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Development of Epoxy Based Composites Filled With Boron Carbide (B_4C), Tungsten Disulphide (WS_2) and Evaluation of its Mechanical Properties

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Abstract

Polymer and their composite have been used as an alternative to metal and its alloys in engineering applications due to its advantages like high strength to weight ratio, stiffness to weight ratio, light weight, high performance, eco-friendly, wear & corrosion resistant material. Aim of this study is to investigate the mechanical properties of Epoxy based composite. Epoxy Resin (AW 106) & Hardener (HV 953 IN) have been used with varying amounts of fillers Boron Carbide (B_4C) & Tungsten Disulphide (WS_2) in weight %. The mechanical properties such as hardness, flexural strength, tensile strength, impact strength & density were tested. The results were encouraging with the increase in filler content the hardness and tensile strength were increased upto 2.5 wt% B_4C and 4 wt% WS_2. All the specimens were tested as per ASTM standards.

Keywords: Epoxy Resin, Boron Carbide (B_4C), Tungsten Disulphide (WS_2), Mechanical Properties.

INTRODUCTION

In the present era, epoxy resins, a type of thermoset material is used extensively in structural & other light weight applications because it have unique combination of properties like high strength to weight ratio & high stiffness to weight ratio. Epoxy offer high strength, low shrinkage, excellent adhesion to various substrates, effective electrical insulation, low cost & low toxicity. Epoxy resins are commonly used as adhesives, casting material, coating, potting compound & binders. The mechanical properties of Epoxy resins can be improved by adding filler materials & used in the variety of engineering applications such as gears, cams, wheels, brakes, clutches in automotive industry and also in aerospace, mining, agriculture sectors. The selection of filler depends upon the requirements and demands of the final product.

The present study involves an experimental investigation of improving the mechanical properties of Epoxy based composites by addition of particulate fillers Boron Carbide (B_4C) & Tungsten Disulphide (WS_2).

Vijay B R et al. (2016) [1] have carried out a study on mechanical characterization of carbon fiber reinforced epoxy composites with and without Molybdenum Disulphide (MoS_2) filler. They found that carbon fiber reinforced epoxy composite with 8% MoS_2 additives showed the least flexural strength and modulus whereas the one with 4% of MoS_2 filler indicated maximum value of flexural strength.

D Sarvanan et al. (2015) [2] have evaluated mechanical properties of Boron Carbide (B_4C) filled glass epoxy composite. From the experimental study they found that with addition of Boron Carbide filler increased the tensile strength where as a little deviation of yield strength. Glass epoxy composite exhibited lower weight loss in addition of B_4C & dropped further by increasing the content of filler material.

Najwa et al. (2015) [3] have conducted Charpy Impact test for SiO_2 (nano/micro) particles/epoxy composites. From result they found that Impact strength of EP/SiO_2 nanocomposites was increased with increasing volume fractions of SiO_2 nanoparticles in random manner. They noticed that the Impact strength reach to maximum value (20.11KJ/m^2) at 3 vol % of SiO_2 nanoparticle. Impact strength of EP/SiO_2Microcomposite decrease with increasing volume fraction of SiO_2 microparticles at high concentration

J. S. Sidhu et al. (2014) [4] have carried out a study on Epoxy Composite (ARL 136 + AH 126) filled with Tungsten Disulphide (WS_2) as filler. They found that the appropriately cured sample gave excellent mechanical properties. The tensile strength of composite increased with increase in filler content for the range of filler content (2.5 - 4 vol %) and decreased with increase in filler content 5 vol %. onwards. The result indicated that at 3 vol % of filler concentration the tensile strength obtained is good with moderate density & hardness.

Ramesh K. Nayak et al. (2014) [5] have conducted experimental investigation to study the effect of epoxy modifiers (Al_2O_3/SiO_2/TiO_2) on mechanical performance of epoxy/glass fiber hybrid composites. They observed that mechanical properties like flexural strength, flexural modulus are more in case of SiO_2 modified epoxy composite compare to other micro modifiers. Alumina modified epoxy increase the hardness and impact energy compare to other modifiers.

