RESEARCH REVIEW JOURNALS
Volume-04
Issue-01
January -2019

ISSN: 2455-3085 (Online)
RESEARCH REVIEW International Journal of Multidisciplinary
www.rrjournals.com [UGC Listed Journal]

A Study on Enhancement of Mechanical Properties in Particulate Reinforced MMC (Metal Matrix Composites)

[1]Vijay Lavdia and [2]Dr. G.R. Selokar

[1]Research Scholar, SSSUTMS -Sehore, MP.
[2]Professor of Mechanical Engineering Department, SSSUTMS-Sehore MP.

ARTICLE DETAILS

Article History
Published Online: 20 January 2019

Keywords
mechanical, tribological, thermal, metallic, matrix, Composites.

ABSTRACT

In this paper we have discussed about enhancement of mechanical properties of MMC. Metal Matrix Composites are made out of a metallic matrix (aluminum, magnesium, iron, cobalt, copper) and a dispersed ceramic (oxides, carbides) or metallic (lead, tungsten, molybdenum) phase. This paper deals with the detailed experimental strategy carried out in the current investigation. As referenced in the past chapters the work was aimed at creating chilled aluminum alloy-Nano ZrO2 particulate MMC for automotive, defense and other structural applications. In this manner, the alloy chose was LM 13 which is widely utilized in the automobile industries for the manufacture of cylinder and chamber sleeves. Further, the investigation was carried out at the chill end of castings, which was done to study the impact of the chill on the microstructure, mechanical, tribological, thermal behavior of the composites.

1. Introduction

Metal Matrix Composites are made out of a metallic matrix (aluminum, magnesium, iron, cobalt, copper) and a dispersed ceramic (oxides, carbides) or metallic (lead, tungsten, molybdenum) phase. In metal matrix composites, aluminum, magnesium, titanium and nickel-based alloys are generally utilized as matrix materials. In MMCs, aluminum alloys are generally utilized as matrix materials and strengthened with ceramic particles. In comparison with organic matrices, MMC have some attractive properties. These are solid at higher temperatures, higher transverse strength, great electrical conductivity; higher disintegration resistance, better thermal conductivity and so forth Metal matrix composites can be used at higher elevated temperatures. Notwithstanding, Metal matrix composites have the limitations, for example, higher density, lower mechanical properties when compared to polymer matrix composite and the fabrication of Metal Matrix Composites which is also challenging and costly one.

2. Literature Review

T.Somasekhar, P Niteesh Kumar (2018) several specialized difficulties exist with casting technology yet it tends to be utilized to defeat this issue. Accomplishing a uniform appropriation of support inside the matrix is one such test, which influences legitimately on the properties and nature of composite material .In the present investigation an unassuming endeavor would be made to create Aluminum based silicon carbide particulate MMCs with a goal to build up a regular low cost strategy for delivering MMCs and to get homogenous scattering of ceramic material. To accomplish these targets two stage blending strategy for mix casting system has been proposed and ensuing property investigation has been made. Aluminum (98.41%) and SiC (320-coarseness) has been picked as matrix and fortification material individually. Aluminum alloys are generally utilized in aviation and car enterprises because of their low density and great mechanical properties, better corrosion resistance and wear, low warm coefficient of extension when contrasted with customary metals and alloys. The brilliant mechanical properties of these materials and moderately low creation cost make them an appealing contender for an assortment of utilizations both from logical and innovative perspectives. The point engaged with planning aluminum based metal matrix composite materials is to consolidate the alluring qualities of metals and Ceramics.

M. Haghshenas (2016) over most recent two decades researchers and makers, i.e., car and aviation, have paid considerations and interests to metal–matrix composites (MMC) inferable from their extraordinary physical/mechanical properties and performance. MMC have prevalent mixes of raised temperature capacities, high warm conductivity, high strength and solidness, high strength-to-density proportion, and low coefficient of warm extension. In this Chapter, upon a general prologue to composite materials, the properties of fortification and matrix materials and the properties of MMC, specifically, are audited. To this end, microstructure, structure thought, creation techniques, strengthening components, matrix/support based orders and uses of MMC are tended to in detail in the following Chapter.

