



FABRICATION AND STRUCTURAL ANALYSIS OF NANOCOMPOSITES BY VARYING COMPOSITION OF AL – Al₂O₃ USING ANSYS

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Abstract

Aluminium Alloy (LM4) reinforced with 1, 1.5, 2.5 and 5% of nano particle aluminium oxide (Al₂O₃) were fabricated by using stir casting method. The fabricated Aluminium-Aluminium oxide (Al-Al₂O₃) nanocomposite materials under three types are tested such as tensile and hardness test and the mechanical properties are determined. A microstructure was also conducted. Finally the analysis value and the experimental value are carried out using Ansys version 10.0

Keywords: Aluminium Alloy (LM4), Al-Al₂O₃, Nanocomposite, Ansys

1. INTRODUCTION

Nowadays, demands for developing metal matrix composites for use in high performance applications, have been significantly increased. Among these composites, aluminum alloy matrix composites attract much attention due to their lightness, high thermal conductivity, moderate casting temperature, etc. Various kinds of ceramic materials, e.g. SiC, Al₂O₃, MgO and B₄C, are extensively used to reinforce aluminum alloy matrices. Superior properties of these materials such as high hardness, high compressive strength, wear resistance, etc. make them suitable for use as reinforcement in matrix of composites. Nevertheless, low wet ability with molten metal's and density differences increase their tendency toward agglomeration, which deteriorate mechanical properties. Numerous attempts have been made to overcome the mentioned weakness. These composites, sometimes, are subjected to subsequent age hardening for improving mechanical properties. The (Al₂O₃) particles, Aluminium LM4 nano

composites which are fabricated via in stir casting represents improved mechanical properties and homogeneous microstructures. Al₂O₃/Al LM4 composites fabricated via infiltration of aluminum alloy into an Al₂O₃ performs, show improved toughness and strengths. Al-alloy powders may be used to produce such kinds of composites with improved properties. In this way, subsequent and appropriate sintering procedure needs to be performed. Stir casting, as an alternative and relatively simple route can be successfully used to produce metal matrix composite. However, precise optimization of reinforcement content, casting temperature, stirring velocity, etc. should be considered. Additionally, incorporating ultra fine particles, such as nano-particles into the matrix, significantly improves mechanical properties by reducing the inter particle spacing. However, fine particles represent higher tendency toward agglomeration. Therefore, optimum particle size, amount of reinforcement and processing parameters, should be determined for the matrix. In this study,

nano-particle Al_2O_3 was used to reinforce A LM4 alloy, using stir casting method. Nano-particle Al_2O_3 , were incorporated into the molten metal, Simultaneous stirring of molten metal at constant stirring rate was also employed. Optimum casting temperature and reinforcement content were determined by analyzing microstructure and mechanical properties.