V. Fiore et al. (2014) [6] have investigated the feasibility of using natural and inexpensive filler obtained by grinding the culms of Arundo Donax as reinforcement of epoxy resins. The static mechanical characterization showed that the composite exhibits higher tensile moduli, comparable flexural moduli and lower strength properties compared to neat resin.

Mukul Kant Paliwal et al. (2012) [7] have carried out an experimental investigation on epoxy based composite filled with Calcium Carbonate ($CaCO_3$). They found that as the weight fraction increases the tensile strength of the composite increases rapidly and as the filler content increases tensile strength of the composite decreases.

A study on mechanical properties of epoxy resin-fly ash composites was carried out by Manoj Singla et al. (2010) [8] from experimental results they found compressive strength increased with increase in fly ash particles. After reinforcing glass fibre both compressive & impact strength has been increased due to energy absorbed in fibre pull out.

MATERIALS & METHODS

Materials:

A) Epoxy Resin and Hardener

Epoxy Resin AW 106 with hardener HV 953 IN is a multipurpose, two component, room temperature curing, paste adhesive of high strength and toughness. It is suitable for bonding a variety of materials including metal, ceramic, plastic and wood. It is product of Huntsman International (India) Pvt. Ltd. & was purchased from M/s. M. K. hardware Nanded, Maharashtra, India. Properties of the resin and hardener are shown in Table 1.

Table 1: Properties of Epoxy Resin AW 106 and Hardener HV 953 IN used in the present study

Property	**Test method**	**AW 106 Resin**	**HV 953 IN Hardener**	**Mix**
Color	Visual	Neutral	Pale yellow	Pale yellow
Specific Gravity	ASTM D-792	1.15	0.95	1.05
Viscosity at 25^0C	ASTM D-2393	30-50	20-35	30-45
Shelf life	--------	2 years	2 years	-------

B) Tungsten Disulphide:

It is the chemical compound with the formula WS_2. It occurs naturally as the rare mineral tungstenite. Tungsten Disulfide (WS2) is a low friction dry lubricant coating that improves performance and service life better than other dry lubricants by reducing friction, improving mold release, and solving problems of excessive wear, seizing, galling and fretting. With Coefficient of Friction at 0.03, it offers excellent dry lubricity unmatched to any other substance. It can also be used in high temperature and high pressure applications. It offers temperature resistance from -450 °F (-270 °C) to 1200 °F (650 °C) in normal atmosphere and from -305 °F (-188 °C) to 2400 °F (1316 °C) in Vacuum.

Tungsten disulphide (WS_2) powder having particle size of 4 micron is supplied by M/s Sajan Overseas, Vatva, GIDC, Gujrat, India. Properties of the WS_2 used in the present study shown in Table 2.

Table 2: Properties of WS_2 used in the present study

Properties	**Tungsten disulphide (WS_2)**
Color	Silver grey
Appearance	Crystalline solid
Melting point	1250 °C
Boiling point	1260 °C
Density	7500 Kg/m^3
Molecular weight	248 g/mol
Coefficient of friction	0.03 Dynamic ; 0.07 Static
Chemical Durability	Inert substance, Non-toxic
Hardness	30HRc

C) Boron Carbide (B_4C):

Boron Carbide (B_4C) is the third hardest material after Diamond and cubic boron nitride. It is ceramic which is used mainly as abrasive and wear-resistant products, in lightweight composite materials, and in control rods for nuclear power generation. As an abrasive, it is used in powdered form in the lapping (fine abrading) of metal and ceramic products, though its low oxidation temperature of 400–500 °C (750–930 °F) makes it unable to withstand the heat of grinding hardened tool steels. Because of its hardness, together with its very low density, it has found application as a reinforcing agent for aluminum in military armor and high-performance bicycles.