H.A. Kishawy (2012) Metal matrix composite materials (MMCs) offer different mechanical properties that are not offered by traditional unreinforced monolithic metal partners; explicitly, high temperature stability, explicit strength, and wear resistance. Accordingly, these composite materials have various applications in a few ventures including car and aviation. Notwithstanding, machining of MMCs still remains a test Understanding the assembling techniques, strengthening components and consequently mechanical properties of MMCs is critical to perception of their twisting conduct during machining and the subsequent work piece surface trustworthiness and instrument wear. This part depicts the sorts of composites and their interesting physical properties. Also, the cutting performance of some composite materials is talked about.

Chennakesava Reddy (2011) The matrix compound Al 6061 contributes exceptionally huge estimations of yield strength, extreme tensile strength, pliability and twisting power to the Al-amalgam/SiC metal matrix composites. The matrix amalgam 7072 shows lower pliability to the Al-combination/SiC metal matrix composites than the matrix compound Al 6063. Mg improves the wettability among Al and SIC particles by lessening the SiO2 layer on the outside of the SiC. The SiC particles are disseminated unevenly in the as-cast composite with no particular proof of bunching however next to no agglomeration. MgO and $MgAl_2O_3$ are framed along the grain limits. The stages Al_2Cu, Mg_2Si, $Al_5Mg_8Cu_2Si_5Al_3Fe$ and Al3FeSi are additionally seen in the microstructures of Al-compound/SiC composites. With expanding volume portion, more load is transferred to the support which results in a higher yield strength, extreme tensile strength and bowing power to the Al-combination/SiC composites. The diminishing in flexibility can be ascribed to the prior beginning of void nucleation with expanding measure of support in Al-compound/SiC metal matrix composites. The decline in the particle size expands the yield strength, extreme tensile strength, bowing power and flexibility (tensile extension).

A.Thirumoorthy K.L.Senthil Kumar (2018) the utilization of aluminum based composite is expanding step by step in the whole assembling areas because of their exceptional properties, for example, high strength to weight proportion, great mechanical properties and better toughness. Along these lines a ton of research has occurred in aluminum composite material with expansion of carbides based particulate fortification. Be that as it may, in the present aggressive market, the assembling divisions look for the better properties, producing simple nature and eco-accommodating based materials. It's seen that there is colossal research hole for great properties improvement and eco-accommodating materials. This present investigation surrenders sump of the most recent advancements occurred in aluminum based composite and other particulate support impacts. The tribologoical conduct of aluminum based composite has been secured. This investigation is centered on AA6061 and AA7075 compound because of business simple accessible and it's broadly utilized for basic reason in assembling segments. From this ebb and flow contemplate, it's unmistakably recognizes that the many research has been done uniquely on expansion of carbides and couple of oxides based reinforcements. No much sufficient research on expansion of nitrides and oxides particulates support in aluminum alloys has been finished. The properties can be improved by expansion of nitrides fortification and furthermore by mix of oxides with nitrides. Indeed, even there is research hole in usage of development portrayal methods in composites portrayal examine.

3. Research Methodology

This paper deals with the detailed experimental strategy carried out in the current investigation. As referenced in the past chapters the work was aimed at creating chilled aluminum alloy-Nano ZrO2 particulate MMC for automotive, defense and other structural applications. In this manner, the alloy chose was LM 13 which is widely utilized in the automobile industries for the manufacture of cylinder and chamber sleeves. Further, the investigation was carried out at the chill end of castings, which was done to study the impact of the chill on the microstructure, mechanical, tribological, thermal and electrical behavior of the composites.

Materials

The chemical composition of the base metal used in this investigation to produce the chilled composite was analyzed using optical emission spectrometer BAIRDAS and the compositions of the base alloys are as given below in wt%.

Table 1 Chemical composition of supplied Aluminum alloy Series (LM 13).

