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STUDY OF MECHANICAL PROPERTIES OF EPOXY BASED COMPOSITES FILLED WITH h-BN & SiC

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ABSTRACT

The aim of this present work is to study the effect of h-BN & SiC on the mechanical properties of epoxy composites. SiC is the wear resistant material which is one of the most commonly used ceramic materials. The epoxy composites filled with h-BN (0.2 wt% to 0.8 wt %) & SiC (7 wt % to 13 wt %) have been prepared by using the stir casting method. These composites were experimented to carry out tests hardness, tensile strength, flexural strength, impact strength, & density. It was found that the presence of h-BN & SiC show the improvement in density, hardness where as impact strength decreases & flexural strength decreases up to C4 (0.5 wt% of h-BN & 10 wt% of SiC) then afterward increases.

As far as tensile strength is concerned C4 has maximum tensile strength & beyond that if fillers are increased tensile strength falls. Finally it has been concluded that among all composites C4 composite with 0.5 wt% of h-BN & 10 wt% of SiC gives the significant results than other composites.

Keywords: Hexagonal Boron Nitride, Epoxy, Silicon Carbide, Mechanical properties.

I. INTRODUCTION

Engineering polymers have been widely used in the aerospace field, industrial field, defence, marine applications etc. Epoxy is a strong adhesive material which is used to stick things together with strong bonding. The polymer & their compositions with other materials have found the number of applications such as seals, bearing materials, cams, gears, rollers, wheels, clutches & transmission belts. The big advantage of polymer composites is the ease of processing, productivity, cost reduction, high strength light weight etc. over metallic materials.

Amal Nassar (2014) [1] studied the mechanical properties of epoxy composites filled with SiC & it resulted into increase in mechanical properties with increase in SiC fine particulate filler content up to 10 wt% where as further addition of SiC beyond 10 wt %, mechanical properties deteriorate. The investigation studied by Sidhu J.S. et. al. (2014) [2] on "Mechanical characterization of WS_2 reinforced epoxy composites". It was found that as percentage of WS_2 filler increases the hardness, density & tensile strength (up to 3 vol%) increases & came to conclusion that polymer composites are suitable for engineering components assigned to wearing environment which can be successfully prepared by filling micro tungsten disulphide. Suresh J.S. (2017) [3] studied on mechanical properties of epoxy modified with TiO_2 & SiC and results show that mechanical properties are improved by filler materials. Hardness increases with increase in wt% of TiO_2 & SiC fillers. Impact strength increases up to composite reinforced with 5 wt% SiC and then after decreases. Sarbjit singh (2018) [4] studied "Effect of reinforced SiC particulates of different grit size on mechanical and tribological properties of hybrid polymer matrix composite". It was found that the tensile strength can increases by 20 % on addition of SiC fine particles. Tensile strength is directly proportional to weight fraction of SiC & inversely proportional to grit size. The 220 grit size SiC assisted composite is superior in terms of resistance against wear rate & also superior in tensile strength. Amal Nassar (2013) [5] studied on mechanical properties of epoxy polymer reinforced with Nano SiC particles & results indicate that the tensile strength & young's modulus increases up to 5 wt% of SiC then after decreases. And the wear resistant of unreinforced polymer increases with increase in wt % of SiC with counterface against which they slide. Mechanical strength & wear resistance of the composite increases up to 10 wt % of SiC. Dongju Lee (2013) [6] investigated the influence of surface modification on the mechanical properties of epoxy h-Bn nano-flakes (BNNF) & results showed that the incorporation of non-covalently functionalized BNNF into epoxy resin yields on elastic modulus of 3.34 GPa & 71.9 MPa ultimate tensile strength at 0.3 wt% & toughening enhancement is as high as 107%

