PROPERTY EVALUATION OF ALUMINIUM 12% SILICON ALLOY REINFORCED WITH ZRO2 PARTICULATES (MMC'S) SUBJECTED TO EXTRUSION PROCESS

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Abstract: *In the present investigation, aluminum alloy (LM 13) is dispersed with Nano-ZrO_2 particles by spray casting technique followed by the hot extrusion process using UTM machine. Aluminum and its alloys are normally grain refined and transfer their columnar structure during solidification into equi-axed one which improves their mechanical behavior and surface quality. In the present work, the effect of addition of ZrO_2 on the metallurgical and mechanical aspects, hardness, ductility and wear resistance of commercially pure aluminum after extrusion is investigated. The results of the study showed that the mechanical properties (strength, elongation and hardness) for the nano-reinforced castings using ZrO_2 were enhanced. In recent years, metal matrix composites have been considered as materials that offer better mechanical properties compared to conventional alloys. This paper is aimed at reviewing the best result techniques to fabricate the Aluminium matrix nano-composite (Al-MNCs).*

Keywords: Reinforcement, Extrusion, Spray Casting, Al-MNC, Hardness.

1. Introduction:

Metal Matrix Composites (MMCs) are engineered combinations of two or more materials (one of which is a metal) where good properties were achieved by systematic combinations of different constituents. Conventional monolithic materials have limitations in respect to achievable combinations of strength, stiffness and density. Engineered MMCs consisting of continuous or discontinuous fibers, whiskers or particles in a metal achieve combinations of very high specific strength and specific modulus. Furthermore, systematic design and synthesis procedures allow unique combinations of engineering properties in composites like high elevated temperature strength, fatigue strength, damping property, electrical and thermal conductivities, friction coefficient, wear resistance and expansion co-efficient. The mechanical components, which are subjected to severe wear, mainly due to sliding action, abrasive, erosion and erosion-corrosion. During the sliding action, the hard ceramic particles protrude the composite surface and resist wear of the material. The sliding wear resistance of the composites with respect to that of matrix material varies with the test parameters. The wear rate of the composite is reported less as compared to that of the alloy. Reinforcement of hard particles in aluminium matrix protects the matrix surface against the destructive action of the abrasive during the wear process.

A Composite is a combination of two or more dissimilar materials having a distinct interface between them such that the properties of the resulting material are greater than the individual constituting components [1]. Composite material is composed of two or more constituent phase (i.e): matrix phase and reinforcement phase. A Metal matrix composite is one of the types of composite in which the matrix phase is predominantly a metal or a metal alloy. The metal is the base material which constitutes the major part and the minor constituents are reinforcements that can be in the form of particles, continuous and discontinuous fibers. The MMC consists of superior properties such as high strength, high stiffness, and high electrical and thermal conductivity, greater resistance to corrosion, oxidation and wear comparable to base material. Aluminium is an ideal material to be selected as a matrix as it consists of desirable properties like abundance, low cost, low density, high strength-to-weight ratio, controlled co-efficient of thermal expansion, increased fatigue resistance and superior dimensional stability at elevated temperatures etc

2. Scope of project work:

For the last few decades, the development of materials shifted from monolithic alloy to composite materials to meet the global industrial needs. Conventional monolithic materials have limitations to achieve good combination of strength, stiffness, toughness and density. To overcome the shortcomings and to meet the ever increasing demand of modern day technology, composites are the most promising materials of recent interest, and continuous advancements have led to the use of composite materials in more and more diversified applications such as aerospace, automobile, biomaterials as well as sports components. The scope of applications of composites being unlimited, these materials will dominate the materials field for a very long period in the years to come. Composites can be tailor made to possess high strength, high toughness light weight, low cost, good damping capacity, wear resistance, corrosion resistance, hardness, conductivity, creep strength, fatigue strength, negative thermal expansion coefficient and unusual combinations of electric, magnetic, and optical properties. The examples of naturally occurring composites are shell, wood, bone, and teeth.

