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Preparation and Analysis of Silicon Carbide and Graphite Particulte Reinforcements in Aluminium Matrix

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Abstract

Nowadays composite materials have become more popular for its wide range of applications and design flexibility. Since the fuel costs are increasing day to day, most of the automobile industries are conducting various experiments to develop composites having less densities and superior mechanical and tribological properties which are equally cost effective. In view of these types of composites most of the research is focused on improving mechanical and tribological properties aluminum alloys by adding with ceramic reinforcements. This work mainly focuses on the Preparation and Analysis of Silicon Carbide &Graphite Particulate Reinforcements in Aluminum Matrix.

Keywords: Composite, Silicon Carbide, Matrix, Aluminum, Casting, Reinforcements, Graphite, Particulate.

1. Introduction

A composite material is made by combining two or more materials – often ones that have very different properties. The two materials work together to give the composite unique properties. However, within the composite you can easily tell the different materials apart as they do not dissolve or blend into each other. Many of us may not be noticed that several, naturally formed materials around us are composites. Wood is a composite made from cellulose and lignin. The advanced forms of wood composites can be ply-woods. An excellent example of natural composite is muscles of human body. The muscles are present in a layered system consisting of fibers at different orientations and in different concentrations. These result in a very strong, efficient, versatile and adaptable structure.

Why use composites?

The biggest advantage of modern composite materials is that they are light as well as strong. By choosing an appropriate combination of matrix and reinforcement material, a new material can be made that exactly meets the requirements of a particular application. Composites also provide design flexibility because many of them can be moulded into complex shapes.

History of Composites

The main employments of composites go back to the 1500s B.C. at the point when early Egyptians and Mesopotamian pioneers utilized a blend of mud and straw to make solid and sturdy structures. Straw kept on giving support to old composite items including stoneware and pontoons. In 1935, Owens Corning introduced the first glass fiber, fiberglass. Fiberglass, when combined with a plastic polymer creates an incredibly strong structure that is also lightweight. This is the beginning of the Fiber Reinforced Polymers (FRP) industry as we know it today.

2. Literature Review

A.R Riahi and A.T Alpas 2001 have concentrated on systemic tests of the part of tribo-layers which are framed on contact surfaces of half breed composites with A356 aluminum base. Tests were done on Al/SiC/Gr half and half composite with A356 base, 10% SiC with molecule size of 16 µm and 3% of graphite with molecule size of 80 µm and 138 µm. Performed tribological tests decided reliance amongst wear and sliding velocity and burden. The tests were performed on piece on ring tribometer for heaps of 5–420 N and for sliding paces of 0.2– 3.0 m/s.

Basavaraju.S, November 2012 et al (18), studied the behaviour of graphite and fly ash by varying the percentage of Silicon Carbide and aluminum LM25 as base metal Prepared MMC's provide excellent wear characteristics up to a limit load. The tensile strength improves for 2% addition of SiC and 4% of SiC in Al+Graphite. This proportion is ideal for many results to outcome easily. Similarly, 2% and 4% addition of SiC in Fly ash combination makes an efficient material. The hardness of the material increases with the combination of 2% addition of SiC and Graphite. The compressive strength is ideal at 2% and 4% addition of SiC graphite and Flyash.

3. Problem formulation

Among various aluminium alloys LM16(Al –Si5CulMg0.5) is one of the most popular aluminium alloy used for water jackets, cylinder blocks, fire hose couplings, air compressor pistons, fuel pump bodies, aircraft supercharger covers and similar applications where leak-proof castings having the high strength produced by heat-treatment are required.

Selection of Reinforcements

Aluminium has very poor wear resistance compared to ferrous alloys. To improve the hardness and wear properties of aluminium alloy, reinforcement must possess relatively high hardness and wear resistance. Ceramics are the materials which stood in the top and well ahead of ferrous alloys. Silicon carbide is a compound of silicon and carbon with chemical formula SiC. Grains of silicon carbide can be bonded together by sintering to form very hard ceramics that are widely used in applications requiring high endurance, such as car brakes, car clutches and ceramic plates in bulletproof vests.