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compared to value of neat epoxy. Wenying Zhous, et. al. (2013) [7] studied on thermal, electrical and mechanical properties of hexagonal bororn nitride reinforced epoxy composites & results show that increase in h-BN particles concentration increased both the tensile strength & flexural modulus of the composites within the range of 0 wt% - 19 wt% only. The mechanical strength & toughness of the composites decreased with increase in the h-BN concentration. Haiyan Yan (2013) [8] studied on enhanced thermal-mechanical properties of polymer composites with hybrid boron nitride nano-fillers & results show that the composites have 95% increase in thermal conductivity & 57% improvement in young's modulus by addition of 1 wt% BNNT's-BNNS's. Kamble V.N. et. al. (2016) [9] investigated on mechanical properties of epoxy based composites reinforced with particle/particulate fillers AL_2O_3 & Talc results show that density increases with increase in Talc wt % where as tensile strength of bare polymer C0(0 wt% Talc & 0 wt% Al_2O_3) is higher than all other composites & Impact strength decreases with increases in AL_2O_3 wt% which is very hard. Hardness increases as AL_2O_3 wt % increases. S.Muhummad Firadaus (2015) [10] studied on properties of nano sized synthetic Diamond (SD) & boron nitride filled with epoxy resin & results show that both SD & BN fillers filled D431 (where D431 is penchem that is matrix material). Epoxy composites have higher flexural strength those of E8281 epoxy composites. In short 4 wt% of synthetic diamond (SD) & BN fillers filled D431 epoxy composites show much flexural strength modulus. Till now, there are no available released reports & publication considering the h-BN & SiC filled epoxy composites. Hence in this work, study of the mechanical properties of epoxy composites filled with h-BN & SiC were carried out.

II. MATERIALS AND METHODS

2.1 Materials

In this present work the matrix material system is epoxy resin (Araldite AW 106) & the hardener (HV 953 IN). The fillers are hexagonal boron nitride (h-BN) as solid lubricant & SiC (Silicon Carbide) as wear resistant material. Hexagonal boron nitride (h-BN) of an average size of 5 microns & Silicon carbide of mesh size 325 provided by M/s. Pareshwamni metals, Mumbai, Maharashtra, India. & Epoxy resin AW 106 & hardener HV 953 IN have been purchased at M.K. Hardware, Nanded, Maharashtra, India.

The detailed properties of the matrix materials & fillers selected for the present work are listed below.

2.1.1 **Epoxy Resin AW 106 & Hardener HV 953 IN**

Table-2.1: Properties of epoxy resin AW 106 & hardener HV 953 IN

Property	Test method	Epoxy AW 106	Hardener HV 953 IN	Mix
Color	Visual	Neutral	Pale yellow	Pale yellow
Specific gravity	ASTMD 792	1.15	0.95	1.05
Viscosity at 25^0 C.	ASTMD 2393	30-50	20-35	30-45
Shelf life	-----	2 yrs	2 yrs	----

2.1.2 Hexagonal Boron Nitride (h-BN) and Silicon Carbide (SiC)

Table-2.2: Properties of h-BN

Properties	Description of h-BN
Color	White
Density	2.1 g/cm3
Heat capacity	19.7 J/k.mol

Melting point	2973 deg. Celsius
Particle size	5 microns
Form	Powder
Purity	99.98 %
R.I.	1.8

Table-2.3: Properties of SiC

Properties	Description of SiC
Color	Black
Density	3.21 g/cm3
Melting point	2730 deg. Celsius
Purity	99.92 %
Form	Powder
Particle size	326 mesh
Hardness	9 Mohr

2.2 Methods

The technique used to synthesize the composites is a simple stir casting. The epoxy resin (AW 106) & its hardener (HV 953 IN) which is of low temperature curing epoxy are mixed in the ratio of 100:80 by volume. After their proper mixing with h-BN & SiC of different weight percentage are mixed with epoxy resin. The mixed composite is then stirred thoroughly into the liquid epoxy resin taking care of no introduction of air bubbles & the even dispersion of the fillers. Ensuring the homogeneous mixing then the mixture is poured into a metallic mold cavity fig.1 coated with a silicon based released agent called Silicon Spray (mold releasing agent) used for plastic, supplied by Dipa enterprises, Ahmednagar, Maharashtra. to get specimens of size 200 mm in length, 25 mm in width & 8 mm in thickness as shown in fig.2

