Name of the College: Ramaiah Institute of Technology, Bangalore

Project Title: "Development of Magnesium Hybrid Nano Composites Reinforced with Al_2O_3 and Zro_2 Nano Particles for Structural Application"

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Name(s) of project guide(s):

1. Name: Dr. Siddaraju C.
   Email id: siddaraju@msrit.edu
   Contact No.: 9880612806
2. Name: Dr. Niranjan C A
   Email id: drnca@msrit.edu
   Contact No.: 9740226808

Name of Team Members

1.Name: Anand Deshpande
USN No.: 1MS20ME400
Email id: ananddeshpande588@gmail.com
Mobile No.: 8197422948

2.Name: K M Mohammed Akram
USN No.: 1MS20ME405
Email id: kmmohammedakram44@gmail.com
Mobile No.: 7892314001

3.Name: Kartik Sugandhi
USN No.: 1MS20ME406
Email id: kartiksugandhi11@gmail.com
Mobile No.: 7676714641

4.Name: Shaikh Shahid N
USN No.: 1MS20ME410
Email id: shahidnshaikh2@gmail.com
Mobile No.: 9380874094

Introduction:

Magnesium based materials are the lightest of all structural materials. Magnesium is 33% less dense than Aluminum and offers high specific strength (approximately 130 kNm/kg) where weight critical applications are considered. These lightweight materials in structural applications enhance the efficiency of automobiles by reducing mass. Improved efficiency of automobile will further leads enhance the fuel efficiency by reducing fuel consumption. For E.g. If a weight of passenger car is reduced approximately by 10% then it saves 20% -30% of the fuel which directly reduces the burden on the limited sources. However, Magnesium based alloys limits their performance at high temperature application due to their poor ductility, poor stiffness, corrosion resistance, hardness and creep resistance. To overcome limitations of Mg alloys, literature have indicated that use of hard ceramic particles to base alloy will enhance the mechanical properties and can extend high temperature application areas. Various reinforcement through different fabrication methods have been successfully incorporated to the Mg alloys in recent years. Among different reinforcement, SiC, Al_2O_3, AlN, TiB_2, Y_2O_3, ZrO_2 etc. However, these ceramic particles may increase one of the properties such as high strength at the expense of one or other mechanical properties such as hardness or ductility. Therefore, present study aims to develop magnesium hybrid nano composites using nano Al_2O_3 and ZrO_2 as reinforcement to better balance the high strength and ductility. To date, considerable amount of research has been carried out by introducing Al_2O_3 nano particles to achieve better Yield strength and Ultimate tensile strength and few investigations have been carried out on Mg composites containing ZrO_2 nano particles to enhance the corrosion and wear resistance properties. But, as per our knowledge no work has been previously published on Mg composites containing Al_2O_3 and ZrO_2 nano particles. Therefore, present study aims to develop hybrid mg nano composites that can enhance mechanical properties for structural applications.

Keywords: Magnesium, hardness, reinforcement, fuel efficiency

Objectives:

- To develop a hybrid magnesium nanocomposite reinforced with Al_2O_3 and ZrO_2 Nano particles
- To characterize the developed nanocomposite material.
- To evaluate the mechanical properties such as Tensile strength, microhardness and density.
- To study the micro structure, element composition of the developed material.
- Feasibility studies on developed hybrid nano composites for structural applications such as biomedical sectors, aerospace, electronics etc.

Methodology:

1. AZ91 magnesium alloy was selected as a base alloy and it is most widely used alloy in the present world.
2. Al_2O_3 and ZrO_2 nanoparticles were selected as a reinforcement in order to enhance the properties.
3. Stir casting process with stirrer made of ceramic was adopted in order to produce a hybrid composite material.
4. Three different cast blocks were prepared with varying the wt. % of Al_2O_3 and ZrO_2 (0.5%-1.5%).
5. Required pieces were cut by using wire EDM process from each sample.
6. Microstructure & SEM analysis was carried out get the material composition and the see the grain refinement.
7. Vickers Hardness test with 100gf load & 10s dwell time was carried out to get the hardness value of each composition sample.
8. Tensile test was carried out using the UTM having 0.2mm/min strain rate in order to get the tensile strength.
9. Density test was carried out using the Archimedes Principle to know the density value of developed material.
10. Evaluation and discussion were made regarding the project considering the results.

Results and Conclusions:

1. Stir casting method has been successfully used for processing the developed hybrid nanocomposite without any casting defects.
2. The produced cast is cut to desired dimensions by using wire EDM (Electric Discharge Machining) process with minimal burrs and high accuracy.
3. Etching is carried out initially to obtain mirror polished surface by using emery paper (Grit 1200) and cleaned with acetone and dried before each test to get better results.
4. By using Vickers hardness test the microhardness of the developed composite material was increased to 70 to 80 HV as compared to the matrix material Mg AZ91 having microhardness value 50 to 60 HV.
5. SEM (Scanning Electron Microscopy) is used for Microstructure analysis of Mg AZ91 alloy reinforced with Al_2O_3 & ZrO_2. revealed that developed material has refined grain size and shape which improved mechanical properties such as strength, hardness and elasticity.
6. The EDS results of the developed material showed the quantitative information about the relative amounts or concentrations of different elements. It is found that where ever there are clusters there is a higher concentration of reinforcements in that area.
7. In order to determine the strength of the composite material tensile strength was carried out. As mg is a brittle material increase in the hardness may not correspond to an increase in the tensile strength. So, it was found from the test outcome that there is a decrease in the tensile strength compared to the base alloy.
8. As we know that the density of the base alloy Mg AZ91 is 1.74 g/cc. While the density of one of the developed hybrid samples was found to be slightly increased which is 1.8036 g/cc.

Innovation in the project:

1. Societal Contribution: Light weight material for structural applications
   - Aerospace: Aircraft and spacecraft components which includes engine parts, etc.
   - Automotive: Body panels, engine blocks, racing vehicles.
2. Technology Adopted: Flux protected Stir casting
   - Earlier studies reported with the use of SF6 gas to protect Mg melt and use of SF6 increases global warming.
   - Therefore, Harmless flux containing NaCl mixtures are used to protect Mg melt during casting
3. Commercial Implications: Light weight structural applications such as Engine case, steering wheel, automobile body etc.,
4. Magnesium alloys can be introduced as orthopedic biomaterials.
5. These lightweight materials in structural applications enhance the efficiency of automobiles by reducing mass.

Scope for future work:

- The hybrid material can be further improved by optimizing the composition of the reinforcements in the base metal.
- The work can be further carried out by introducing new reinforcements, adopting different processing techniques, wettability enhancement methods and using energy efficient casting procedures.
- The developed hybrid Mg nanocomposite can be further processed by using heat treatment, or any other secondary processing techniques like ECAP (Equal Channel Angular Pressing), FSP (Friction Stir Processing) or rolling to improve its mechanical properties.
- Further many mechanical tests can be carried out so as to suit different mechanical applications.
- Stirring time and speed can be optimized for effective distribution of nano particles and to prevent formation of clusters in the hybrid material.
- Rear earth elements can be used as reinforcements for further enhancement of mechanical properties.

Under The guidance of

Dr. C Siddaraju

Assistant Professor, Department of Mechanical Engineering Dept. of MSRIT
Bangalore -560054

Co- Guide

Dr. Niranjan C A

Assistant Professor in Industrial Engineering and Management Dept. of MSRIT
Bangalore -560054