2. LITERATURE REVIEW

1. Microstructure and mechanical properties of aluminum alloy matrix composite reinforced with nano-particle MgO [A. Ansary Yara, M. Montazerianb, H. Abdizadehb, H.R. Baharvandic] In this research, aluminum alloy (A356.1) matrix composites reinforced with 1.5, 2.5 and 5 vol% nanoparticle MgO were fabricated via stir casting method. Fabrication was performed at various casting temperatures, viz. 800, 850 and 950 °C. Optimum amount of reinforcement and casting temperature were determined by evaluating the density, microstructure and mechanical properties of composites. The composites were characterized by scanning electron microscopy (SEM) and X-ray diffraction (XRD). Hardness and compression tests were carried out in order to identify mechanical properties. The results reveal that the composites containing 1.5 vol% reinforcement particle fabricated at 850 °C have homogenous microstructure as well as improved mechanical properties.
2. Enhanced properties of Mg-based nano-composites reinforced with Al_2O_3 nano-Particles [M. Habibnejad-Korayema, R. Mahmudia, W.J. Pooleb] In this study, 0.5, 1 and 2 wt.% of alumina nano-particles were added to pure Mg and AZ31 magnesium alloy via a stir-casting method. A uniform distribution of the Al_2O_3 nano-particles with an average diameter of 100 nm, refined the grain structure of the cast materials and decreased the coefficient of thermal expansion (CTE), thus improving the dimensional stability of both pure magnesium and AZ31 alloy. The addition of 2 wt. % nano- Al_2O_3 particles showed great potential in the reduction of CTE from 27.9 to $25.9 \times 10^{-6} K^{-1}$ in pure Mg, and from 26.4 to $25.2 \times 10^{-6} K^{-1}$ in AZ31. Some of the cast samples were hot rolled and annealed to investigate the pinning effect of nano-particles on the recrystallization and subsequent mechanical property behavior. Characterization of mechanical properties revealed that the presence of nano-particles significantly increased yield stress and tensile strength but decreased the ductility of both pure magnesium and AZ31. The yield stress and tensile strength both increased by 40MPa in the Mg-2 Al_2O_3 nano-composite, whereas this improvement was about 65MPa for AZ31-2 Al_2O_3 . The yield strength improvement was mostly due to the CTE mismatch between the matrix and the particles, and to a lesser extent to the Orowan and Hall-Petch strengthening mechanisms. The contribution of each of these mechanisms was used in a modified shear lag model to predict the total composite-strengthening achieved. Examination of fracture surfaces showed that the relatively ductile fracture of the monolithic materials changed to a more brittle mode due to the presence of nano- Al_2O_3 particles.
3. Microstructural Analysis and Properties of Al-Cu-Mg Mg/Bagasse Ash Particulate Composites [V.S Aigbodion, S.B Hassan, J.E Oghenevweta] The effects of bagasse ash particles on the as-cast microstructure and properties of Al-Cu-Mg alloy composites produced by double stir-casting method have been studied. 2-10 weight percent bagasse ash particles were added. The microstructure and phases of the alloy particulate composites produced were examined by SEM/EDS and XRD methods. The physical and mechanical properties determined includes: density, ultimate tensile strength, yield strength, compression strength, hardness values and impact energy. The results revealed that, additions of bagasse ash reinforcement increased the hardness and compression strength values by 43.3 and 57.7% respectively, the density and impact energy decreased by 10.27 and 45% respectively as the weight percent of bagasse ash increases in the composites. The yield strength and ultimate tensile strength increased by 49.76% and 34.25% up to a maximum of 8wt% bagasse ash addition respectively. These increases in strength and hardness values are attributed to the distribution of hard and brittle ceramic phases in the ductile metal matrix. The microstructure obtained reveals a dark ceramic and

white metal phases, which resulted into increase in the dislocation density at the particles-matrix interfaces. These results show that better properties are achievable by addition of bagasse ash to Al-Cu-Mg alloy.

4. Mechanical properties of nickel silicon carbide nanocomposites [A.F. Zimmerman, G. Palumbo, K.T. Aust, U. Erb] Nanocomposite materials consisting of a nanocrystalline Ni matrix (grain size 10–15 nm) reinforced with sub-micron size SiC particulates (average particle size: 0.4 μm) up to 10.5 vol. % have been produced by pulse electro deposition. Substantial improvements in mechanical properties including hardness, yield and tensile stress were obtained for the nanocomposite material, as compared with conventional Ni–SiC composites with a matrix grain size in the micrometer range. Tensile strengths up to four times that for conventional polycrystalline Ni and two times that for conventional polycrystalline Ni–SiC of comparable SiC content were measured. The tensile and yield strengths of the nanocomposite material with SiC content less than 2 vol. % were higher than those for pure nanocrystalline Ni of comparable grain size. For these nanocomposites an unexpected increase in tensile ductility was also observed when compared to pure nanocrystalline nickel. At higher SiC content (2 vol. %) the strength and ductility were found to decrease to the detriment of the nanocomposite.