Boron carbide (B_4C) is supplied by M/s Gannon Norton Metal & Tools, Delhi, India. In the present study Boron Carbide powder with mesh size 1500 is used. B_4C used in the present study have properties shown in Table3.

Table 3: Properties of B_4C used in the present study

Properties	**Boron Carbide (B_4C)**
Color	Black
Appearance	Crystalline solid
Melting point	2,763 °C
Boiling point	3500 °C
Density	2.52g/cm^3
Molecular Weight	55.25 g/mol
Knoop Hardness	2750 kg/mm^2
Thermal Conductivity	28 W/m-K @ 30 °C
Specific Gravity	2.1

Methods:

Stir casting method is used for the specimen preparation, as it is simple method. In this process, Epoxy resin & Hardener are poured in the ratio 100:90 by weight in glass beaker. The required composition of filler was mixed in a solution of Epoxy resin & Hardener, and then stirred gently to form homogeneous solution at room temperature. While stirring care was taken that air bubbles should not entrap in the solution.

Specimens were prepared in mould die of dimensions 200 mm length X 25mm width X 8mm thickness shown in fig. 1. Die was sprayed with silicon based release agent to facilitate easy removal of specimens. After pouring solution in mould, it is kept in an electric furnace shown in fig.2 with controlled temperature of 150 °C for 45 minutes. The cured specimens were removed from the mould.

Fig 1: Metallic Die used for specimen Preparation

Fig 2: Furnace used in the present study

The above procedure was followed to prepare specimen of different compositions which are mentioned in the Table 4.

Table 4: Details of Composite specimens prepared

Composition	**Matrix (Wt%)**	**B_4C Filler (Wt %)**	**WS_2 Filler (Wt %)**
C1	97.5	0.5%	2%
C2	96.5	1%	2.5%
C3	95.5	1.5%	3%
C4	94.5	2%	3.5%
C5	93.5	2.5%	4%
C6	92.5	3%	4.5%

Fig 3: Prepared specimens for the present study

EXPERIMENTAL RESULTS:

The prepared specimens were tested at M/s Central Institute of Plastic Engineering and Technology (CIPET), Aurangabad, Maharashtra (India) according to ASTM standards. The Mechanical properties such as Hardness, Flexural Strength, Tensile Strength, Impact Strength & Density were tested.

(a) Density is a characteristic property of a substance. The density of a substance is the relationship between the mass of the substance and how much space it takes up (volume). Density of composites was determined by using a high precision weigh balance as per ASTM D792.

