

# “THE EFFECT OF ALUMINA AND TITANIA ON THE MECHANICAL PROPERTIES OF EPOXY RESIN”

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**Abstract-** *The study is done to find out the behavior of epoxy matrix composite made by using raw material of resin and hardener with alumina ( $Al_2O_3$ ) and titania ( $TiO_2$ ). To improve the various mechanical properties of polymer fillers may be used. Various compositions by weight of alumina and titania with epoxy were prepared by stir casting. The effect of alumina and titania on hardness, microstructure, compressive and impact properties were studied in details. Hardness is tested on Vickers hardness testing machine, compaction is tested on UTM, and impact is tested by I-ZOD testing.*

*The presented work in this thesis includes study of two different problems of natural fiber composites:*

- a) *A study of favorable mechanical properties of fillers in thermosetting matrix composite.*
- b) *An experimental analysis of mechanical potential of fillers reinforced composite.*

*The result show that the compressive strength of the foam was decreased from 215.6 MPa (for pure resin) to 170.67 MPa (for 15 weight% alumina) and 166.66 MPa (for 15 weight % titania). The hardness strength of the foam was increased from 242 MPa to 255 MPa (for 10 weight % alumina) and 260 MPa (for 10 weight % titania). The lowest values of hardness strength were found minimum in 15 weight % in both compositions, which was still greater than pure resin.*

**Keywords:** Epoxy matrix composite, stir casting, alumina and titania as filler material,

**1. INTRODUCTION:** Over the last thirty years composite materials, plastics and ceramics have been the established emerging materials. The volume and numbers of applications of composite materials have developed progressively, penetrating and conquering new markets persistently. Modern composite materials establish a significant proportion of the engineered materials market ranging from daily products to sophisticated niche applications.

A composite is therefore a synergistic combination of two or more micro-constituents that are distinct at macroscopic or microscopic level within the finished structure. Our central objective is to take advantage of the superior properties of both materials without compromising the adverse effects.

Composites have already proven their worth as weight-saving materials; the current challenge is to make them cost effective. The hard work to produce economically attractive composite components has resulted in numerous innovative manufacturing techniques currently being used in the composites industry. The composites industry has begun to recognize that the commercial applications of composites promise to offer much larger business opportunities than the aerospace sector due to the sheer size of transportation industry.

Due to the low-cost and enhanced chemical resistance and ability to make bond to the epoxy matrix, the alumina particles are drawing significant attention for nano-scale polymer reinforcement. The miss alignment of the fibers within the matrix causes the shear instability in compressive mode of failure, also the compressive strength drastically reduced [1], [2]. Stephen et al. has reported that compression loading for fiber reinforced composite leads to 3-diamemnsional states of stress, and the compression strength improved under pressure [3].

A composite material is defined as a material system consists of a mixture or a combination of two or more different materials which are insoluble in each other and differ in form or chemical composition. Hence composites are arrangement of two materials in which one of the materials called reinforcing phase is in the form of fiber sheets or particles and are embedded in other materials called the matrix phase. Composites are made by combining two or more natural or artificial materials to exploit their useful properties and minimize their flaws. Composites are typically used in place of metals because they are equally strong but much lighter.

**2. LITERRATURE REVIEW-** Winsom M.R. [4] reported that Due to the lower cost and better chemical resistance and ability to make bond to the epoxy matrix, the alumina particles are drawing significant attention for nano-scale polymer reinforcement.

Vlasveld D.P.N. [5] reported that at the higher temperatures the particle impregnated fiber reinforced composites shows the improvement in compressive and flexural strength. This may be due to supplementary supports provided through the nano particles to the fiber against kinking.

The microscopic study by Srivastava et al. [6] has confirmed that the shear mode of failure of fibers is major in compressive loading, which then direct to matrix crack and absolute failure of the composite.

Ph Viot et. al. [7] studied the effect of the strain rate and density on dynamic behavior of syntactic foam. Author observed that the volume fraction of glass sphere plays major role in compressive characteristics like compressive modulus and compressive strength. An increase in strain rate was increasing compressive modulus and compressive strength.

Witold Brostow et.al[8] Studied Brittleness of materials: implications for composites and a relation to impact strength authors observe that brittleness of polymer composite may change by adding of ceramic particle. It totally depends on the particle distribution filler matrix adhesion and the amount of filler added and may increase or decrease.