Selection of Optimal Composition

Copper	1.0 - 1.5
Magnesium	0.4 - 0.6
Silicon	4.5 - 5.5
Iron	0.6 max
Manganese	0.5 max
Nickel	0.25 max

Zinc	0.1 max
Lead	0.1 max
Tin	0.05 max
Titanium	0.2 max
Aluminium	Remainder

Tensile Stress (N/mm2)	270 – 280
Impact Resistance Izod (Nm)	1.4
Brinell Hardness	100 – 110
Modulus of Elasticity (x103 N/mm2)	71

Since a hybrid composite is going to be prepared, composition of reinforcements for obtaining better composite may differ from the results obtained from studies done with a single reinforcement. The resulting composite may show combined results of SiC and graphite. By studying Al- Graphite composites, it was observed that the graphite can be limited to 4% w/w and the SiC can be varied from 10% to 15% w/w with a step of 5%.

4. Experimental work

A conventional stir casting furnace consists of the following basic components.

a. Furnace b. Crucible c. Stirring Equipment

A furnace is prepared by using a cylindrical thick sheet metal drum. The inner wall of furnace is lined with refractory ceramic material to prevent heat losses and is sealed with glass wool material which is prepared form glass.

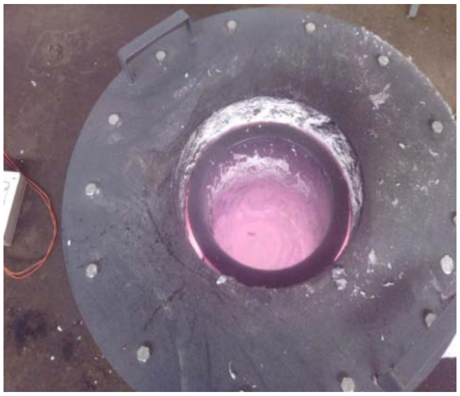

Figure 1: Furnace

Total furnace was made with kanthaal wire. It is applicable to produce heat up to 13500C. It is protected by 15mm thickness of ceramic material integrated with 10% of iron.

Preparation of Stirrer

A 1200 rpm high torque reversible motor is taken and connected with a potentiometer for varying speeds as per the requirement. The motor shaft is coupled to a stainless steel rod and the other end is connected to a graphite three-blade impeller and is tested by stirring water in the crucible and grinded to the desired angle for producing vortex.

Figure 2: Stirrer Setup

Assembly of stir casting

Stir Casting is a liquid state method of composite materials fabrication, in which a discontinuous reinforcement is mixed with a molten matrix metal by means of mechanical stirring.

Figure 3: Stir Casting Process

At first, the matrix metal is melted in the crucible and then metal treatment (like degassing, fluxing, etc.) is carried out without stirring. Later, stirrer is inserted into the crucible and allowed to rotate the molten metal. Vortex is formed in the crucible due to the rotation of stirrer. Required quantity of reinforcement is preheated in a separate chamber and is gradually added to the vortex for uniform mixing of reinforcement in to the matrix. After the addition of reinforcement stirrer is removed from the crucible and the liquid composite material is then cast by conventional casting methods and may also be processed by conventional Metal forming technologies.

Figure 4: Test Sample with Riser

All the samples were fully heat treated which includes solution heat treatment for 12 hours at 520-530oC and quenched in hot water followed by precipitation treatment of 8 hours at 170^{o}C.

5. Results and Discussions

For convenience of presentation and plotting, from here onwards pure M-16 alloy samples were referred as Group 0, LM-16 with 4% Graphite and 10% SiC samples were referred as Group 1and LM-16 with 4% Graphite and 15% SiC samples were referred as Group 2.