Elements	Zn	Mg	Si	Ni	Fe	Mn	Al
% by wt	0.5	1.4	12	1.5	1.0	0.5	Bal

Table 2 Properties of standard aluminum alloy (LM 13)

Properties	Values
VH	130
Density g/cc	2.7
UTS M.Pa..	220
CTE at 20^0C $\mu m/^0C$	19
Thermal conductivity (25^0C) W/mK	185

Micro hardness test

The Micro hardness of the examples was resolved utilizing a Zwick/Roell Indentec Hardness Tester with load range of 10 to 1000 gms. The item focal point magnification was from 10x to 40x. The load applied was 0.05 kgs for 10 secs and the indentation was recorded at 40X magnification. Diamond cone indenter was utilized. The test was carried out at five unique locations of the examples and the average was recorded. The examples utilized for microstructure evaluations were utilized for this reason. Fig 1 shows the Micro Hardness Tester utilized in the study.

Fig 1 Micro Hardness Tester

Tensile Test

The test was carried out on an Instron strain testing machine. The machine was controlled by DSP based digital controller with 24 cycle resolution Signal conditioners for stroke (LVDT), load and two channels of strain Loaded with required firmware and basic software. The transducers comprised of Extensometer with 12.5 mm gage length and travel of ± 0.5 mm, COD gage with gage length of 7mm and travel of + 4 mm and - 1 mm. The transducers included electronics for full extension circuit along with external shunt reference for easy calibration. The Furnace was a 3210 arrangement ATS Make with a Maximum temperature - 12000 C, and a force pack of 3 Zone, 4000 watt, 230 V. The test was led at an ambient temperature of 27ºC. The test was performed with uniaxial loading till failure.

Wear Test

The wet wear test was carried out according to ASTM G 99 standard utilizing the PC integrated wear and friction monitor TR-201CL (Ducom make) Pin-On-Disk wear tester with plate speed from 0-800 rpm, load 0-100 N, and frictional force 0-100 N. The integrated software was LABVIEW 6.0. The specimen utilized was the same as those utilized in the thermal conductivity test. The plate is alloyed steel with HRB 120 having a diameter of 120 mm and thickness 10 mm. The surface of the pin was cleaned with acetone before the test. The test was carried out by applying normal load on pin from 10 N to 50 N in steps of 10 N for a time-frame of 300 seconds duration at a constant plate speed of 400 rpm. At the finish of 300 sec the decrease in weight was resolved utilizing an electronic balance. The outcome obtained in weight misfortune is changed over to wear rate of pin expressed in mm3/m. The test facility is as appeared in Fig 2.

Fig 2 Pin-On –Disc wear tester

Thermal Conductivity Test

The test was directed by the instrument that was fabricated solely for the reason since there were no standard instruments available in any of the testing facilities. ASTM E1225 – 99 was alluded during the test set up preparation. Basic Fourier law of conduction idea for unidirectional steady state conduction heat flow was utilized for the heat flow measurements. The test specimens were machined to the necessary dimensions as appeared in the Fig 3.14. The Nicrome heater (φ8mmx75mm) with a sleeve was embedded into the cylindrical gap of the specimen as appeared in the Fig 3.13. The specimen was completely insulated with asbestos thread to forestall any heat misfortune to the environmental factors.

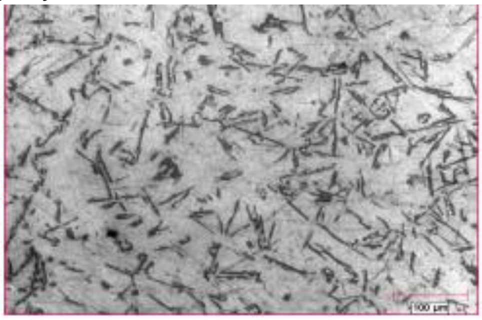
4. Results and discussions

In this investigation, Al-12%Si alloy/Nano-Zircon particulate composites are fabricated utilizing DMD technique of stir-casting under controlled heat transfer condition gave by an end-chill. The fabrication of the composites are carried out by adding 3%, 6%, 9% and 12% weight fractions of Nano-Zircon particulates in the size range of 50-80 nm. The subsequent composites are suitably machined and tested for their microstructures, mechanical properties, sliding wear behavior, electrical properties, thermal properties and carburization. This section presents and talks about the consequences of the testing and analysis of the created Al-12%Si alloy/Nano-Zircon composites.

