EVALUATION IN MECHANICAL PROPERTIES OF ALUMINIUM METAL MATRIX REINFORCED WITH TITANIUM DIOXIDE (TiO_2) COMPOSITE VIA STIR CASTING

1.Mithilesh Kumar Tiwari ,2. A.K. Jain, 3.Pranjal Sharma
1. Research Scholar, Department of mechanical engineering, JEC Jabalpur
2. Assistant professor Department of mechanical engineering, JEC Jabalpur
3. Research Scholar, Department of mechanical engineering, JEC Jabalpur

Abstract: Aluminium alloy materials found to be the best alternative with its unique capacity of designing the materials to give required properties. Aluminium alloy Metal Matrix Composites are gaining wide spread acceptance for automobile, industrial, and aerospace applications because of their low density, high strength and good structural rigidity. In this study metal matrix composite is fabricated through stir casting method. Titanium Oxide (TiO_2) is used as reinforcement for the present study. The Metal Matrix Composite is prepared with varying the TiO_2 volume fraction which is 4%, 8%, 12% and16%. Metal Matrix Composite is fabricated successfully through stir casting method and found that the mechanical properties of fabricated metal matrix composite materials like tensile strength, compressive and torsional strength of the metal matrix material found by using different experimental methods. The experimental results show that the tensile strength of the metal matrix composites is increasing with volume fraction of Titanium Dioxide. Similarly, compressive and torsional strength of Metal Matrix Composite are increasing with volume fraction of Titanium Dioxide.

Keywords: Aluminium , Tio_2, stir casting method, tensile strength, compressive strength, torsional strength.

1. Introduction:

There is a tremendous demand for advanced engineering materials with high strength, light weight, and increased resistance to wear in aerospace, civil and sliding components of automobile sectors. This leads to the development of aluminium matrix composites (AMCs). Aluminium is principally reinforced with hard phases such as Sic, Tic, TiB2 and Al2O3 and soft phases like graphite (Gr) and MoS_2.Aluminium metal matrix composite filled with nano particles featuring physical and mechanical properties very different from conventional metal. The nano particles can improve the base material in terms of Tensile strength, compressive strength, hardness, wear resistance, damping properties, porosity, corrosion resistance and mechanical properties. The Exploitation of reinforcement of nano particles on metal matrix depends on the type of primary and secondary processing, matrix composition, size, volume fraction, morphology of reinforcement and heat treatment. Among all the investigated nano particles reinforcement with Titanium dioxide was found to be most effective in enhancing the strength properties of Aluminum when incorporated via ingot metallurgy process.

Metal matrix composites have a high application potential in automotive engineering in braking systems, piston rods, piston pins, pistons, frames, valve spring caps, brake discs, disc brake caliper, brake pads, card a shaft etc. They have also found application in military and civil aviation in the area of axle tubes, reinforcements, blade and gear box casing, turbine, fan, and compressor blades. In the aerospace industry MMCs have been applied in frames, reinforcements, aerials, joining elements etc. Al-based metal matrix composites (MMCs) are well-known for their high- specific strength, hardness, and attractive tribological properties. The silicon carbide- reinforced aluminum composites are increasingly used as substitute materials for cylinder heads, liners, pistons, and brake disks in automobile industry. The main purpose of the particulate-reinforced metal matrix composite production is to obtain materials having high-wearing resistance, light weight, and high-specific strength in order to reduce the costs of technological applications and fuel consumption.