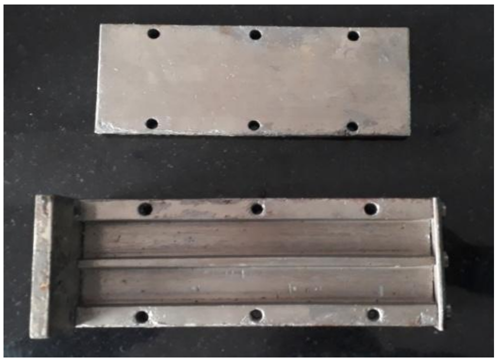

Figure 1: Metallic Die Used For Specimen Preparation

Figure 2: Composite Specimen For Mechanical Testing Filled With SiC & h-BN

When the mould get fully filled then placed in an electric furnace & heated at a constant temperature of 100^0 C for 45 minutes for curing and upon curing the mould is opened to release specimen from the mold carefully and allow the specimens for post curing at room temperature further for 30 minutes. The composite specimens prepared for mechanical properties testing are made up of the different percentages of SiC & h-BN as shown in the table 2.4.

Table-2.4: Composite specimens prepared for present study

Sr. No.	Composites	Epoxy Wt. %	Silicon Carbide Wt. %	Hexagonal Boron Nitride Wt %
1	C 0	100	0	0
2	C 1	92.98	7	0.2
3	C 2	91.97	8	0.3
4	C 3	90.60	9	0.4
5	C 4	89.50	10	0.5
6	C 5	88.94	11	0.6
7	C 6	87.93	12	0.7
8	C 7	86.20	13	0.8

III. EXPERIMENTATION

All the specimens were tested at Central Institute Of Plastic Engineering & Technology, Aurangabad, Maharashtra, India. and the parameters tested are Density, Hardness, Tensile Strength, Impact Strength & Flexural Strength.

Hardness of the composites was tested by "Barcol Hardness Method" as per standard ASTMD 2583. Impact strength was carried out by IZOD/ CHARPY impact tester (Timus-olsen-USA) as per ASTMD 256 of specimen size (63.5 mm X 12.7mm X 7.5mm). Density of composite was tested by using high precision weigh balance (Meltler-Toledo-Switzerland) as per ASTMD 792. Universal Testing Machine (UTM) (Shimadzu- Japan) in accordance with ASTMD 638 of specimen size 165mm X 12.7mm X 7.5mm has been used to measure tensile strength. Flexural Strength was measured by UTM (Shimdzu-Japan) of specimen size 200mm X 25mm X 7.5mm as per ASTMD 7.

3.1 Experimental Results

3.1.1 Effect of fillers loading on hardness

Barcol Hardness method as per standard ASTMD 2583 has been used to measure the hardness. The recorded values are given in fig.3. It has been noticed that the presence of SiC increases the hardness & the hardness of specimen goes on increasing as the weight percentage of SiC increases. Here in present work maximum hardness is found to be with C7 (13 wt% of SiC & 0.8 wt% of h-BN) equals to 30 (Barcol hardness).

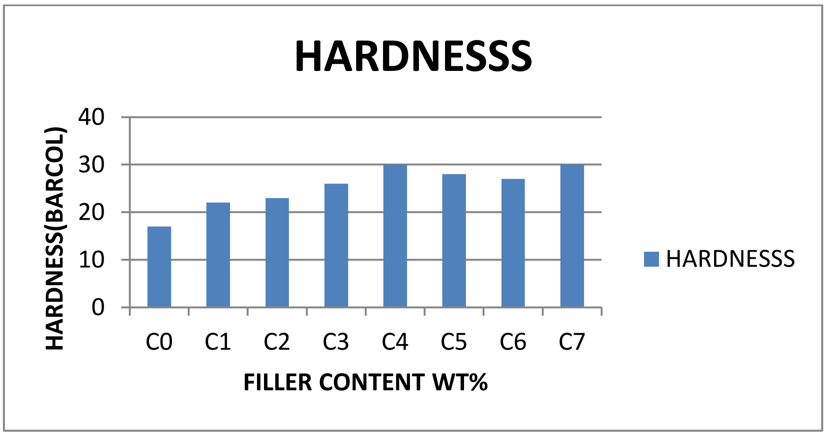

Fig.-3: Hardness Vs Filler Content Wt %

3.1.2 Effect of fillers loading on impact strength

For impact strength there is a fact that as hardness increases, toughness goes on decreasing as material becomes more & more brittle. Here in the present work, it has been found that with increase in filler content, hardness goes on increasing which is favorable change expected.