5.1. Density

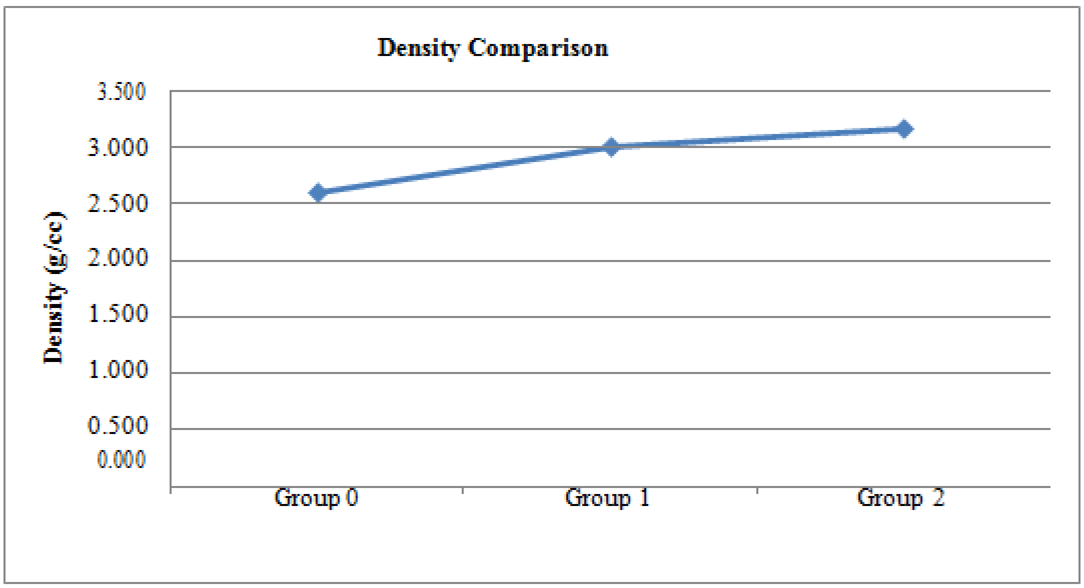

Figure 5.1: Comparison of Density

5.2. Hardness

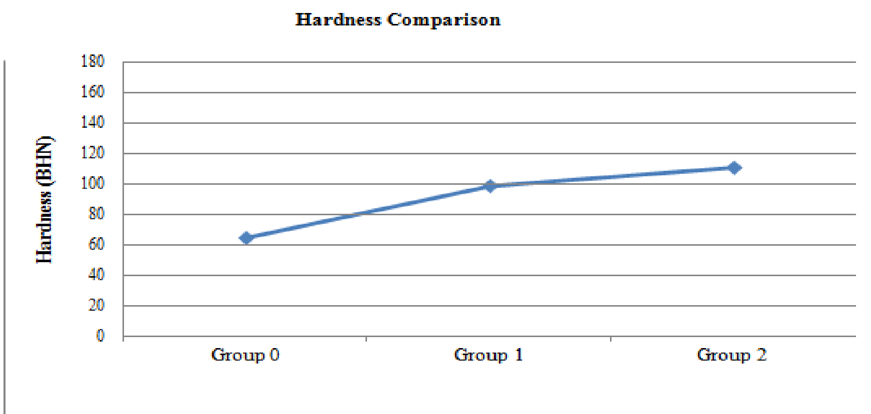

Figure 5.2 Comparison of Hardness

5.3. Tensile Strength

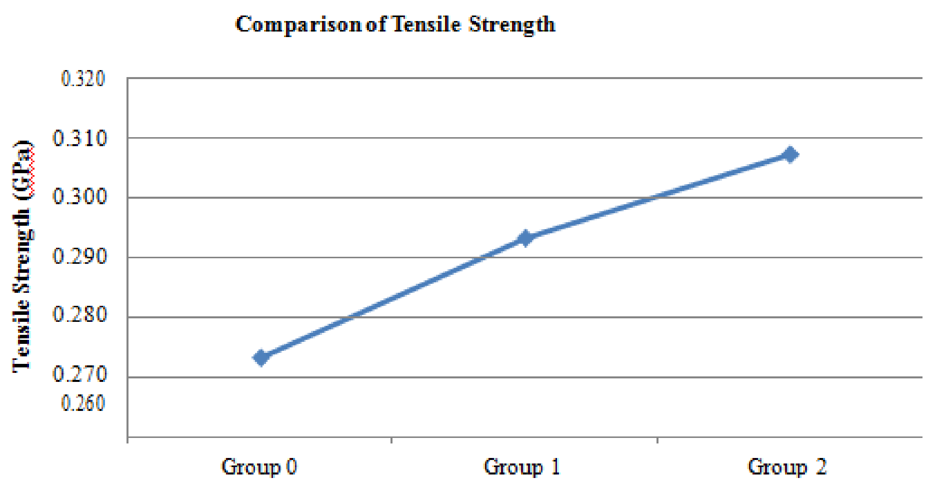

Figure 5.3: Comparison of Tensile Strength

5.4. Modulus of Elasticity

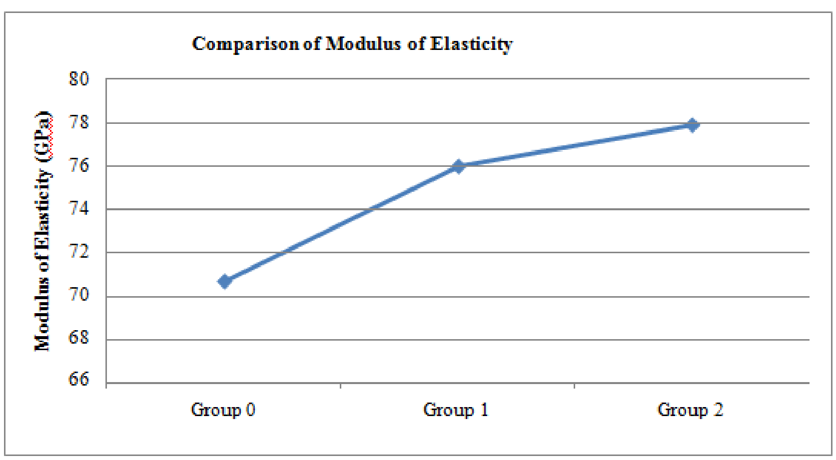

Figure 5.4: Comparison of Modulus of Elasticity

5.5. Analysis of Composites using ANSYS 13.0

A pre modeled petrol engine cylinder is taken and is imported to ANSYS WORKBENCH. The model is meshed using a tetrahedral element and is subjected to boundary conditions i.e. Forces, contacts, supports etc.