5. Effect of different types of nano-size oxide particulates on micro structural and mechanical properties of elemental Mg. [S. F. HASSAN, M. GUPTA] In the present study, magnesium based composites were fabricated with three different types of 1.1 volume percent nanosize oxide particulate reinforcements (i.e., Al_2O_3 , Y_2O_3 and ZrO_2) using blend-press-sinter methodology avoiding ball milling. Micro structural characterization of the materials revealed reasonably uniform distribution of nano-reinforcement, significant grain refinement and the presence of minimal porosity. Mechanical properties characterization revealed that the incorporation of nano-sized oxide particulates as reinforcement led to a simultaneous increase in hardness, 0.2% yield strength, UTS and ductility of pure magnesium. The results further revealed that the 0.2% yield strength,

UTS and ductility combination of the magnesium containing nano-size Al_2O_3 remained higher when compared to high strength magnesium alloy AZ91 reinforced with much higher amount of micron size SiC particulates. An attempt is made in the present study to correlate the effect of different types of nano-sized oxide particulates on the micro structural and mechanical properties of magnesium.

3. MATERIAL SELECTION

3.1 Aluminium LM4

Aluminum, with its low melting point and excellent flow characteristics combined with light weight, durability and different alloy combinations, is the best starting point for your casting needs. Aluminum has a lower melting point than other metals. Casting characteristics can be altered affecting cost.



Figure: 1 Aluminium LM4

3.2 Aluminum Oxide, Al_2O_3

The key properties of Aluminium oxide is as follows

- Hard, wear-resistant
- Excellent dielectric properties from DC to GHz frequencies

- Resists strong acid and alkali attack at elevated temperatures
- Good thermal conductivity
- Excellent size and shape capability
- High strength and stiffness
- Available in purity ranges from 94%, an easily metallizable composition, to 99.5% for the most demanding high temperature applications.



Figure: 2 Al₂O₃ Nanopowder

3.3 Composition of Al-Al₂O₃

Aluminium alloy (g)	Aluminium oxide (Al ₂ O ₃) (%)	Aluminium oxide (Al ₂ O ₃) (g)	Total (g)
990	1	10	1000
985	1.5	15	1000
975	2.5	25	1000
950	5	50	1000

Table: 1 Composition of Al-Al₂O₃

4. FABRICATION OF NANOCOMPOSITE

4.1 Stir Casting Process

1.) Al(LM4) was first super heated to its melting point in graphite crucible. Nano-powder Al₂O₃(1,1.5, 2.5 and 5 vol%) was wrapped in aluminum foils and added to the molten metal

2.) Stirring was carried out at constant rate of 420rpm for 14min.

- 3.) Finally, specimens fabricated in four various conditions were prepared for subsequent mechanical analyses.



Figure: 3 Molten Metal Poured In the Mould



Figure: 4 Fabricated Nanocomposite

3. MICROSTRUCTURE STUDY OF Al_2O_3 NANOCOMPOSITE

The microstructure study of various composition fabricated nanocomposite are displayed below



Figure : 5 Microstructure test setup



Figure: 6 Microstructure of 1.0% Al_2O_3



Figure: 7 Microstructure of 1.5% Al_2O_3



Figure: 8 Microstructure of 2.5% Al_2O_3



Figure: 9 Microstructure of 5.0% Al_2O_3

4. ANALYSIS

The stress analysis is performed in order to find the minimum stress obtained in various composition of Al_2O_3