Bare polymer (0 wt % of SiC & 0 wt % of h-BN) has the maximum toughness of 3.4 KJ/m^2 which is gradually goes on decreasing with increase in hardness. The standard specimen size as per ASTMD 256 is 63.5mm X 12.7mm X 7.5mm.

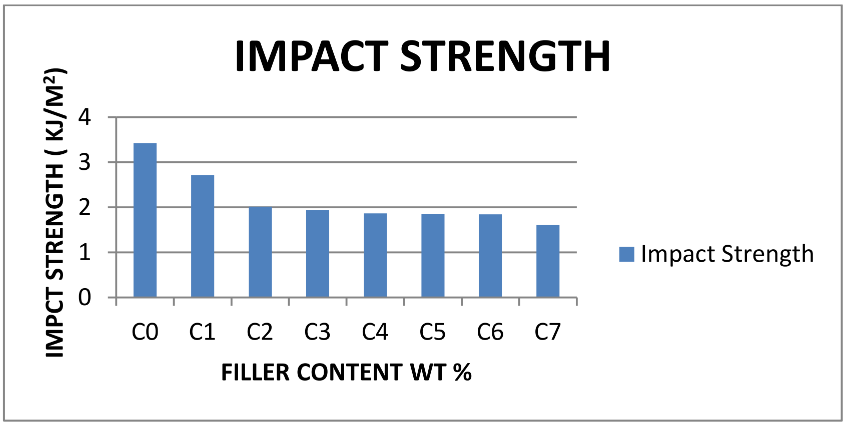

Fig.-4. Impact Strength Vs Filler Content Wt %

3.1.3 Effect of fillers on Density

The measured densities of all the specimens are listed in below figure 5. As per ASTMD 792. Density increases with increase in of filler content weight percentage. In present work, we have got results that density of specimens increases gradually up to composite C7 (13 wt% of SiC & 0.8 wt% of h-BN) with value of 1.15 g/cm^3. Except C5 which is noise reading

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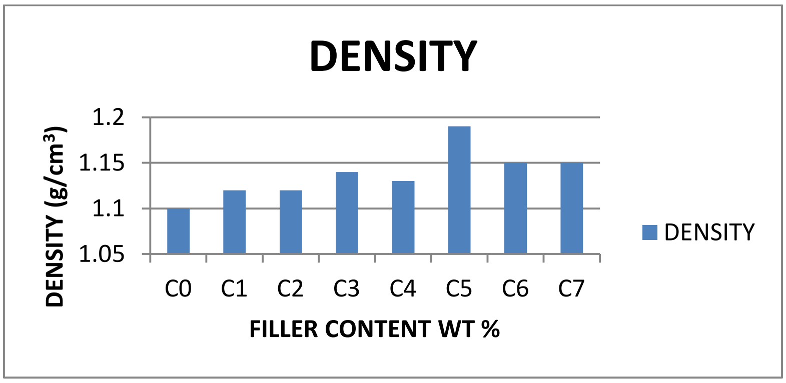


Fig.-5: Density Vs Filler Content Wt %

3.1.4 Effect of fillers loading on tensile strength

As far as tensile strength is concerned, tensile strength increases with increase in filler content wt% up to C4 (10 wt% of SiC & 0.5 wt% of h-BN) with value of 17 N/mm^2. After which as the filler content wt% increases the hardness turns into brittle one. And hence, its tensile strength decreases as shown in fig. 6