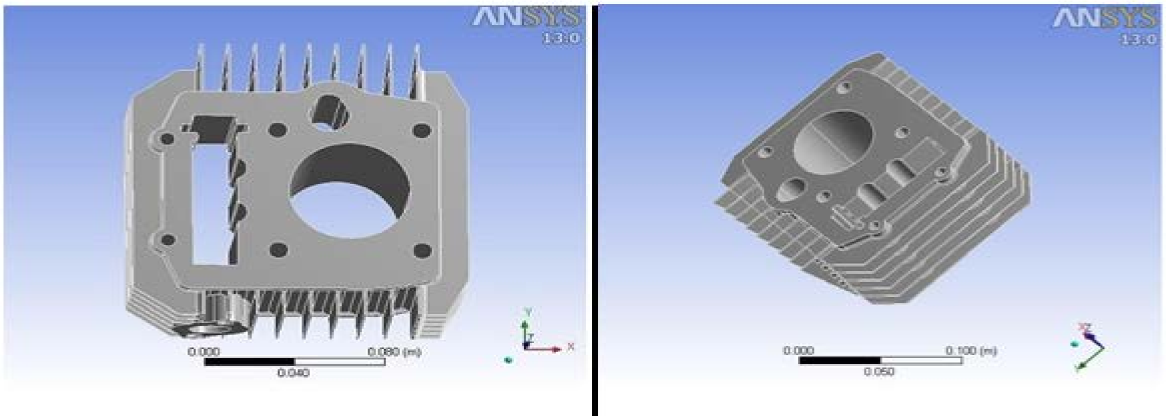

Figure 5.5: Dimensional Petrol Engine Cylinder Model

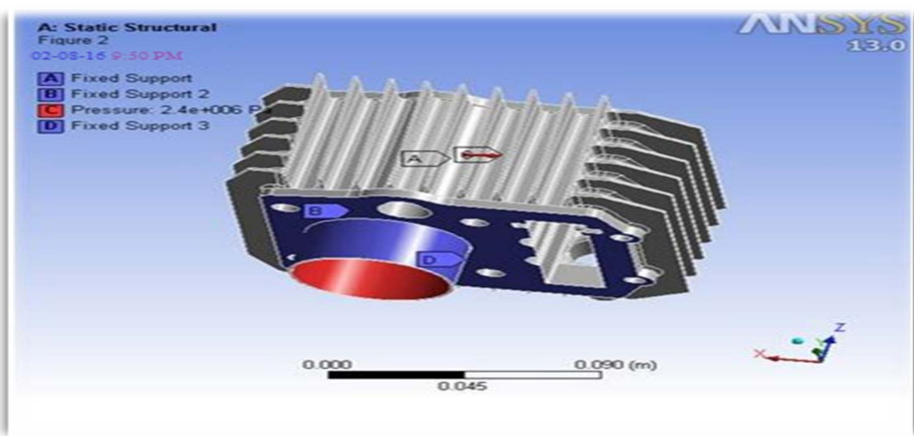

Figure 5.6: Boundary Conditions and Constraints Defined to Model

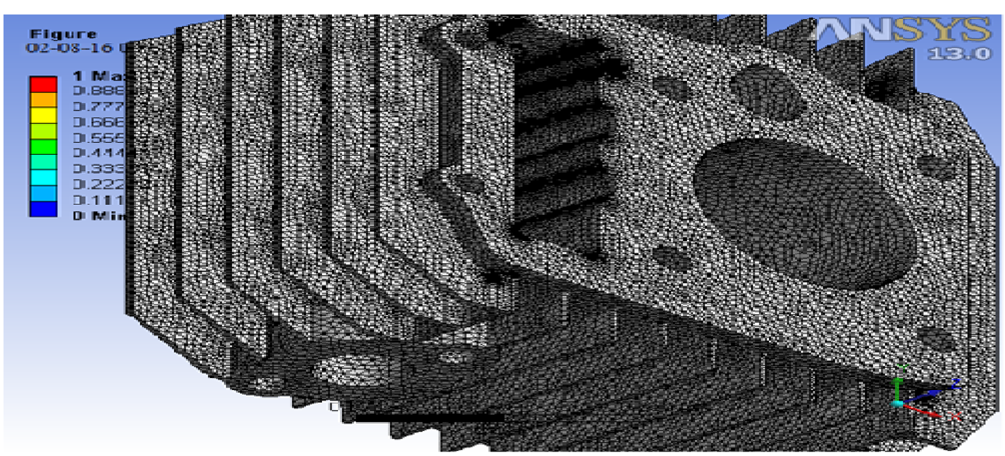