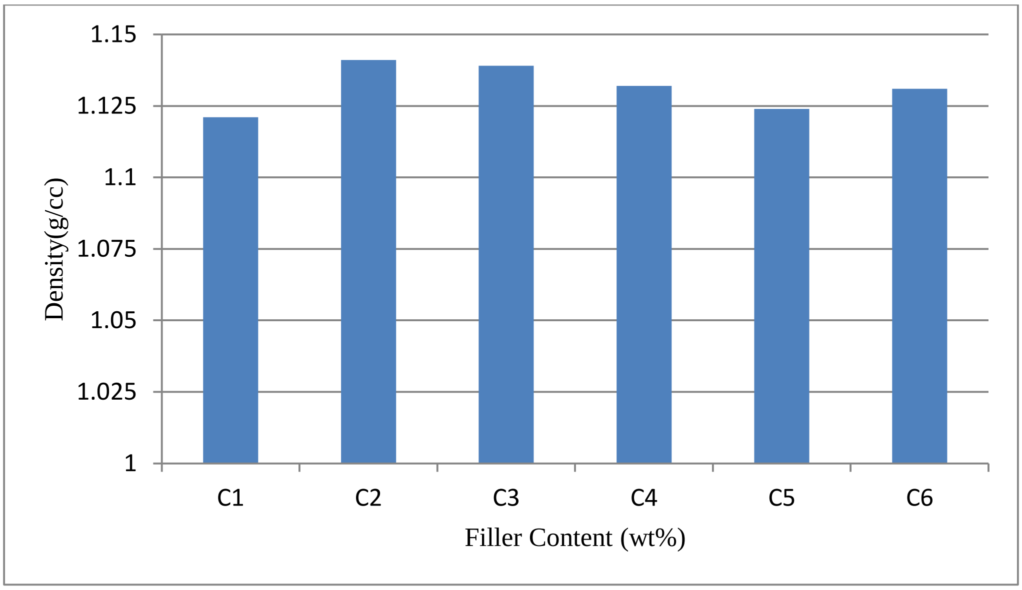

Fig 4: Density Vs Filler Content

The Figure 4 shows that with the addition of B_4C & WS_2, it is observed that there is slight variation in density value. Among all specimens the highest value for density is for specimen C2 i.e. 1.141 g/cc.

(b) Hardness is the property of material which enables it to resist penetration, abrasion, indentation. The hardness is measured by using Shore D hardness test. The Specimen was placed under the indenter & pressure is applied such that indenter will make the contact with specimen. This Test was conducted as per ASTM D2240 at 25°C.

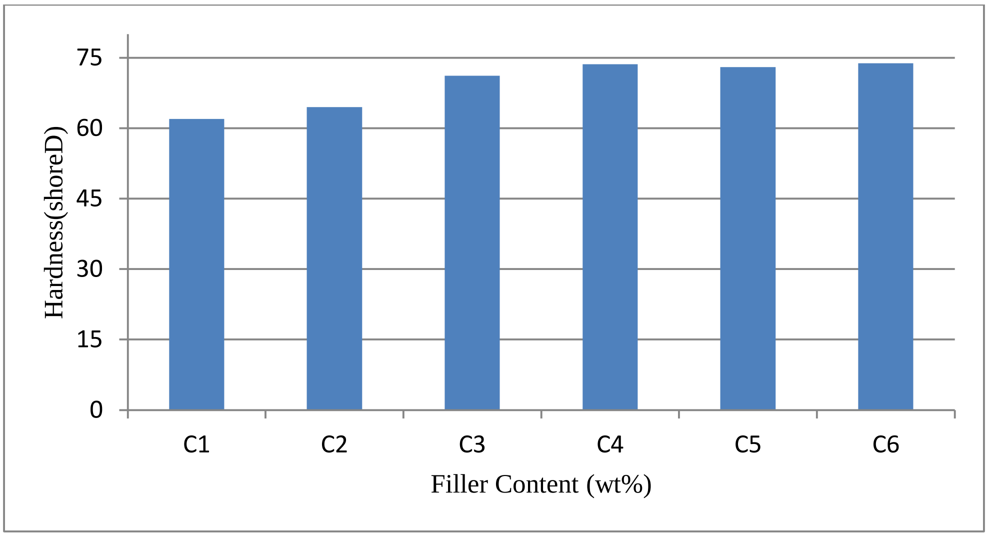

Fig 5: Hardness Vs Filler Content

The hardness is measured by using the Durometer tester. The variation in the hardness values is different composites is shown in figure 5. From the figure 5 it is seen that as percentage of filler increases the hardness increases. Increased hardness can be attributed to presence of B_4C particulate filler. The maximum value for Hardness obtained for specimen C6 (B_4C 3 wt% & WS_2 4.5 wt%). With further increase in filler content the hardness gradually decreases not shown here, as it is not discussed.

(c) Tensile strength is the ability of a material to withstand a pulling (tensile) force. It is customarily measured in units of force per cross-sectional area. The ability to resist breaking under tensile stress is one of the most important and widely measured properties of materials used in structural applications. Tensile test was conducted on Universal Testing Machine (UTM) using ASTM D638 standards.