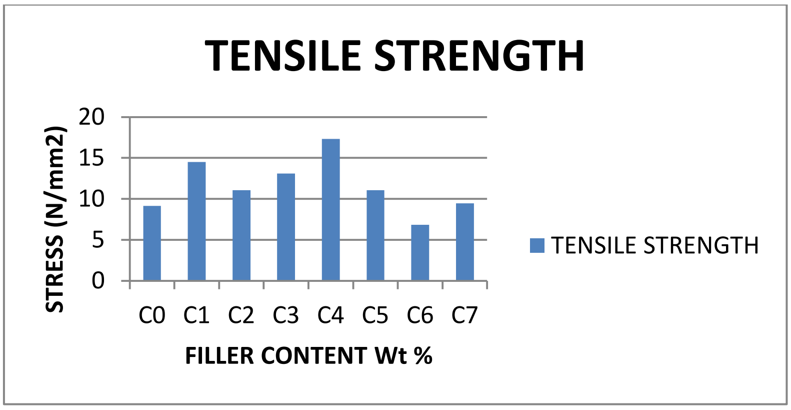


Fig.-6: Tensile strength Vs Filler Content Wt %

The specimen size as per ASTMD 638 is 165mm X 12.7mm X 7.5mm.
Tensile strength of C0 = 9 N/mm^2, Tensile strength of C4 = 17 N/mm^2, Tensile strength of C7 = 9.43 N/mm^2

3.1.5 Effect of fillers loading on Flexural strength

In the present work the flexural strength of the SiC & h-BN filled polymer composite was measured with respect to filler content. The standard specimen size as per ASTMD 790 is 127mm X 12.7mm X 7.5mm. As far as flexural strength is concerned it decreases from C0 to C4.

The minimum value of flexural strength at C4=36 N/mm^2 (10 wt% of SiC & 0.8 wt% of h-BN) & the maximum value of flexural strength is at C0=69 N/mm^2 & then after it increases from C4 to C7. The value of flexural strength at C7=56.62 N/mm^2. As shown in fig.

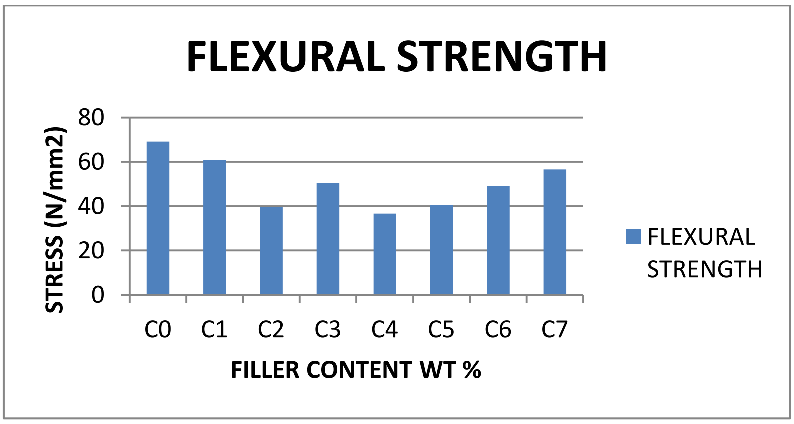


Fig.-7: Flexural Strength Vs Filler Content Wt %

3.1.6 Comparative chart of properties

The study of the composites reveals that inclusion of any particulate filler has strong influence on the mechanical properties of composites. The modified values of the properties of the composites under this investigation are presented in table 3.1.

Table-3.1: -Mechanical Properties of Epoxy Composites Filled with h-BN and SiC.

Sr. No.	Composites (Wt %)	Tensile strength (Mpa)	Flexural strength (Mpa)	Impact strength (KJ/M^2)	Density (g/cm^3)	Hardness (Barcol).
1.	C0	9.15	69.05	3.42	1.10	17
2.	C1	14.49	60.82	2.71	1.12	22
3.	C2	11.07	39.61	2.01	1.12	23
4.	C3	13.10	50.29	1.93	1.14	26
5.	**C4**	**17.32**	**36.68**	**1.86**	**1.13**	**30**
6.	C5	11.05	40.59	1.85	1.19	28
7.	C6	6.83	49.12	1.84	1.15	27
8.	C7	9.43	56.62	1.61	1.15	30

Overall, from the above study C4 composite filled with h-BN of 0.5 Wt % and SiC of 10 Wt % shows the significant results with all round balance of mechanical properties with further research, it can be put to appropriate industrial applications.