2. Experimental Procedure:

2.1. Materials and Method -

The matrix material in present study is Al. The reinforcing material selected is Titanium oxide TiO2 of different composition. The Titanium oxide is varied by 4%, 8%, 12% and 16% weight of Aluminium .The Aluminium alloy was used as the base matrix. This is melted at 585°C which is slightly more than 30°C above the liquids temperature. The reinforcing material used is TiO2 powder of 4%, weight of Aluminium . The stir casting technique is adopted to fabricate the specimens in which a stir casting is created in the melt of the matrix alloy through a mechanical stirrer coated with aluminate and rotating at 550 rpm. The composites are fabricated with 4-16 weight % of the TiO2 particle in steps of 2 weight %. The TiO2 particles are added to the melted Aluminium. Aluminium alloy is first preheated at 2000 for 2h before melting and TiO2 is added to melted material which improves the wetting properties by removing the absorbed hydroxide and other gases. The composite melt is thoroughly stirred. The composite slurry is then reheated to a fully liquid state and mechanical mixing is carried out for 20 min at 200 rpm average stirring speed. Finally, the composite slurry is poured in permanent metallic mould. The composites are then cast in permanent moulds. Al alloy composites containing various TiO2 contents, namely 4%, 8%, 12% and 16% by weight of Aluminium and similarly the composites are fabricated with 4-16 weight % of TiO2. The TiO2 particles are added to the melted Aluminium , were fabricated and tested and their properties. All tests are conducted in accordance with ASTM Standards. Tensile tests are performed at room temperature using a Tensile Testing Machine.

2.2 Experimental Setup:

Initially Al was melting with the help of Crucible furnace .The furnace was heated for the reinforcement materials as Sic and Tio_2 gradually raised the temperature up to 857 ^{0}C slightly more than the liquid temperature maintained at particular period of time. Vortex technique is used to disperse the reinforced matrix of Sic and Tio2 particle size 5- 30µm was used in FCC structure. This reinforcement material preheated at 200-350 ^{0}C of vortex was created to mix with the liquid metal at a rate of 150 g/min. To increase the wet ability of base material a small amount of ceramic was used. After the melting process, composite material has fully stirred and to create a good binding capacity. Totally four specimens are prepared along the cylindrical die. It was machined named by universal testing machine xxxx.