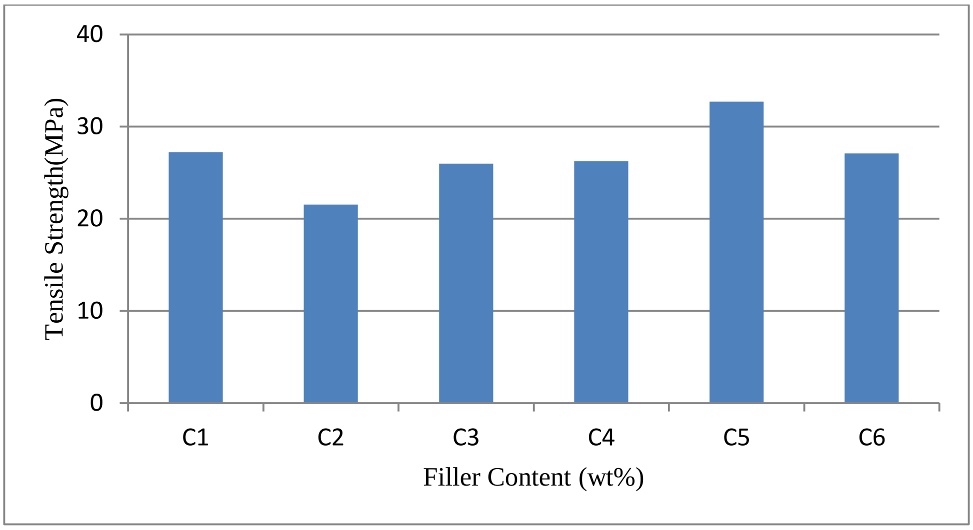

Fig 6: Tensile Strength Vs Filler Content

Figure 6 shows gradual increase in the tensile strength as the filler content increases. This is also in confirmation to the trend of hardness shown in figure 5. But upto C5 (2.5 wt% and 4 wt%) the tensile strength have shown an upward trend. Beyond C5 the filler percentage increases and resin probably cannot hold the fillers, hence tensile strength decreases.

(d) Flexural strength defined as the stress in a material just before it yields in a flexural test. It represents highest stress experienced within the material at its moments of rupture. The Flexural Strength tests were performed using three point bending method according to ASTM D790.

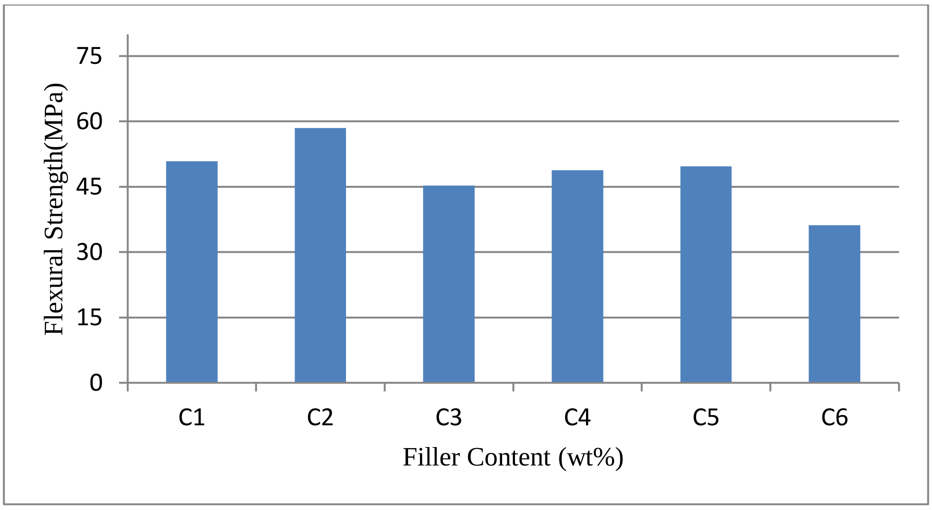

Fig 7: Flexural Strength Vs Filler Content

From figure 7, it is observed that with the increase in filler content the flexural strength of the composite goes on decreasing. It is because the hardness and brittleness increases. The maximum flexural strength is seen for C2, i.e. 1 wt% B_4C and 2.5 wt% WS_2.