IV. RESULTS AND DISCUSSION

Hardness of the composite increased with increase in particulate filler content weight percentage. It has been seen that the SiC (Silicon Carbide) filler increases the hardness of the specimen. Actually as the filler content increases the number of particulates increases hence, result in the dense matrix with uniform dispersion which shows the high hardness. Impact strength (toughness) of bare polymer C0 is 3.4 KJ/m^2. Which happens to decrease with increase in composition of composites. After C0 (bare polymer) with addition of fillers results show that there is decrease in toughness. This is due to higher filler content which occupied the interstitial volume of matrix result in enhancement of hardness and reduction in impact strength.

Density of composites is one of the most important factors determining the properties of the composites ex., hardness, toughness and tensile strength etc. Density of composites depends on the relative proportion of matrix & reinforcing materials. Difference in densities of all composites is nothing but measure of voids & pores present in the composites. The presence of voids significantly affects the numerous mechanical properties & also the performance. Higher void contents usually mean lower fatigue resistance, greater susceptibility to water penetration and weathering. The knowledge of void content is desirable for estimation of the quality of the composites. It is understandable that a good composite should have fewer voids. However, presence of void is unavoidable in composite made by stir casting method. Here the density of C0 (Bare polymer) is C0 = 1.10 g/cm^3 & the density of C7 = 1.15 g/cm^3. As such with change in composition there is no appreciable change in density seen. Density readings of C5 seems to have some noise.

Tensile strength of bare polymer is C0 = 9 N/mm^2 & the tensile strength of C4 = 17 N/mm^2. Which is found to be maximum. Here in this test, it clearly shows that tensile strength increases as hardness increases up to C4 after which it falls down. This is because as increase in filler content the composite turns into brittle one. Flexural strength of the composites found experimentally by the bend test. Here in this present work, it decreases from C0 to C4 & then increases from C4 to C7. C4 composite gives good flexural strength and tensile strength.

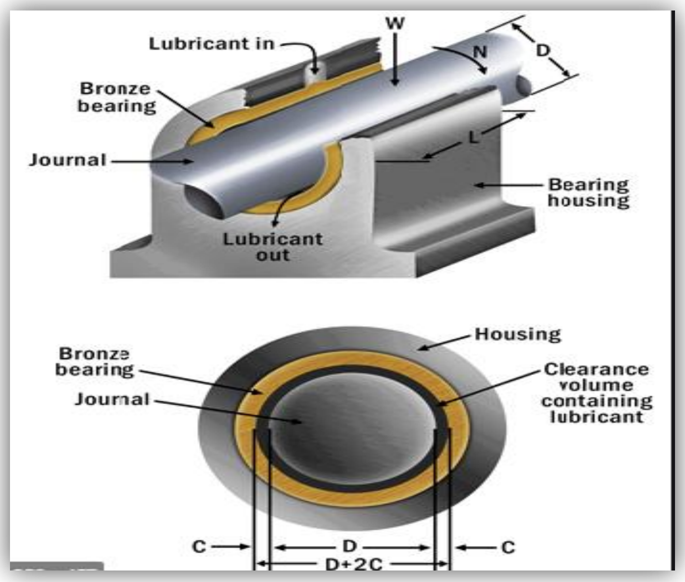
V. APPLICATIONS OF THE SYNTHESIZED COMPOSITE

1) Gears:

Gears demand the various properties for smooth operation such as lubricity & wear resistant properties against wearing. Also it can be more beneficial if its weight gets reduce and all this possible by means of synthesized composites formed into gear which is lighter in weight and also rustproof. In present work we have used SiC which is wear resistant material and h-BN which is solid lubricant responsible for self lubrications of gears. These gears find suitable applications in clocks, food processing machinery, various toys, chemical processing machinery, paper processing machinery etc.

