3.1 that density of the composite increases as the wt % of filler goes on increasing. The density of the bare polymer is 1.068 g/cc. The density of the composite increased upto 1.083 g/cc. But beyond 4 wt % filler specimen density goes on decreasing due to the void formation.

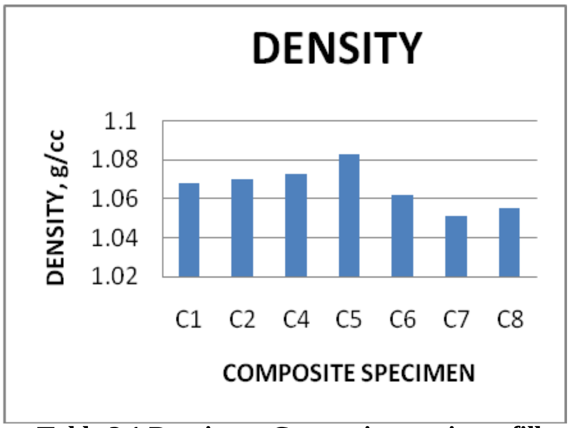

Table 3.1 Density vs Composite specimen filler content in wt %

3.2.2 Effect of filler loading on Hardness

Shore D Hardness test is used to measure hardness. Values are recorded as shown in graph. It can be seen that in all test specimen wt % of the Graphite is kept constant i.e 3 wt % of the Graphite only wt % of TiO_2 is changed. As the wt % of the TiO_2 is increased, hardness is increased upto 5 wt %. But after that as the wt % of the TiO_2 increased hardness reduced.

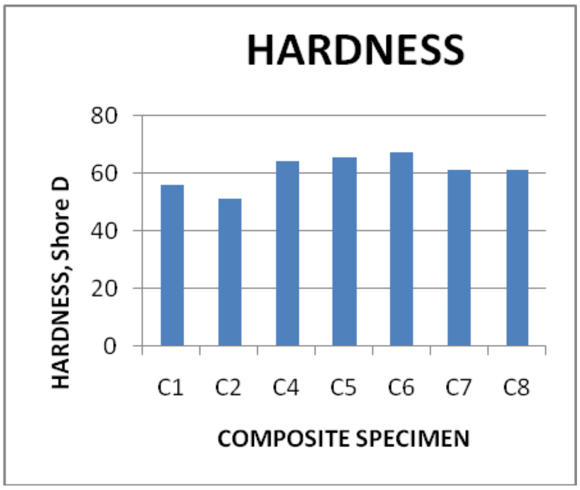

Table 3.2 Hardness vs Composite specimen filler content in wt %

3.2.3 Effect of filler loading on Tensile Strength

Tensile strength of the composite specimen was evaluated & test results for the epoxy composites filled with Graphite & TiO_2 are presented on Table 4.3. The standard specimen size as per ASTM D 638 is 165mm × 12.7mm ×7.5mm±.5mm. Tensile strength of the bare polymer is 15.3957 MPa. Polymer having the higher tensile strength is 24.3151 MPa. As the filler TiO_2 wt % increased, tensile strength also increased. While we consider other properties, C6 specimen gives optimum tensile strength.

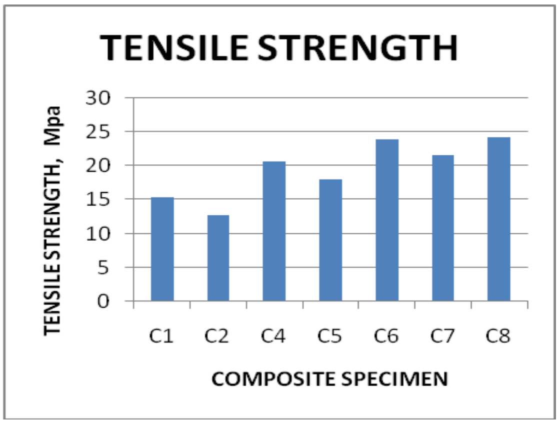

Table 3.3 Tensile strength vs Composite specimen filler content in wt %

3.2.4 Effect of filler loading on Flexural Strength

In this study flexural strength of the Graphite & TiO_2 filled epoxy composite was measured with respect to filler content. The standard specimen size as per ASTM D is 200mm × 25mm ×7.5mm±.5mm . The study reveals that flexural strength increases from C1 to C5 as shown in Table 3.4 Specimen C5 gives maximum & optimum value of flexural strength 21.93MPa. When wt % of the TiO_2 increased, flexural strength of the specimen reduced due to the weak van der Waal bonds.