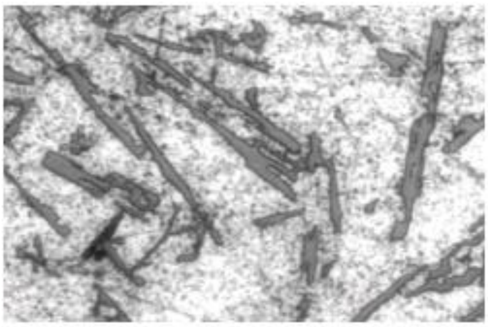
Al-12%Si Alloy/Nano-Zircon Composite

Micro-structural study

The micro-structural study is led on the hot rolled specimens drawn near the chill-composite interface so as to understand the impact of end-chills. The microstructures of the base alloy at various magnifications are as appeared in Fig. 3(a) and Fig.3 (b). The microstructure of the base alloy shows silicon needles dispersed all through the alpha phase of aluminum. The micro structure reveals that the base alloy isn't altered by any additives.



3 (a)

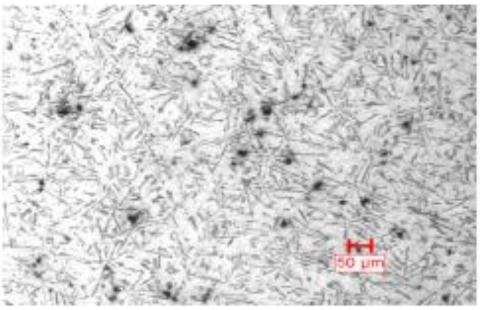


3(b)

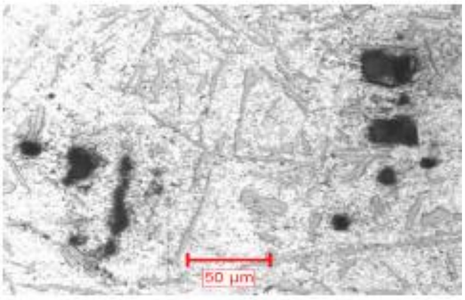
Fig. 4.1(a) & (b) Microstructures of the Al-12%Si alloy as seen at 100X and 500X respectively.

The microstructure of Al-12%Si alloy/Nano-Zircon composite is at various magnifications appeared in figure 4 speaks to uniform distribution of Nano-Zircon (50-80 microns) all through the matrix. Detailed study of particulate distribution in the matrix affected by chill is introduced later.

Results obtained at higher magnifications as in figures 5(a) and 5 (b) reveals interfacial characteristics of the composite connoting solid bond without interfacial reaction. Enhancement of tensile strength of the composite compared to the base alloy quantitatively establishes the strength of the bond.

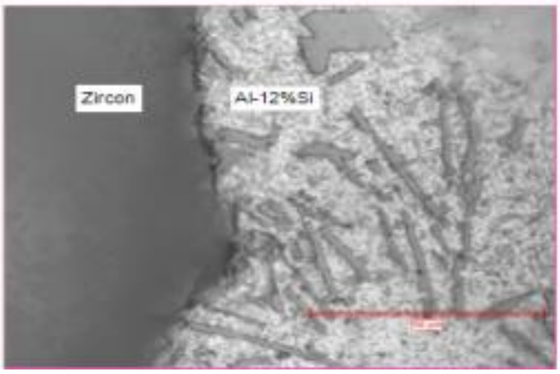


4 (a)

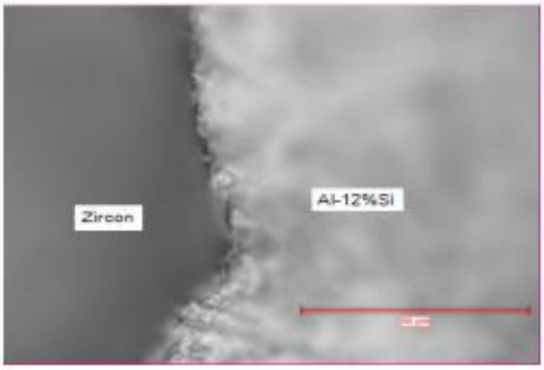


4 (b)

Fig. 4 (a) & (b) Microstuctures of chilled Al-12Si alloy/Nano-Zircon composite at 50X and 200X respectively.