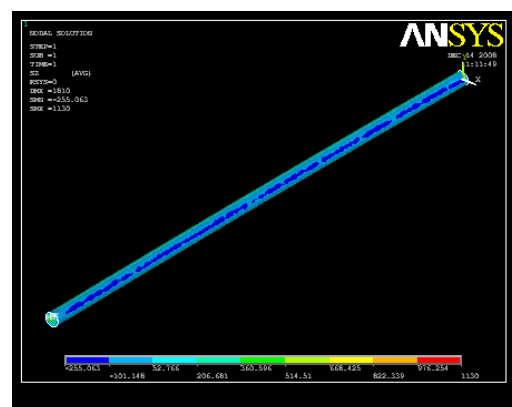


Figure: 10 Stress acting on 1% Of Al_2O_3

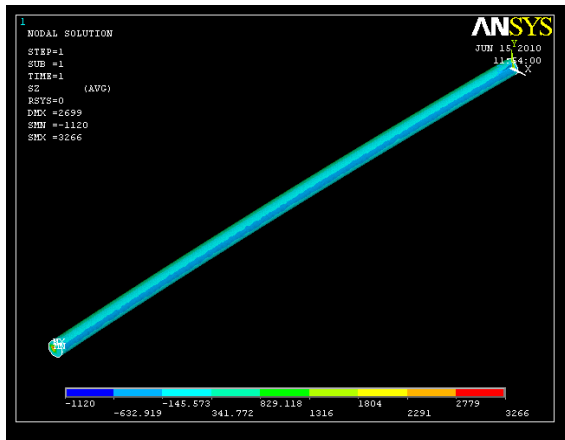


Figure: 11 Stress acting on 1.5% Of Al₂O₃

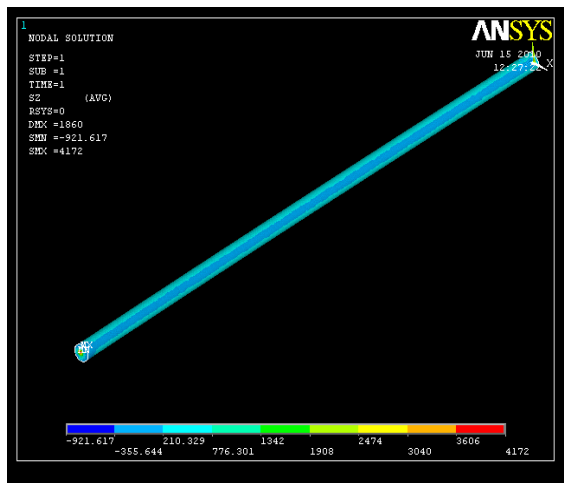


Figure: 12 Stress acting on 2.5% Of Al₂O₃

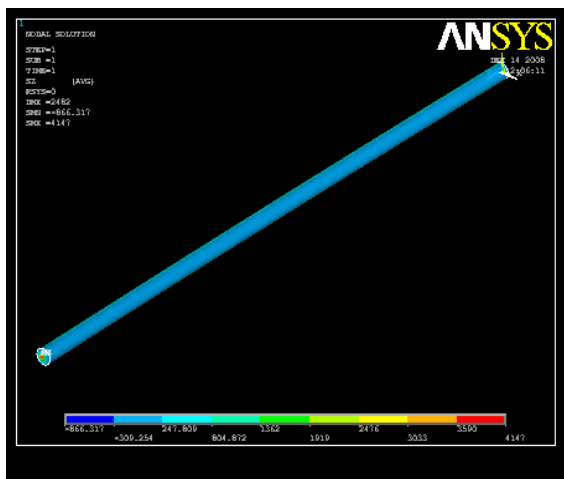


Figure: 13 Stress acting on 5.0% Of Al₂O₃

5. CONCLUSION

The aluminium-aluminium oxide (Al-Al₂O₃) metal matrix nanocomposite was fabricated via stir casting method in various compositions and tensile tests and hardness tests were carried out. The microstructure study was also carried. It is found that *aluminium - aluminium oxide (Al-Al₂O₃) in composition with 5% is better* than 1%, 1.5% & 2% when compared regarding the tensile & rock hardness number. In the analysis part, the stress & displacement in Z axis is found to be less when compared other fabricated compositions. Hence 5% of Al-Al₂O₃ is considered to be suited in usage of application where applied.

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