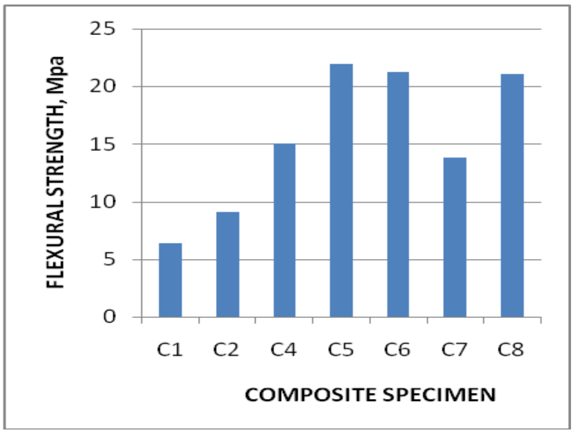

Table 3.4 Flexural strength vs Composite specimen filler content in wt %

3.2.5 Effect of filler loading on Impact Strength

It was evident from the Table 3.5 that Impact strength of the bare polymer is 214.7 MPa. Impact strength of the bare polymer is higher compare to the other specimen. As wt % of the TiO_2 increases impact strength of the specimen decreases. It is due to the aggregation effect of matrix.

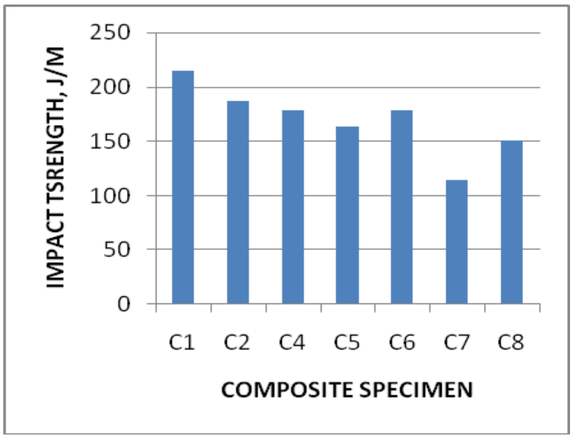

Table 3.5 Impact strength vs Composite specimen filler content in wt %

IV. RESULT & DISCUSSION

Sr No.	Composite Specimen (wt %)	Tensile Strength (MPa)	Impact Strength (J/M)	Flexural Strength (MPa)	Density (g/cc)	Hardness Shore D
1	C1	15.3957	214.7	6.37134	1.068	56.1
2	C2	12.7227	186.6	9.06103	1.070	51.5
4	C4	20.6217	178.2	15.0741	1.073	64.3
5	C5	18.0895	163.9	21.9257	1.083	65.7
6	C6	24.0037	178.0	21.2659	1.062	67.5
7	C7	21.5429	114.3	13.8316	1.051	61.3
8	C8	24.3151	150.9	21.0953	1.055	61.5

Table 4.1 Mechanical Properties vs Composite specimen

The modification of the mechanical properties of polymer by combined action of TiO_2 & Graphite as solid lubricant has shown promising results & has been subject of considerable interests. Addition of graphite has significant effect on the alteration of mechanical properties. Polymer composites play an important role due to its property light in weight, low cost, ease in manufacturing. Graphite can be used as solid lubricant where external lubrication is practically not feasible.

With the addition of constant 3.0 wt % of Graphite filler has significant effect on mechanical behavior of composite. Graphite effectively reinforce epoxy matrix & modify its property from brittle to tough. Toughening effect also causes an improvement in the modulus of the matrix. This same effect contributed in the improvement in the energy absorption characteristics of the epoxy. Interfacial adhesion between filler & matrix is strong which leads to an effective load transfer between matrixes to the reinforcement. Strong interaction is responsible for improvement in the tensile & flexural strength. Matrix filler interaction depends on effective load transfer& distribution of filler particle in the matrix. It can be concluded that toughening of the matrix, effective filler matrix interaction effective load transfer play vital role to enhancing mechanical properties.

If there is further addition of Graphite i.e 6 wt % or 9 wt %, it deteriorates the mechanical property. Uneven dispersion & distribution of graphite particle create stress concentration & voids. This cause delamination of matrix from fiber at higher load. Due to uneven dispersion where pressure applied on the surface early release of the agglomerated zones from the composite surface. There is greater extent of the wear loss & early damage to fiber take place.

TiO_2 is conventional filler material & is used extensively for developing new material. It has strong potential & used in combination with Graphite. In this study reinforcement of TiO_2 particulate in epoxy resin has shown encouraging result in terms of the mechanical properties.

The table 4.1 indicates the mechanical properties of the developed composite. It can be observed that density of the composite specimen increased marginally upto specimen C5 i.e. 4 wt % of the TiO_2 compared to the other specimen. Density of the composites depends on the relative properties of the matrix & reinforcing material & this is one of the important factors determining the properties of composite. The void content is the cause for difference between values of the density & theoretical calculated one Void significantly affect the some of the mechanical property even the performance of the composite in the places of use.

The knowledge of the void content is desirable for estimation of quality of composite. It is understandable that good composites should have fewer voids. The composite under present investigation i.e upto 4 wt % of the TiO_2 posses very less voids & can thus be termed as good composite. After further addition of TiO_2 density of the composite decreased. From this it is clear that TiO_2 & Graphite have contributed to the density of the epoxy composite.

Addition of 5% of the TiO_2 has moderately improved the hardness of the composite specimen; at this stage it gives better result. At 6 wt % & 7 wt % of TiO_2 it gives lower hardness compare to the other specimen. To avoid the alteration of the mechanical properties of epoxy composite 3 wt % of graphite kept constant.