Figure 5.7: Cylinder Model after Mesh Generation

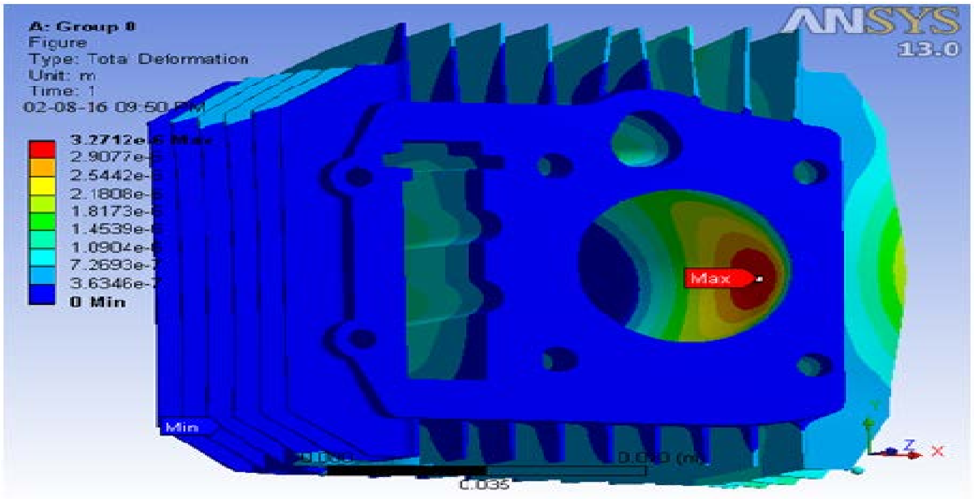

Figure 5.8: Variation of Total Deformation for Group 0 (Pure Alloy)

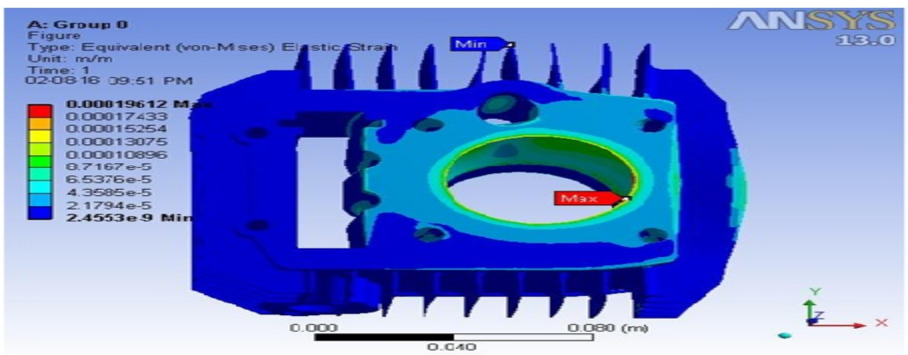

Figure 5.9: Variation of Strain for Group 0 (Pure Alloy)