(e) Impact strength as used in studying the toughness of material. A material's toughness is a factor of its ability to absorb energy during plastic deformation. The instrument used for impact test is Izod Impact Tester. The Tests are done as per ASTM D256 standards.

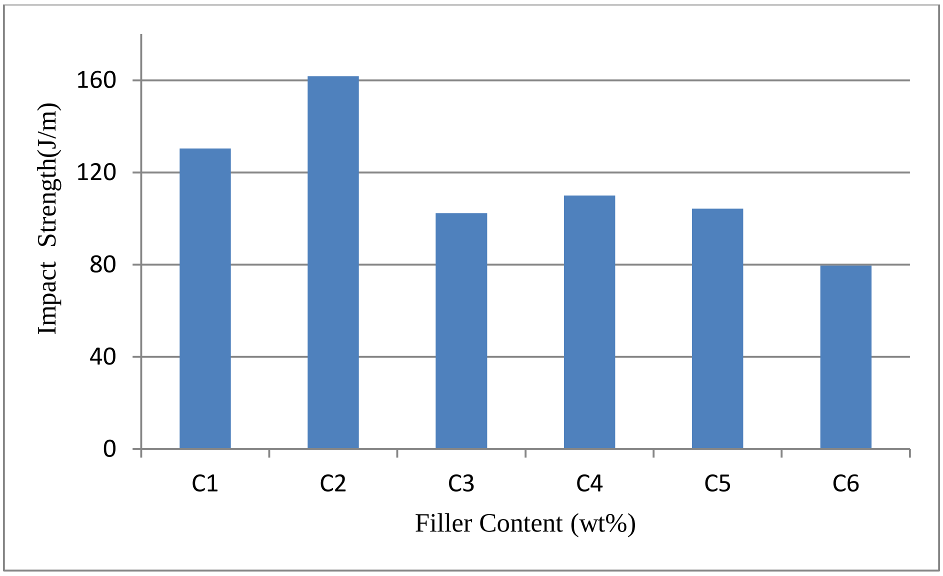

Fig 8: Impact Strength Vs Filler Content

The results obtained from the test, showed in figure 8, it shows with increasing the filler content of B_4C & WS_2, there is decrease in impact strength. This is due to the fact that hardness increases with increase in filler content. The specimen C2 has maximum impact strength & then it decreases gradually.

DISCUSSIONS

From the analysis it was found that, as hardness of the composite increases gradually the other properties like Tensile strength, Flexural Strength & Impact Strength are varying. The relation between Hardness & Tensile Strength were revealed as hardness increases tensile strength also increases up to a Composition C5 but thereafter tensile strength is decreasing with increasing hardness. Probably the cause of the fact that material is becoming more and more brittle; which can also be verified from decreasing trend of flexural strength and impact strength.

CONCLUSION

From the experimental study of mechanical properties of Epoxy based Composites filled with B_4C & WS_2 brings about the following conclusions

1) Hardness increases linearly with increase in percentage of filler & it is maximum with a value of 73.8 for composition C6
2) Tensile Strength increases as filler % increases. The maximum Tensile Strength obtained was 32.69 MPa.
3) Flexural strength decreases with the increase in filler content. The maximum flexural strength is for composite C2 58.50 MPa.
4) Impact strength of the composites goes on decreasing with increase in filler percentage.
5) The composition between C3 to C5 seems to show some visible desirable changes in properties of the composite i.e. 1.5 wt% B_4C and 3 wt% WS_2 to 2.5 wt% B_4C and 4 wt% WS_2. In this range a suitable Engineering application of the composite can be suggested after study.

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