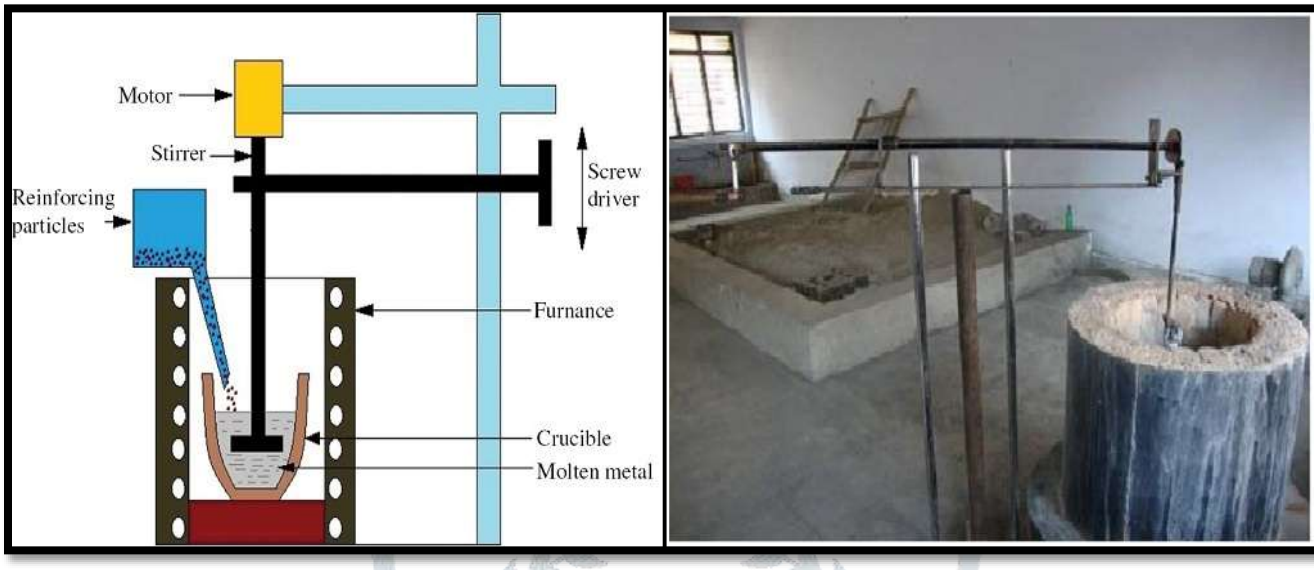

Fig.1: Open hearth furnace with stiring technology

3. Results and Discussions:

Various tests have been conducted on fabricated metal matrix composites samples to analyse the strength characteristics of aluminium / TiO2 metal matrix composite. Mechanical properties such as tensile strength, compressive strength and torsional strength have been determined on fabricated metal matrix composite. The tensile strength is carried out at room temperature on Tensile testing machine. Compressive strength is carried out at room temperature on Compressive testing machine. Torsion test is carried out on a hydraulic Torsion testing machine.

3.1. Tensile Strength:

For evaluating the tensile strength the five samples were taken which are reinforced with the different TiO_2 compositions they are –

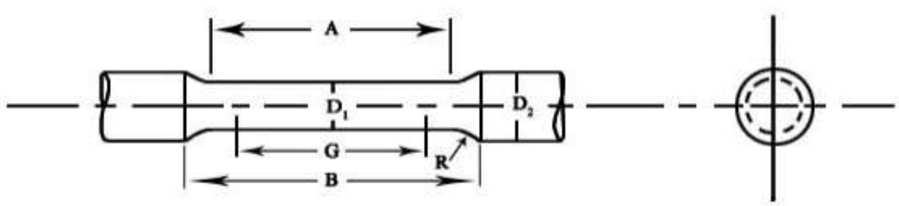

Fig.2: Tensile specimen

Guage length (G)= 7 mm , Distance between shoulders (B)=10mm,
Length of reduced section (A)=9mm, Diameter of reduced section (D_1)=14mm
Grip diameter(D_2)= 19mm, Radius of curvature (R)=4mm

Fig.3:Amsler tensile testing machine

1. Pure aluminum
2. Aluminium with 4% Tio_2
3. Aluminium with 8% Tio_2
4. Aluminium with 12% Tio_2
5. Aluminium with 16% Tio_2

The results show that the effect of TiO_2 content on tensile strength, compressive and Torsion strength of aluminium /TiO_2 metal matrix composite. Figure 1 clearly shows that the effect of TiO_2 content on tensile stress of aluminium alloy composites. It can see that as the TiO_2 content increases the tensile strength of the composite material increases monotonically by signification amount if other factors are kept constant. Increase in tensile strength is due to the uniform distribution of TiO2 particles and strong bonding with aluminium matrix.

Formulation:

$\sigma_t = P/A$

$A = (\pi/4)D^2 = 153.86\ mm^2$ (which is constant for all samples)

Where,

σ_t =Tensile strength(Mpa)

P=Load(TON)

A=Cross-section area(mm^2)

Therefore for

1. Sample (p_1)=1.568 TON, σ_{t1}=101.32 Mpa
2. Sample (p_2)=1.863 TON, σ_{T2}=121.33 Mpa
3. Sample (p_3)=2.264 TON, σ_{T3}=147.14 Mpa
4. Sample (p_4)=2.642 TON, σ_{T4}=171.71 Mpa
5. Sample (p_5)=3.263 TON, σ_{T5}=212.50 Mpa