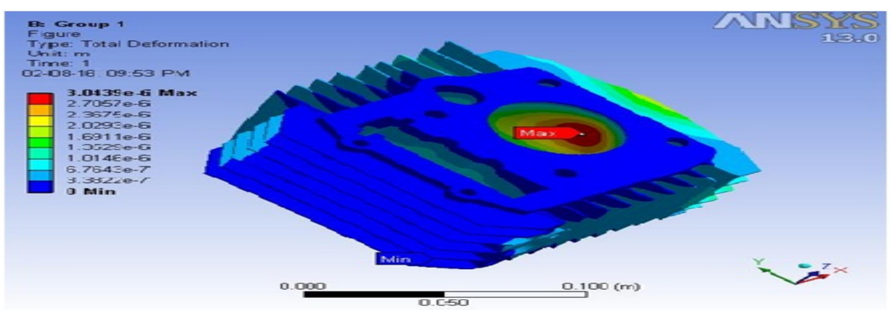

Figure 5.10: Variation of Total Deformation for Group 1.

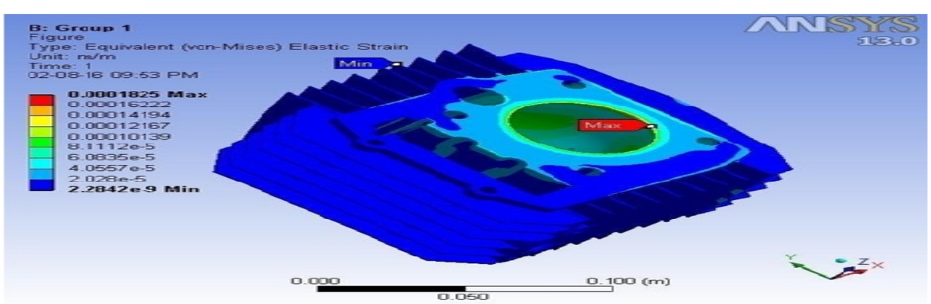

Figure 5.11: Variation of Strain for Group 1

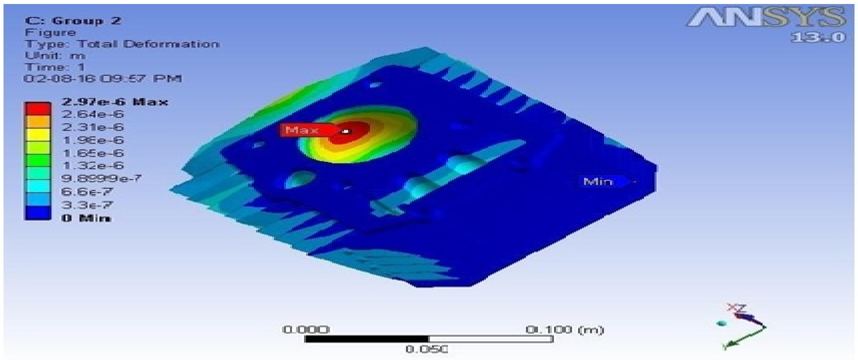

Figure 5.12: Variation of Total Deformation for Group 2

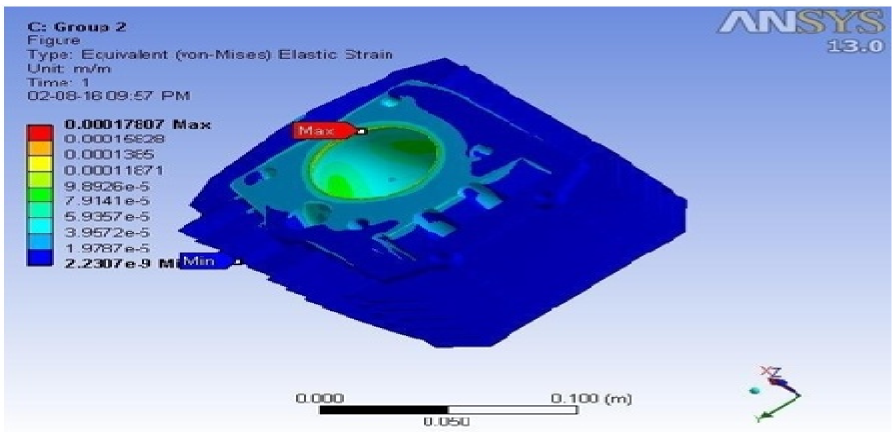

Figure 5.13: Variation of Strain for Group 2

5.5.1. Comparison of Total Deformation

The slope of the curve from Group 0 to Group 1 is steeper than the curve from Group 1 to Group 2.