### 3. EXPERIMENTAL PROCEDURE

#### 3.1 MATERIALS USED:

**RAW MATERIALS:** Raw materials used in this experiment are:

- i. Epoxy resin
- ii. Hardener
- iii. Alumina powder
- iv. Titania powder

**3.1.1 Epoxy resin:** Epoxy resin (Araldite LY 556) having the following outstanding properties has been used.

- i. Outstanding adhesion to different materials
- ii. Abundant strength, toughness resistance
- iii. terrific resistance to chemical attack and to moisture
- iv. Brilliant mechanical and electrical properties
- v. Odorless, tasteless and completely nontoxic
- vi. Insignificant shrinkage.

**3.1.2 Hardener:** In the present work Hardener (araldite) HY 951 is used. This has a viscosity of 10-20 poise at 250°C.

**3.1.3 Alumina:** Alumina is one of the most cost effective and widely used materials in the family of engineering ceramics. And the reason for choosing alumina for the present is given as following:

#### Key points

- Hard, wear resistant,
- Resists strong acid and alkali attack at elevated temperatures
- Good thermal conductivity
- Excellent size and shape capability
- High strength and stiffness.

**3.1.4 Titania :** Titanium dioxide, also known as titanium (IV) oxide or titania, is the naturally occurring oxide of titanium, chemical formula  $TiO_2$ . **Titania is regarded as one of the hardest materials/composites.**

**3.2 SAMPLE PREPARATION:** The low temperature curing epoxy resin (LY 556) and corresponding hardener (HY951) supplied by Cloudtail India Private Limited, are mixed in a ratio of 10:2 by weight as recommended. Alumina and titania with average size of 100  $\mu m$  are reinforced in the epoxy resin to prepare the composite. Calculated amount of epoxy, hardener was weighed first and was taken in a plastic beaker. The solution was then mixed by manual stirring using a glass rod till small amount of heat was released; this release of heat is an indication of exothermic reaction between hardener (i.e. catalyst) and epoxy that leads to cross-linking of polymers. After that required amount of filler was added gently to the resin-hardener mixture. Enough care was taken during the slow manual stirring. Gentle mechanical stirring was continued for 12-15 min to ensure uniform distribution of filler in the resin matrix.

With the increase in filler content, the viscosity also increases and the resin- filler mixture has putty like consistency. Beyond (15 weight %) of filler (maximum weight percentage used in the present study), the viscosity of the mixture became so high, it was difficult to process it further. Composites of six different compositions (with 5% alumina, 10% alumina, 15% alumina, 5 % Titania, 10% Titania, 15% Titania by weight with respect to mixture of epoxy resin & hardener by weight) are prepared. The castings are left for 6 to 8 days to cure at room temperature and then samples are released by breaking the moulds.

**3.3 COMPRESSION TEST:** The test specimens were tested at room temperature and atmospheric circumstance in the **computerized universal tensile machine** supplied by **ENKAY ENTERPRISES**. The cross head speed of 1 mm/min. was maintained throughout the test. The average value of similar manner of three test results was taken in the analysis.

**3.4 HARDNESS TEST:** Hardness tests were conducted on **COMPUTERISED VICKERS HARDNESS TESTING MACHINE (Model: VM50-PC)** setup supplied by **FUEL INSTRUMENTS & ENGINEERS PVT. LTD.** was used. The basic principle, as with all common measures of hardness, is to observe the

ability of material to resist plastic deformation from a standard source.

**3.5 IMPACT TEST:** I-ZOD test is performed to evaluate the toughness of the material; the machine setup was supplied by ENKAY ENTERPRISES.

Specimen was made of standard size. This standard size was 10mm×10mm×75mm; the V notch was made at 28mm away (from any side) of the work piece of 7mm depth along the length.

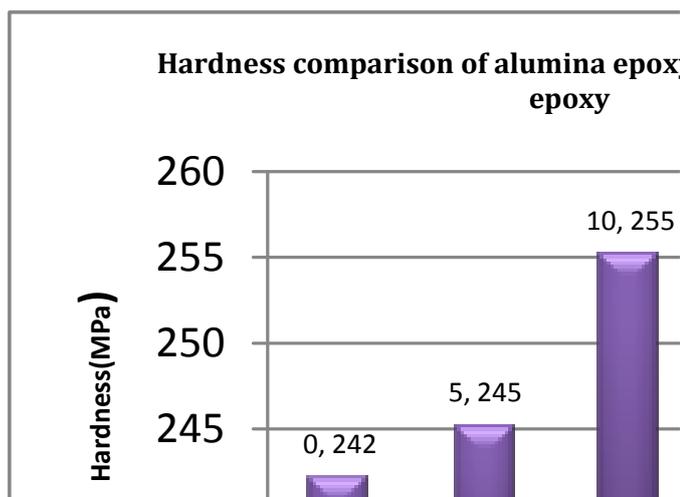
**4. RESULT AND DISCUSSION:**

**4.1 Hardness test of alumina reinforced epoxy:** reinforced sample with 10% weight fraction of fiber content, S<sub>3</sub> stands for filler(alumina) reinforced sample with 15%weight fraction of fiber content.