3. Methodology:

- Melting of aluminium alloy ingots in graphite crucible using electrical resistance heating furnace (melting up to 750°C for 4hrs).
- Preheating of reinforcement (ZrO_2) separately in furnace up to 600°C
- Mixing of reinforcement to the molten metal using mechanical stirrer.
- The Reinforcement treated melt is poured into the crucible fitted with nozzle to disintegrate the molten alloy into fine droplet using inert gas.
- The droplets of the molten alloy are collected on the copper substance kept at 300mm from the nozzle tip.
- The Reinforcement treated molten metal is also poured into metal die of dimension (150mmx150mmx10mm).
- The developed composites are subjected to hot compression under suitable pressure using UTM.
- Micro structural studies are carried out to reveal the effect of weight percentage additions of Nano ZrO_2 and the effect of chills on the composite. Polished and etched specimens are observed using optical metallurgical microscope and Scanning electron microscopes. Morphology test to reveal size and distribution of particulate Zircon is carried out.
- Testing of standard American Foundry men Society (AFS) specimens for ultimate tensile strength (UTS), percentage elongation and hardness (BHN) are carried out in order to investigate the Zircon additions effect. In order to understand the fracture type and interfacial deformation.

Dry sliding wear test using computerized pin-on-disk wear testing machine is carried out to know the influence of varying percentages of nano-ZrO_2 on the wear rate.

4. Results and discussion:

In this investigation, Al-12% Si alloy /Nano-ZrO_2 particulate composites are casted by spray-casting under controlled heat transfer condition. The fabrication of the composites are carried out weight fractions of Nano-Zircon particulates .The resulting composites are suitably machined and tested for their microstructures, mechanical properties, sliding wear behavior, . This section presents and discusses the results of the testing and analysis of the developed Al-12% Si alloy/Nano-Zro_2 composites subjected to extrusion.

4.1. Micro structural study

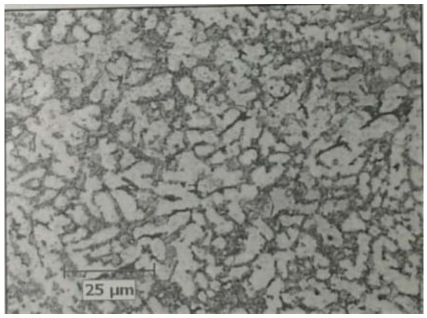


Fig. 1: Kellers Etched 500X

Results obtained at higher magnifications as in figure 1) reveals interfacial characteristics of the composite signifying strong bond without interfacial reaction. Enhancement of tensile strength of the composite compared to the base alloy quantitatively establishes the strength of the bond. Study on an isolated Nano-Zircon particulate in the matrix reveals micro structures as shown in the figures Particle pushing and segregation revealed during the study are as shown in figures.

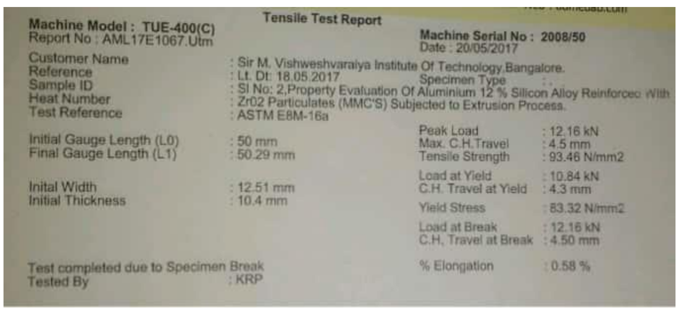
Microstructures Consist of Fine Eutectic Silicon Uniformly Dispersed in Interdendritic Matrix Of aluminium Solid Solutions. Particles Are Uniformly Dispersed.

4.2. Mechanical Properties (Strength and Hardness)

4.2.1. Ultimate Tensile Strength (UTS)

Tensile tests on AFS standard tensile hot rolled specimens of composites are carried out to determine their ultimate tensile strength and percentage elongation values. The tests are conducted on composite specimens taken along the length of the composite from similar locations. Composites with Nano Zircon percentages of 3wt.%, 6wt.%, 9wt.% and 12wt.%. Average of three UTS values is recorded for each of the composite specimen for different dispersed content In several of the earlier research findings on ceramic reinforced metal matrix composites, it has been reported that there exists an optimum reinforcement percentage for which the mechanical properties are maximum.