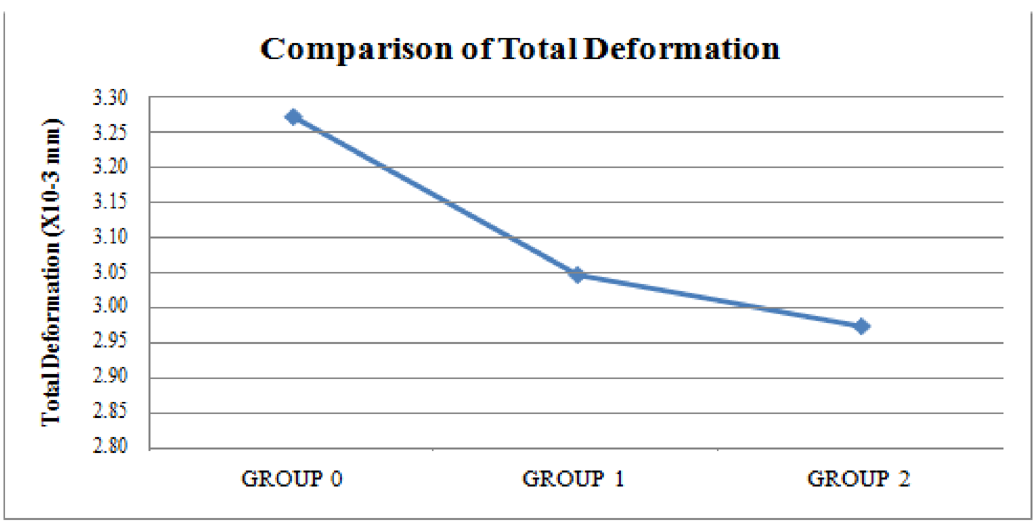

Figure 5.14 Comparison of Total Deformation

5.5.2. Comparison of Strain

As the deformation is proportional to the strain, the maximum strain developed in the model seems similar to the comparison of total deformation.

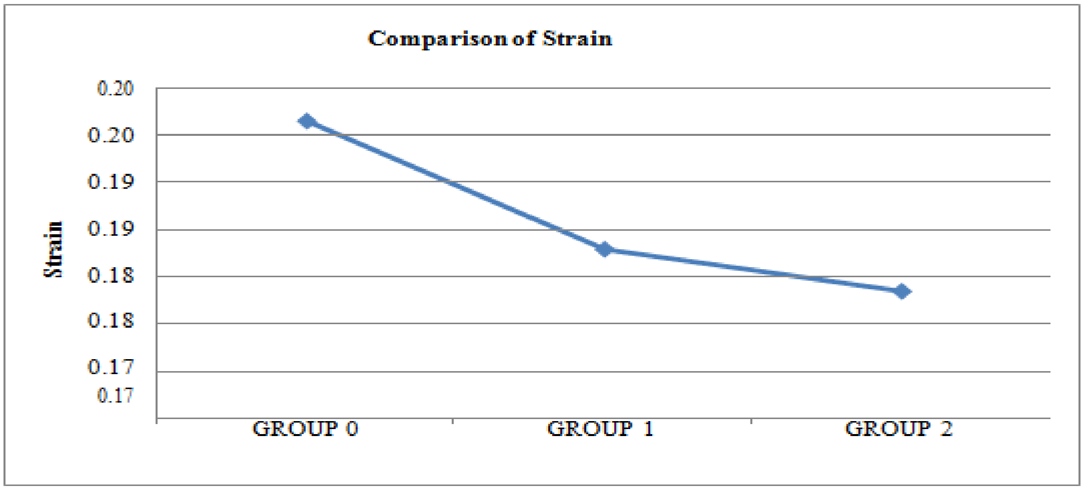

Figure 5.15: Comparison of Strain

6. Closure

6.1. Conclusion

1. Addition of SiC will increase the mechanical properties of the composite.

2. By comparing with amount of SiC in the composite LM-16 with 4% graphite and 15% SiC is most suitable for regular casting process.

3. Hardness of the composite increased by 31.4% for 10% SiC and 42.5% for 15% SiC.

6.2. Scope of Future Work

1. Wear analysis can be done on the same composition to find the wear properties and lubrication effect of graphite in the composite.

2. Microstructure analysis can be performed to study the interfacial strengths and uniform distribution of particulates.

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