So by calculating the hardness strength of all samples it was found that S<sub>2</sub> has the highest hardness strength i.e., 255 MPa.

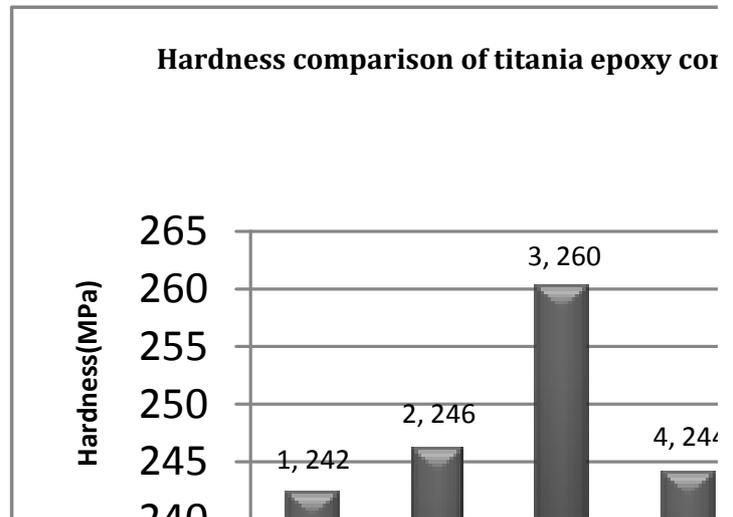
It is well known that fiber content and fiber strength are mainly responsible for strength properties of the composite. Therefore the variation in hardness strength of the S<sub>1</sub>, S<sub>2</sub>, and S<sub>3</sub> layer samples are presented in Table-4.1 and shown in fig 4.1 (a, b).

Although the Hardness of the syntactic foam was increased from 242 MPa (pure epoxy resin) to 255 MPa (10% weight of reinforcement). The lowest value of all compositions was found in 15%. Because beyond 10% the particles of fillers start agglomerated and due to this the bonding between filler material and matrix becomes weak and more pores are formed due to which its hardness decreases.



**Chart 4.1:** hardness comparison of alumina reinforced composite with pure epoxy

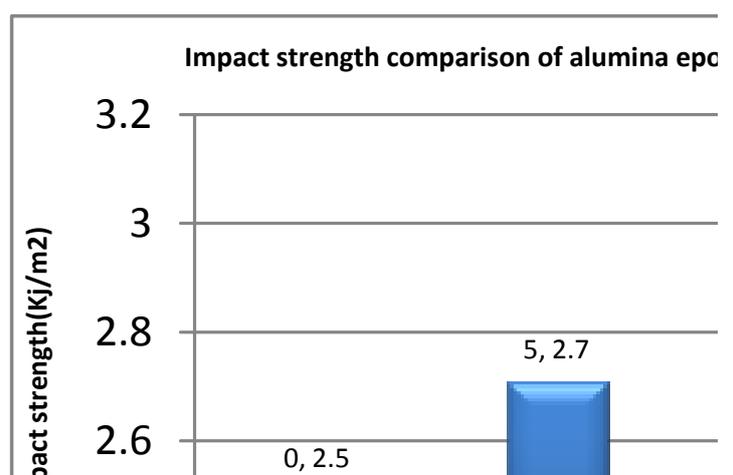
**4.2 Hardness test of titania reinforced epoxy:** All the specimens (composed of titania) were of circular shape of dimension (18 mm diameter & 35 mm length).



**Chart 4.2:** hardness comparison of titania reinforced composite with pure epoxy.

Although the Hardness of the syntactic foam was increased from 242 MPa (pure epoxy resin) to 260 MPa (10% weight of reinforcement). The lowest value of all compositions was found in 15%. Because beyond 10% the particles of fillers start agglomerated and due to this the bonding between filler material and matrix becomes weak and more pores are formed due to which its hardness decreases.

**4.3 Impact test of alumina reinforced epoxy:** All the specimens (composed of alumina) were of rectangular shape of dimension 75mm × 10mm × 10 mm.