2) Journal Bearing:

Journal bearings have been widely used to support high speed rotating machinery such as turbines & compressors. Metallic journal bearing requires external supply of lubricating oils where as if we use epoxy based composite prepared in present work satisfies wear resistant properties & also provide the self lubrication which is possible by the fillers used in this work. Thes journal bearings find suitable applications in Centrifugal pump, Centrifugal compressor, Crankshaft etc.

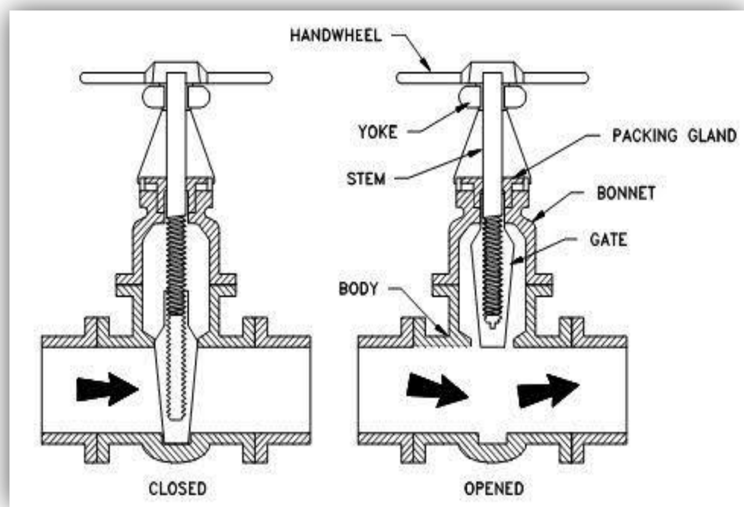


3) Stuffing Box Gland:

Stuffing box is an assembly which is used to house gland seal aim to avoid the leakage of the fluid, such as stem or water through rotating or reciprocating shaft against fluid. A gland is general type of stuffing box. These are used in Gate valve, Steam engine etc.

A gate valve known as sluice valve which opens by lifting round or rectangle gate valve from the path of fluid by rotating the wheel in anti-clockwise direction. The main functions of valve are:

a. To shut off the flow of fluid.
b. To keep the constant direction of the fluid.
c. To regulate flow rate and pressure of the fluid.



If epoxy base composite material of SiC and h-BN material used in gate valve as gland packing in stuffing box we will get following advantages

1. No chemical reaction.
2. Antifriction properties increase because highly resistant material MoS_2 used in it.

3. In composite material, in this MoS_2 as self-lubricating property so never use other lubricant material like grease etc.
4. In this composite material use ZrO_2material so increase strength of material.
5. Easy handling and smooth working in operation.

So above properties are in epoxy based ZrO_2 and MoS_2 composite material use replace by gland packing, there are no scratches on shaft and to avoid leakage of fluid.

VI. CONCLUSION

Study of mechanical properties of epoxy composites filled with SiC & h-BN were carried out & the following conclusions were drawn.

- Hardness of the composites increases gradually & the higher hardness obtained at C7 = 30 by Barcol hardness method. C7 containing 13 wt % SiC & 0.8 wt % of h-BN. This is the effect of SiC because of sufficient matrix material to support.
- Toughness of the composites goes on reducing with increase in percentage of SiC which is very hard & that is the reason why hardness of composite increased & impact strength gets reduce.
- Flexural strength reduced from C0 to C4, C4 has the good balance of mechanical properties among all composites.
- Tensile strength of C4 composite is higher than that of other composites.
- Density of composite is increased due to the inclusion of fillers. Higher density is at C7 = 1.15 g/cm^3 & of bare polymer is C0 = 1.10 g/cm^3.

From all, it has been found that composite C4 with 10 wt% of SiC & 0.5 wt% of h-BN shows the significant good results.

FUTURE SCOPE

a) Future scholars have wide scope to explore this area of research

b) Further tribological studies of the synthesized components can be done.

c) In future, this study can be extended to new hybrid composites using other potential fillers and the results of experimental findings can be similarly analyzed.

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