The tensile strength properties in current study have shown different trend with addition of the fillers. As the wt % of the TiO_2 increased tensile strength of the specimen also increased. There may be possibility of two reasons one is that chemical reaction at the interface between the filler & matrix may be too strong to transfer the tensile stresses & another is that there is no any stress concentration in the epoxy matrix. At 7 wt % of the TiO_2, it gives better result so that there is constant improvement in tensile strength with the addition of TiO_2.

The table 4.1 indicates that impact strength of bare polymer is 214.7 J/M & further addition wt % of TiO_2 reduces the impact strength due to the aggregation effect of the particles into the matrix .At 6 wt % of TiO_2 gives lower impact strength i.e. 114.3 J/M .

The flexural strength of the epoxy resin laminates increases on addition of 3 wt % of the graphite. A further increase in Graphite filler content reduces the inter laminar shear strength. Flexural strength of the bare polymer is 6.37 MPa but when the filler TiO_2 is mixed with the resin then the flexural strength goes on increasing upto 4 wt %. Beyond 5 wt % flexural strength decreases due to the van der Waals bond which is weak one.

V. CONCLUSIONS

The mechanical properties of the epoxy composite filled with Graphite & TiO_2 were studied & following conclusions were drawn

- Densities of the composites are improved upto addition 4 wt % of TiO_2 & at constant 3 wt % of Graphite. Highest density achieved at C5 specimen & further it reduces.
- Highest hardness is achieved at 5 wt % of TiO_2 & at constant 3 wt% of Graphite. Further addition of TiO_2 hardness of C7 & C8 reduces.
- As wt % of TiO_2 increases Tensile strength of the composite also increases.
- Impact strength of the bare polymer is 214 J/M which is maximum & further addition of wt % of TiO_2 it reduces.

Flexural strength of the composite is maximum at 4 wt % of TiO_2 & at constant 3 wt% of Graphite. Further addition wt % of TiO_2, flexural strength gradually decreases.

From the above conclusion, it is observed that composite specimen C6 (Graphite 3 wt % & TiO_2 5 wt %) shows better result.

REFERENCES

[1]. S. Basavarajappa, S. Ellangovan, K.V.Aruns "Studies on dry sliding wear behavior of Graphite filled glass-epoxy composites." *Journal on Materials & Design 30 (2009)* 2670-2675.

[2]. B.Shivamurthy, K. Udaya, S. Anandhan "Mechanical & sliding wear properties of multi-layered laminates from glass fabric/graphite/epoxy composites." *Journal on Materials & Design 44 (2013)* 136-143.

[3]. Siddhartha, Amar Patnaik, Amba D Bhatta "Mechanical & dry sliding wear characterization of epoxy-TiO2 particulate filled functionally graded composites materials using Taguchi design of experiment." *Journal on Materials & Design 32 (2011)* 615-627.

[4]. M Sudheer, K Hemnath, K Raju, Thirumaleshwara Bhat "Enhanced Mechanical & Wear Performance of Epoxy/ glass composites with PTW / Graphite Hybrid Fillers." *3rd International Conference on Materials Processing & Characterization (ICMPC 2014) Procedia Materials Science 6 (2014)* 975-987.

[5]. Farah T Mohammed, Noori, Nadia Abbas Ali & Ekram A Al ajaj "Comparison study of wear & hardness of EP/nano & micro TiO2 composites." *International Journal of Application or Innovation in Engineering & Management (IJAIEM) Volume 2, Issue 3, March 2013 ISSN* 2319 – 4847

[6]. Ikram A Al-Ajaj, Muhannad M Abd & Harith I Jaffer "Mechanical Properties of Micro & Nano TiO2/Epoxy Composites." *International Journal of Mining, Mechanical Engineering (IJMMME) Volume 1, Issue 2 (2013) ISSN* 2320-4060.

[7]. Hamad A. Al –Turaif "Effect of TiO2 surface treatment on the mechanical properties of cured epoxy resin." *J. Coat Technol Res 8 (6)* 727-733, 2011.

[8]. S Manjunath Yadav, S.Basavarajappa, Chakrasali Chandrakumar, K V Arun " The effect of filler on the friction performance of automotive brake friction materials" *Journal of Engineering Research & Studies E-ISSN* 0976-7916

[9]. Shraddha Singh, V K Srivastava, Rajiv Prakash "Influences of carbon nanofillers on mechanical performance of epoxy resin polymer." *Appl Nanosci (2015) 5:* 305-313

[10]. Labeed K Al-Fadhli, Muhammed A Muhammed, Prof.Dr.Hadi S Al-Lami " The Effect of adding Alumina & Graphite particles to improve the mechanical properties of composites " *University of Nahrin (2008)*

C P Ramdasi, et. al. " Study of Mechanical properties of Epoxy composites filled with Graphite & TiO2." *International Journal of Engineering Research and Applications (IJERA)*, vol.11 (2), 2021, pp 49-54.