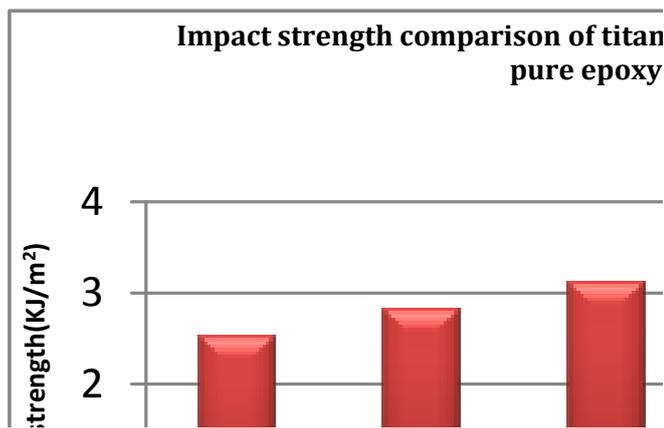


**Chart 4.3:** impact strength of alumina reinforced composite comparing with epoxy.

Above figure shows variation of impact strength by varying (weight %) of alumina reinforced composite. Impact strength of sample increasing little by little with raise in weight percentage of filler up to 5 weight % and increase

rapidly up to 10 weight % and start decreases for 15 weight %. The existence of filler particles in the epoxy matrix leads to several changes in the epoxy chains and their structures, where good distribution and dispersion of particles in epoxy matrix lead to reduction the mobility of the epoxy chains due to formation high immobility layer around each particles, while the matrix chains (epoxy chains not bonded to particles) bonded to that layer constrained the non-contact matrix chains, so the network of particles reduce the overall mobility of the composites system. The addition of Al<sub>2</sub>O<sub>3</sub> particles lead to shrink in space distance (reduce free space distance between epoxy chains) where the addition of Al<sub>2</sub>O<sub>3</sub> particles which are polar particles, lead to filling free space between chains and attract resin molecules and hence epoxy chains during curing processes creating more complicated network chains.

**4.4 Impact test of titania reinforced epoxy:** All the specimens (composed of titania) were of rectangular shape of dimension 75mm ×10mm ×10 mm.

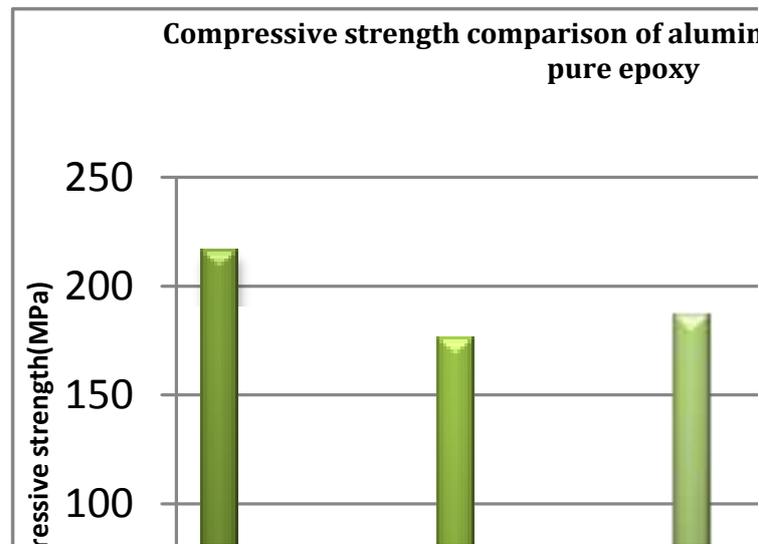


**Chart 4.4:** impact strength of titania reinforced composite comparing with epoxy.

Above figure shows variation of impact strength by varying (volume %) of alumina reinforced composite. Impact strength of sample increasing little by little with increase in volume percentage of filler up to 5 volume % and increase rapidly up to 10 volume % and start decreases for 15 volume %. The reason for this trend may be that the addition of titania particles lead to decrease in space distance and the bonding between the epoxy chain becomes weaker by consequence of which impact strength decreases.

**4.5 Compressive strength test of alumina reinforced epoxy**

All the specimens (composed of alumina) were of circular shape of dimension (18 mm diameter & 35 mm length).



**Fig4.5:** compressive strength of alumina reinforced composite comparing with epoxy.

Figure 4.5 shows the compressive strength of the particles, and fiber reinforced composite materials. The failure strength of the composites decreases with the incorporation of the reinforcing elements within the matrix of epoxy corresponds to a 5 to 10 weight % of filler addition. The lowest value of all compositions was found in 15 weight %. At 15weight % of alumina particle addition, the strength of the composites drops to 170.67 MPa. This drop in strength is due to the agglomeration of the nano particles and formation of air pockets which may be due to their higher surface energy to adhere among themselves.

**4.6 compaction (compressive) test of titania reinforced epoxy**

All the specimens (composed of titania) were of circular shape of dimension (18 mm diameter & 35 mm length).