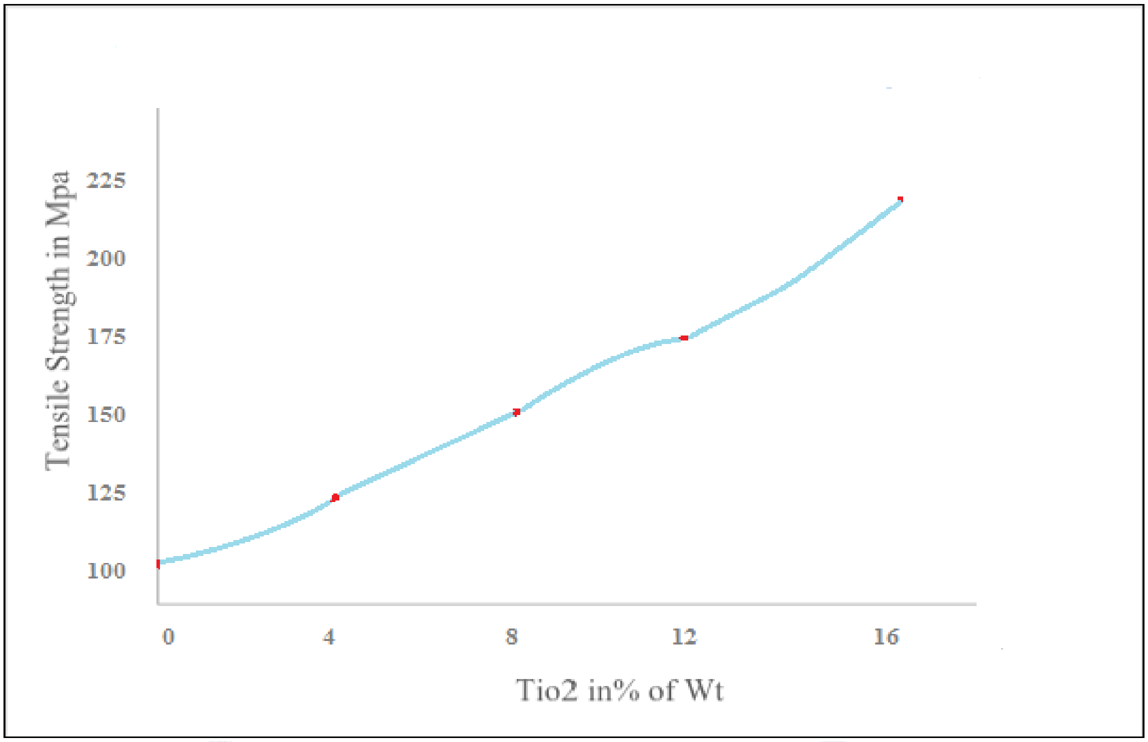

Fig. 4: Effect of content on Tensile Strength of material TiO2

3.2. Compressive Strength:

A compression test determines the characteristics of materials under crushing loads. The sample is compressed and deformation at various loads is noted. Compression Test conducted requires the testing of 5 Specimens prepared by stirr casting of aluminium metal matrix and TIO_2 composite at different composition 4%,8%,12%,16%. Specimen Specifications: L/Deff 1.6 for to assure a geometrical dimensional factor and homogeneous deformation.

L = Length of the Specimen 25

Deff = Effective Diameter of the Cross Section of the Specimen

Hence if Deff =15 mm,

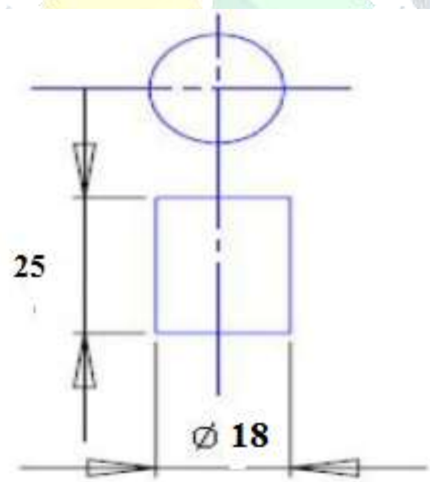

Fig.5: Compressive testing specimen

Formulation:

$\sigma_C = P/A$

A= Area of specimen

$= \pi r^2$

$= 3.14*9^2$

$= 254.34\ mm^2$ (this would be same for every specimen)

Therefore for,

1. Sample (p_1)=24034.5 N, σ_{c1}= 94.49 N/mm^2
2. Sample (p_2)=25497.2 N, σ_{c2} = 100.24 N/mm^2
3. Sample (p_3)=28439.2 N, σ_{c3} = 111.81 N/mm^2
4. Sample (p_4)=33342.6 N, σ_{c4} =131.09 N/mm^2