5 (a)



5 (b)

Fig. 5 (a) & (b) Microstructures of the Interface between Al-12Si alloy matrix and the Nano-Zircon particulate in the composite as seen at high magnification (1000X).

Mechanical Properties (Strength and Hardness)

Ultimate Tensile Strength (UTS) and Percentage Elongation.

Tensile tests on AFS standard tensile hot rolled specimens of composites are carried out to decide their ultimate tensile strength and percentage elongation values. The tests are led on composite specimens taken along the length of the composite from similar locations. Composites with Nano Zircon percentages of 3wt%, 6wt%, 9wt% and 12wt% cast affected by chill block is thought of. Average of three UTS values is recorded for each of the composite specimen for various dispersoid content.

Figure 6 shows the impact of Nano-Zircon additions in composites on UTS cast affected by chill block. The UTS values of the composites have increased with the increase of Nano-Zircon percentage from 3wt% to 9wt% and thereafter decrease with additional addition of 12wt%. It is seen that, UTS value has been the maximum at 9wt% Nano-Zircon addition. In several of the earlier research discoveries on ceramic reinforced metal matrix composites, it has been reported that there exists an ideal reinforcement percentage for which the mechanical properties are maximum. The percentage of Nano-Zircon past the ideal value generates voids leading to easy propagation of cracks during deformation leading to decreased strength values.

The impact of chill material on the strength properties is found clearly. The composites created with an end-chill block with 9 wt.% reinforcement have demonstrated the highest UTS value as compared with different composites. Since the volumetric heat capacity (VHC) of the chill block is more, increased solidification rate probably favored the gain in strength. Further, cooling rate by the end-chill have invigorated increased values which indicate the impact of chill material.

.

Table 3Mechanical properties (strength and hardness) of Nano-MMCs and matrix alloy.

Property wt% ZrO_2	Hardness, VHN	0.2% Yield Strength, MPa	UTS, MPa	Elongation %
3	135	136	245	9.7
6	145	157	253	8.4
9	153	166	277	7.7
12	148	158	262	4.1
Matrix Alloy (LM 13)	130	120	220	12.51

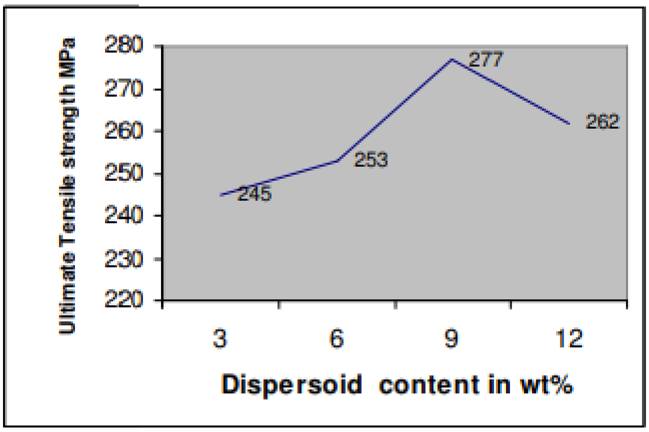


Fig.6 Ultimate tensile strength values of Al-12%Si alloy/Nano-Zircon composites with different Nano-Zircon percentages.

Table 4 Tensile and Hardness values of Al-12%Si alloy (matrix material).

UTS (MPa)	Percentage elongation	Hardness (VHN)
220	**12.51**	**130**

The percentage elongation values for different percentages of NanoZircon additions vary in the range of 2.81-7.41% and have decreased as compared to 4.81% of the matrix alloy (Table 3 & 4). There has been a maximum gain of 25.9% in UTS values and a decrease of 4.81% percentage elongation values in composites with 9 wt% Nano-Zircon additions compared to matrix alloy.

Thermal Conductivity (K)

In general thermal conductivity 'K' of the composite relies upon the weight fraction addition of the dispersoid, its distribution, size and thermal conductivity. Studies led by different researchers demonstrated that thermal conductivity of the MMCs relies upon the size and shape of the reinforcement. This advantages the current investigation in that lower thermal conductivity because of addition of ZrO2 as reinforcement brings about lower heat misfortune from the motor bringing about an increase in thermal proficiency. Table 5 shows thermal conductivity results obtained at various temperatures for chilled NMMCs cast with various wt % of dispersoid substance.