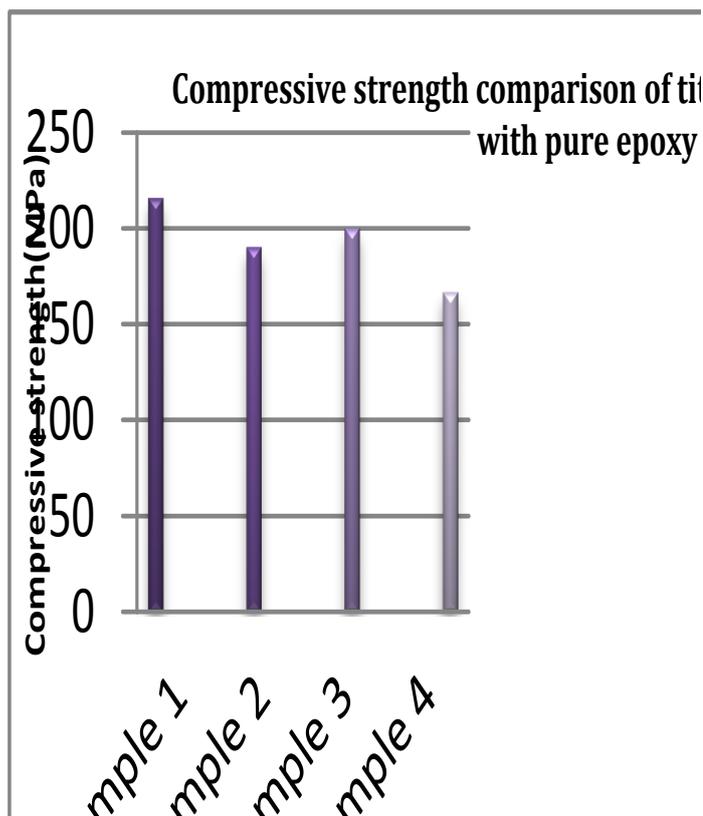


Fig4.6: compressive strength of titania reinforced composite comparing with epoxy.

Figure 4.6 shows the compressive strength of the particles, and fiber reinforced composite materials. The failure strength of the composites decreases with the incorporation of the reinforcing elements within the matrix of epoxy corresponds to a 5 to 10 weight % of titania addition. The lowest value of all compositions was found in 15 weight %. At 15 weight % of alumina particle addition, the strength of the composites drops to 170.67 MPa. This drop in strength is due to the agglomeration of the nano particles and formation of air pockets which may be due to their higher surface energy to adhere among themselves. With the increase in filler content the bonding between the resin and filler becomes weak due to this decrement occur.

**5. CONCLUSION:** The present experimental study on synthesis and mechanical properties of epoxy resin matrix based syntactic foam with varying weight percentages of alumina and titania reveals that,

1. The thermosetting resin (epoxy) matrix based syntactic foam with different weight percentages (0-15 weight %) of alumina and titania were successfully prepared by stir casting method. Beyond 15 weight % of alumina and titania, it was not possible to process the foam mixture due to very high viscosities.

2. Although the Hardness of the syntactic foam was increased from (242 MPa) (pure epoxy resin) to (255 MPa, in case of alumina & 260 MPa, in case of titania) 10% weight of reinforcement. The lowest value of all compositions was found in 15%. Because beyond 10% the particles of fillers start congregated and due to this the bonding between filler material and matrix becomes weak and more pores are formed due to which its hardness decreases.

3. The impact strength of the composition of alumina and titania were found more than pure epoxy. The impact strength was found max in 10% composition of both alumina and titania and found least in 15% composition. The existence of filler particles in the epoxy matrix leads to several changes in the epoxy chains and their structures, where good distribution and dispersion of particles in epoxy matrix lead to reduction the mobility of the epoxy chains due to formation high immobility layer around each particles, while the matrix chains (epoxy chains not bonded to particles) bonded to that layer constrained the non-contact matrix chains, so the network of particles reduce the overall mobility of the composites system. The addition of filler particles lead to decrease in space distance (reduce free space distance between epoxy chains) where the addition of filler particles which are polar particles, lead to filling free space between chains and attract resin molecules and hence epoxy chains during curing processes creating more complicated network chains.

4. The compressive strength of the composition of alumina and titania were found less than pure epoxy. The compressive strength was found minimum in 15% composition and maximum in 10 % composition (186.2 MPa, in case of alumina & 200 MPa, in case of titania) which is less than pure epoxy (215.6 MPa). This drop in strength is due to the agglomeration of the particles and formation of air pockets which may be due to their higher surface energy to adhere among themselves.

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