5. Sample (p_5)=41187.9 N, $\sigma_{c\,5}$=161.94 N/mm^2

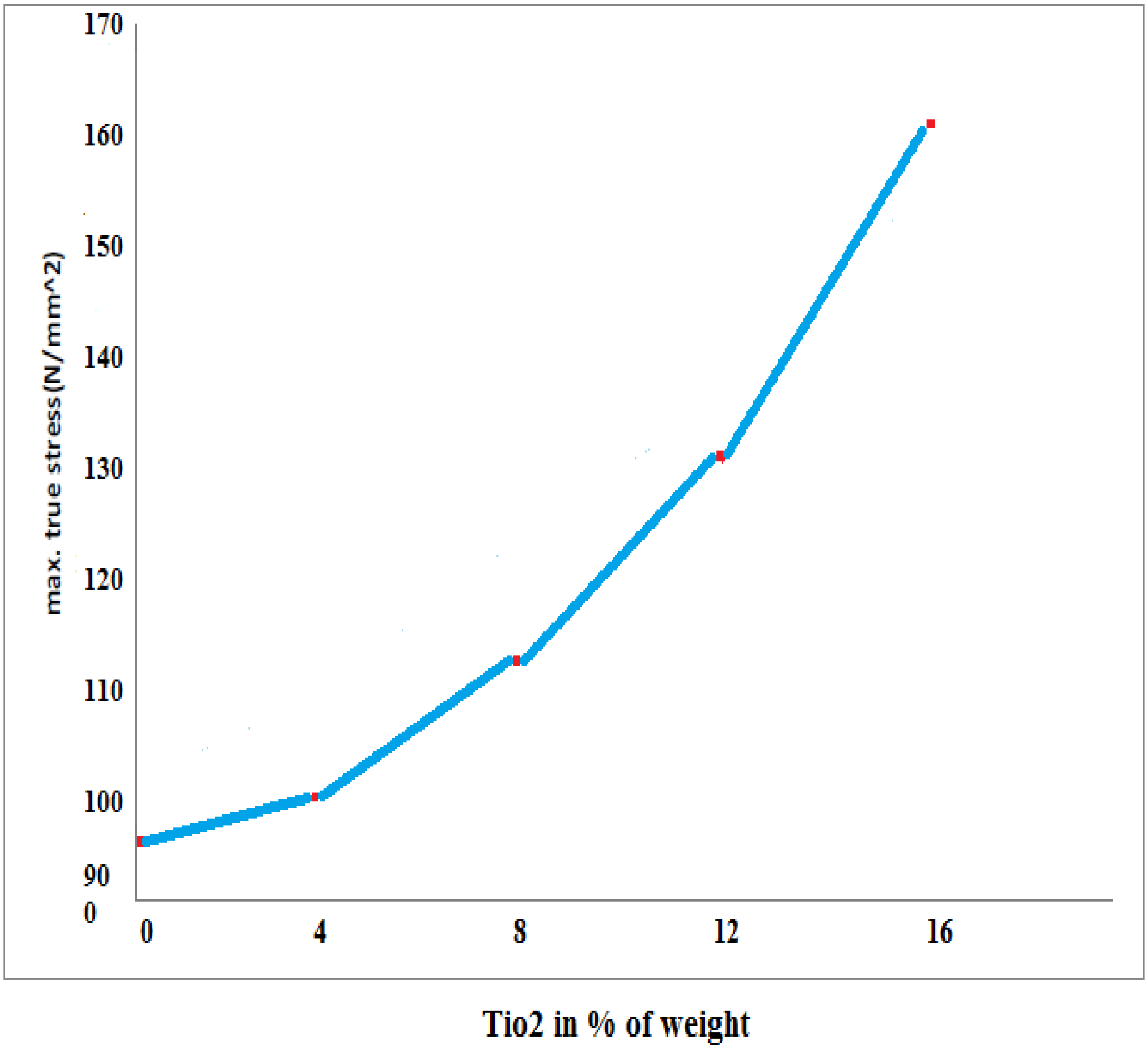

Fig. 6: Effect of content on ccompressive Strength of material TiO2

3.3. Torsional Strength:

Torsion tests twist a material or test component to a specified degree, with a specified force, or until the material fails in torsion. The twisting force of a torsion test is applied to the test sample by anchoring one end so that it cannot move or rotate and applying a moment to the other end so that the sample is rotated about its axis. The rotating moment may also be applied to both ends of the sample but the ends must be rotated in opposite directions. The forces and mechanics found in this test are similar to those found in a piece of string that has one end held in a hand and the other end twisted by the other.

The purpose of a torsion test is to determine the behavior a material or test sample exhibits when twisted or under torsional forces as a result of applied moments that cause shear stress about the axis.for the experiment the same type samples of aluminium metal reinforced with TIO_2 at different % Measurable torsional fatigue life,These values are similar but not the same as those measured by a tensile