Mechanical Properties of Aluminum Metal Matrix Composite
Reinforced with Silicon Carbide using FEM

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Abstract

In this work the SiC reinforced Aluminium composites were studied and Finite Element Method (FEM) analysis carried out and the results of FEM analysis were compared with the actual experimental results. As the Finite Element Analysis has become a major tool for an engineer, the Finite Element Analysis is done to solve advanced analysis issues. In this paper, Finite Element Method based ANSYS software is used to determine the mechanical properties in the aluminium metal matrix composite reinforced with Silicon Carbide by changing the volume fraction of the Silicon Carbide in aluminium. The FEM analysis results were compared with the actual experimental result. The testing of the mechanical properties such as tensile testing and compression testing were carried out in the FEM analysis.

Keywords: FEM, Mechanical Properties, SiC, Aluminium, MMCs.

1. Introduction

Aluminium is a widely used metal in most engineering applications. This is mainly because of its beneficial properties such as its low weight, low density and good formability. Aluminium finds its use in various high-performance applications such as automotive, military, aerospace and electrical industries. In the automobile industry, the Aluminium metal is used in the fabrication of suspension parts, cylinder blocks inside the engine, radiators and transmission bodies. The disadvantage of pure aluminium is its low strength and the fact that it is prone to corrosion. Due to this, Aluminium is reinforced with other metals or non-metals to form suitable alloys and composites to further improve its properties and overcome its disadvantages. One such reinforcement of nanoparticles which is used is Silicon Carbide (SiC). Silicon Carbide has been the most broadly utilized material for the utilization of ceramics in structures. Attributes, for example, low coefficient of thermal expansion, high power to-
weight span, high thermal conductivity, hardness, corrosion and abrasion resistant, and in particular, the support to elasticity at temperatures up to 1650 °C, have prompted a wide scope of employments. A Metal Matrix Composite (MMC) is a composite material constituting two parts, one being a metal mostly and the other part can be a metal or a different kind of material such as an organic compound. The creation of an MMC of a metal improves its properties with respect to its base metal. MMCs combine metallic properties with ceramic properties of the added reinforcement and hence possess greater strength in shear and compression and also ensure high service temperature capabilities. They induce in the Aluminium significant increase in strength and the strength of the composites were found to be directly proportional to the percentage contents and fineness of the reinforced particles up to a certain point.

2. Experimental Procedure

Finite Element Analysis or FEM is a computerized, computational method for predicting force, damping, and other effects. Analysis of FEA, the material breakage, strength, wear and tear can be identified. To solve the exact solution, we will figure out the need to obtain the exact solution. A cylinder was manufactured in this work using the produced aluminium matrix composite and the value of the properties.

2.1 Structural Analysis by Workbench:

The ANSYS workbench program is ideal for estimating the engineering problem complex and providing effective product design. FEA is a tool that can optimize the simulation and produce it, and get resolution. This ANSYS workbench program is designed to solve the physical work quite easily. It was pointed out about the stress distribution of pushrod components. The flow of solving a problem by ANSYS FEA is shown below.
Figure 2.1: Flow in ANSYS

Figure 2.2: Cylindrical Model

Figure 2.3: Meshed Model
2.2 Tensile Test

Figure 2.4: Von Mises Stress for specimen with 5% SiC Reinforcement

Figure 2.5: Total Deformation for specimen with 5% SiC Reinforcement
Figure 2.6: Stress for specimen with 10% SiC Reinforcement

Figure 2.7: Total Deformation for specimen with 10% SiC Reinforcement

Figure 2.8: Stress for specimen with 15% SiC Reinforcement
Figure 2.9: Total Deformation for specimen with 15% SiC Reinforcement

Table 2.2: Stress and Total deformation results

| Weight Percentage Volume | Equivalent Stress (MPa) | Total Deformation (mm) |
|--------------------------|-------------------------|------------------------|
|                          | Maximum                 | Minimum                | Maximum   | Minimum |
| 5%                       | 221.64                  | 56.233                 | 21.101    | 0       |
| 10%                      | 222.46                  | 56.756                 | 23.688    | 0       |
| 15%                      | 223.89                  | 57.183                 | 24.532    | 0       |