Increase in tensile strength (reinforcement up to 9%) is also attributed to increase in grain boundary area due to grain refinement, built of thermal stresses (due to chilling) at the interface due to different Coefficient of Thermal Expansion (CTE) and effective transfer of applied tensile load to the uniformly distributed well bonded reinforcement.



Tensile Test Report

Machine Model : TUE-400(C)
Report No : AML17E1067.Utm

Machine Serial No : 2008/50
Date : 20/05/2017

Customer Name : Sir M. Vishweshvaraiya Institute Of Technology,Bangalore.
Reference : Lt. Dt: 18.05.2017 Specimen Type :
Sample ID : Sl No: 2,Property Evaluation Of Aluminium 12 % Silicon Alloy Reinforced With
Heat Number : Zr02 Particulates (MMC'S) Subjected to Extrusion Process.
Test Reference : ASTM E8M-16a

Initial Gauge Length (L0) : 50 mm
Final Gauge Length (L1) : 50.29 mm

Inital Width : 12.51 mm
Initial Thickness : 10.4 mm

Peak Load : 12.16 kN
Max. C.H.Travel : 4.5 mm
Tensile Strength : 93.46 N/mm2
Load at Yield : 10.84 kN
C.H. Travel at Yield : 4.3 mm
Yield Stress : 83.32 N/mm2
Load at Break : 12.16 kN
C.H. Travel at Break : 4.50 mm
% Elongation : 0.58 %

Test completed due to Specimen Break
Tested By : KRP

Fig.2: Tensile report of composite material

Fig.3: Specimen before subjecting to tensile test

Fig.4: Specimen after subjected to tensile test

4.3. Discussion:

Strength of ceramic materials lies much higher than metallic materials as the UTS of the composite developed is higher than that of the matrix alloy. Under the applied stress, increasing the amount of grain boundaries acts as obstacle to the dislocation movement and end up with dislocation pile up at the grain boundary region. Again, multi-directional thermal stress induced during processing easily starts multi-gliding system under applied stress so that dislocations were found developing and moving in several directions. These multiglide planes agglomerate under the applied stress forms grain boundary ledges. As applied load increases, these ledges act as obstacle to dislocation movement resulting in pile-ups. The coupled effect of these two obstacles leads to increase in the strength of the composite.

5. Conclusion:

Nano composites developed showed an improvement in the UTS, hardness and wear resistance (maximum load and constant sliding distance). This is due to the fact that the reinforcement content and its size as evaluated by the morphological and micro structural analysis in the composite were found to be relatively small and this has resulted in the ductile behavior of the composite which has influenced the above properties. However the wear resistance was found to be influenced by the chill end specimen wherein due to the decreased casting defects like microporasity and microvoids and improved grain refinement, the specimen exhibits good wear resistance. Small size and content of the reinforcement in the composite resulted inthe deterioration of the thermal property of the composite.

Thus it is concluded that the nano composite developed exhibits good tensile strength, hardness and wear resistance properties. Following are the consolidated conclusions of the present Investigation based on the experimental results and discussions.

- Successful fabrication of Al-12%Si alloy/Nano-Zircon pa.rticulate composite has been made under the influence of chill material and varying additions of zircon in weight fraction

- The Micro structural study reveals that the Nano-Zircon particulates are uniformly distributed in the composites and no-interfacial reactions are seen under higher magnifications.

- The dispersion of Nano-Zircon particles in to Al-12% Si alloy melt significantly increases UTS and hardness values, but decreases the percentage elongation in comparison with the matrix alloy. The UTS and hardness has increased with the additions zircon. The limiting value of zircon addition is obtained and, the strength and hardness properties reduce with further increase zircon. UTS and hardness for the base alloy are 59.98 N/mm2 as against 93.3 N/mm2 and 59.3 BHN of the composite with zircon

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