test and are important in manufacturing as they may be used to simulate the service conditions, check the product’s quality and design, and ensure that it was manufactured correctly.

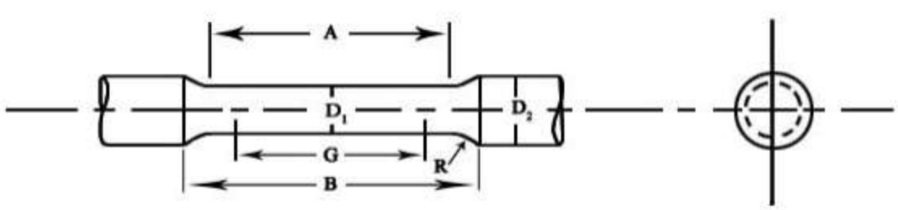

Fig.7: Tensile specimen

Guage length (G)= 7 mm , Distance between shoulders (B)=10mm,
Length of reduced section (A)=9mm, Diameter of reduced section (D_1)=14mm

Grip diameter(D_2)= 19mm, Radius of curvature (R)=4m

Fig.8:Amsler torsion testing machine

Formulation:

The formula to calculate average shear stress is force per unit area.

τ=F/A

where:

τ = the shear stress;

F = the force applied;

A = the cross-sectional area of material with area parallel to the applied force

Therefore,

A= Area of specimen

$A = (\pi/4)D^2$

$=153.86\ mm^2$ (which is constant for all samples)

Torsional strength of specimen

$\tau_{max} = Tr_0/J = 16T/\pi d^3$

Where,

τ_{max} = maximum shear stress

T = Torque

r = Radius of reduced section

J = polar moment of inertia

So for,

1. Sample (T_1)=2600 Kgfmm , τ_1 =47.31 Mpa
2. Sample (T_2)=2800 Kgfmm , τ_2 =51.00 Mpa
3. Sample (T_3)=3200 Kgfmm , τ_3 =58.29 Mpa
4. Sample (T_4)=3500 Kgfmm , τ_4 =64.99 Mpa
5. Sample (T_5)= 3700 Kgfmm , τ_5 =67.40 Mpa