2.3 Compression test

Figure 2.3:
Figure 2.10: Stress in Specimen with 5\% Reinforcement

Figure 2.11: Total Deformation in Specimen with 5\% Reinforcement

Figure 2.12: Stress Deformation in Specimen with 10\% Reinforcement
3 Results and Discussions
Compared with that of the non-reinforced Al6061, strength (UTS) and Young's modulus can be linked to various factors influencing the tensile capacity of composites. It is anticipated that the strain-hardening of composites would be affected by the dislocation rate, dislocation-to-dislocation contact and plastic flow restriction due to particle resistance. The other important aspect is the high multidirectional thermal stress that is caused at the matrix–ceramic particle interface due to the disparity in thermal expansion coefficient between matrix and reinforcement. The other significant thing is the high multidirectional thermal stress induced by the matrix-the ceramic particle interface due to the variation in the coefficient of thermal expansion between matrix and reinforcement. Added; further rise of the SiC content results in decreased intensity values. The aforesaid tensile activity is observed in the variability of micro-composite tensile power. It may be the product of larger particle agglomeration and higher porosity. The sum of device region and micro porosity decreases as SiC material rises and may result in lower composite flow tension. In addition, that dislocation, i.e. defects caused around the reinforcement particles due to discrepancies in the Al(6061) and SiC thermal expansion coefficients, may contribute to the debonding of the interface and a decrease in composite UTS with more SiC volume fraction.

3.1 Tensile Test

Tensile test is also known as the tension test. During the tensile a strong force is applied in opposite directions with the specimen tightly clamped in between. It can be assumed to be a type of pulling test. After the forces are removed the material is studied to determine how it reacts to the elongation.

Table 3.1: Analytical v Experimental Results of Tensile Specimen

| Percentage Composition of SiC in Aluminium | Experimental Value (mPa) | FEM Value (mPa) | Deformation(mm) |
|------------------------------------------|--------------------------|-----------------|-----------------|
| 5%                                       | 218.44                   | 221.64          | 21.101          |
| 10%                                      | 226.82                   | 222.46          | 23.688          |
| 15%                                      | 227.65                   | 223.89          | 24.532          |
Figure 3.1: Tensile Strength

Tensile Tests of the whole arranged example were completed on UTM. At first for widely used commercial aluminum, tensile strength was 139.40 MPa which is lower than Al-5% SiC composite. It is obvious from the above figure that the composite example with 15% SiC exhibits maximum tensile strength of 172.54 MPa. Increasing percentages of SiC in the increments of 5% showed decrease in tensile strength.

3.2: Compressive Test

| Weight Percentage | Equivalent Stress (mPa) | Total Deformation (mm) |
|-------------------|-------------------------|------------------------|
|                   | Maximum                 | Minimum                |
| 5%                | 275.7                   | 57.544                 | 20.434 | 0 |
| 10%               | 275.46                  | 56.756                 | 22.14  | 0 |
| 15%               | 275.74                  | 56.469                 | 22.678 | 0 |
Figure 3.2: Compressive Strength

Compression Tests of the whole arranged examples were likewise done on UTM. Al-15% SiC composite material exhibited the highest value of 322.85 Mpa. The results are shown in the figure 3.2.

3.3 Hardness Test

Figure 3.3: Hardness Test
Sample hardness increases with a rise in the weight percentage of hardened nano particulate matter and a decrease in particle size. This is due to the impediment of motion of dislocations due to increased concentration of particles and decrease in grain size. With rising reinforcing material, the stiffness improved. Hardness test was completed on Brinell Hardness Tester. In each example, four impressions were made by steel indenter balls. Average was taken to figure the Hardness value in BHN. The greatest value of hardness was seen as 87.1 BHN for Al-15% SiC composite. Above figure 3.3 shows that the option of SiC up to 15% in Al which expands the hardness estimation of the readied composites and if SiC is included over 15%, hardness value diminishes.

4. Conclusion

The experimental results of the aluminium metal matrix composite reinforced with Silicon Carbide is compared with the FEM analysis results. As observed there is a deviation in reading when compared to the actual values to the analysis values but there is a similar pattern if the results in both the analysis and experimental results the composite material tends to increase its mechanical properties like tensile strength, compressive strength and hardness at certain volume fraction of silicon carbide. The most effective volume fraction of silicon carbide to improve the mechanical properties of the aluminium metal matrix composite is 15% of Silicon Carbide. After the 15% of silicon carbide there is reduction in the mechanical properties. Therefore it can be concluded that 15% of reinforcement added in the form of silicon carbide is a major advantage to the mechanical properties of the composite material.

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