Table 5 Thermal conductivity of Al- nano ZrO_2 composite for different wt% of dispersoid tested at different temperatures.

Dispersoid Content Temperature	Thermal Conductivity 'K', w/mk			
	3 wt % dispersoid	**6 wt% dispersoid**	**9 wt % dispersoid**	**12 wt % dispersoid**
100^{0}C	428.95	422.55	419.37	414.04
150^{0}C	411.82	409.86	403.28	401.83
200^{0}C	401.87	393.82	384.11	378.23
250^{0}C	367.12	361.32	358.77	350.12

5. Conclusion

The composites were created utilizing DMD technique of Stir casting followed by hot rolling technique because of its uniform blending capability and economy of operation. All the matrix alloy is reinforced with the Nano-ZrO_2 particles, which were about 50-80 nm in size and had an aspect ratio of almost solidarity. In spite of the fact that 9 wt% of the reinforcement was added during casting it was seen that a portion of the added reinforcement separated out of the molten metal and floated on the surface regardless of ceaseless stirring. This may be attributed to the non wetting of the reinforcement particles by the molten alloy. Hence during the morphology and microstructure analysis it was seen that the reinforcement was uniformly dispersed in the matrix. This might have been forestalled by utilizing a two stage method of blending where the particles start settling down the slurry is heated again above its liquids temperature and then stirred. This is found to enhance homogenous blending. Successful fabrication of Al-12%Si alloy/Nano-Zircon particulate composite has been made affected by chill material and varying additions of zircon in weight fractions. Thermal conductivity decreases as dispersoid substance and temperature increases and this outcome in lower heat misfortune. CTE of Al-Nano ZrO_2 chilled 174 composite were found to decrease linearly with increasing the dispersoid content, to as much as 44.82% not as much as that of aluminum alloys and it increases linearly with temperature. It was also discovered that microstructure of the carburized samples also changes with the deposition of carbon particles.

References

1. T.Somasekhar, P Niteesh Kumar (2018) REVIEW PAPER ON PROCESSING OF METAL MATRIX COMPOSITES & ITS PROPERTIES. © 2018 IJCRT | National Conference Proceeding NTSET Feb 2018 | ISSN: 2320-2882
2. M. Haghshenas, in Reference Module in Materials Science and Materials Engineering, 2016

3. H.A. Kishawy, in Machining Technology for Composite Materials, 2012
4. CHENNAKESAVA REDDY (2011) EVALUATION OF MECHANICAL BEHAVIOR OF Al/SiC METAL MATRIX COMPOSITES WITH RESPECT TO THEIR CONSTITUENTS BY TAGUCHI'S TECHNIQUES" i-manager's Journal on Mechanical Engineering, Vol.1, No.2. February – April 2011"
5. A.Thirumoorthy K.L.Senthil Kumar "Latest Research Development in Aluminum Matrix with Particulate Reinforcement Composites – A Review Volume 5, Issue 1, Part 1, 2018, Pages 1657-1665
6. Hayashi T., H. Ushio and M. Ebisava,"The Properties of Hybrid Reinforced Metal and its application for Engine Block", SAE paper 890557.
7. Humphreys F. (1988), J., Proc. 9th Risø Int. Symp. On Mechanical and Physical Behavior of Metallic and Ceramic Composites, S. I. Anderson, H. Lilholt, O. B. Pederson (Eds.), Risø National Laboratory, Roskilde, pp. 51– 74.
8. Humphreys F. J., A. Basu, M. R. Djazeb, (1991), Proc. 12th Risø Int. Symp. on Materials Science, Metal-Matrix Composites–Processing, Microstructure and Properties, N. Hansen et al. (Eds), Risø National Laboratory, Roskilde, pp. 51–66.
9. Hosking F.M.,F.Folgar Portillo, R.Wunderlin and R Mehrabian, (February 1992), Journal of materials science,Volume17,number 2, pp.477-498.
10. Hanumanth G.S. and G.A., (1996) Irons, Metall. Mater. Trans. B, vol.27B, pp.663-71.