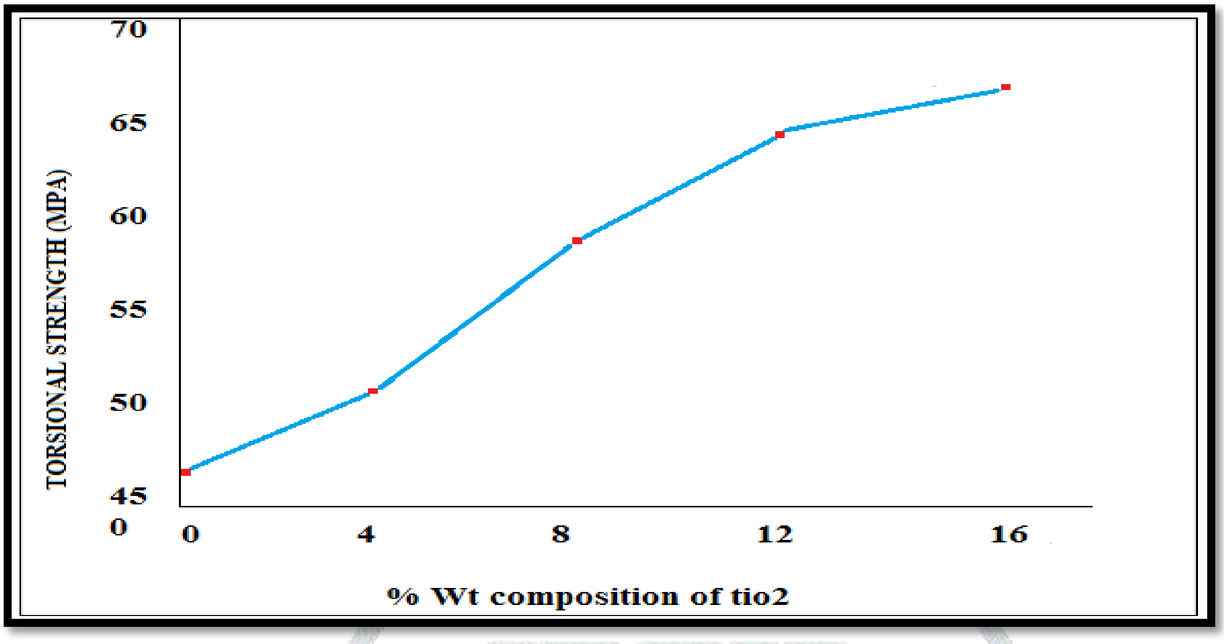

Fig. 9: Effect of content on Torsional Strength of material TiO2

4. Conclusion:

The present investigations of mechanical behavior of Aluminum metal matrix revealed that the tensile strength, compressive strength and Torsional strength is greatly influenced by the Titanium Dioxide (TIO_2) content/ weight fraction of reinforcement in matrix. A reinforced composite shows more tensile, compressive strength and Torsional strength than unreinforced epoxy. With increase in 4%,8%,12%,16% of weight fraction of (TIO_2) over pure Aluminum, the following conclusion can be made….

- Stir casing is an easy and accurate method of fabricating aluminum composite with Titanium Dioxide (TIO_2).
- The percentage increase of reinforcement increases the tensile, compressive and torsional strength of the composite.
- Tensile, compressive, and torsional strength increases with the increase in % 0f the reinforcement but between 12%-16% reinforcing of tio_2 tensile strength increases tremendously. This concludes that higher the percentage of the tio_2 higher the strength of the composite.
- The uniform distribution of TiO2 particles and strong bonding with aluminium metal matrix are the causes for increase in tensile strength, compressive and torsional strength of the composite.
- Table showing the reinforcement conclusion.

SPECIMEN	% increase in tensile strength of (AL) due to reinforcement of (TIO_2)	% increase in compressive strength of (AL) due to reinforcement of (TIO_2)	% increase in torsional strength of (AL) due to reinforcement of (TIO_2)
Pure aluminium (Al)	σ_{t1}=101.32 Mpa	σ_{c1}= 94.49 Mpa	τ_1 =47.31 Mpa
AL + 4% OF TIO_2 (by wt.%)	σ_{T2}=121.33 Mpa	σ_{c2} = 100.24 Mpa	τ_2 =51.00 Mpa
AL + 8% OF TIO_2 (by wt.%)	σ_{T3}=147.14 Mpa	σ_{c3} = 111.81 Mpa	τ_3 =58.29 Mpa
AL + 12% OF TIO_2 (by wt.%)	σ_{T4}=171.71 Mpa	σ_{c4} =131.09 Mpa	τ_4 =64.99 Mpa
AL + 16% OF TIO_2 (by wt.%)	σ_{T5}=212.50 Mpa	$\sigma_{c\,5}$=161.94 Mpa	τ_5 =67.40 Mpa

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