5th World Conference on Applied Sciences, Engineering& Technology
02-04 June 2016, HCMUT, Vietnam

Development of Aluminium Based Hybrid (AA5083/FLYASH/SiC_p) MMCs for Ship Building Applications

TUSHAR SONI[1], S MANISH[1], V.K. HARSHAVARDHAN[2], SANDEEP RAMINI[3], RUDRANAIK M[1], AVINASH L[1], MURALIDHAR AVVARI[4]

[1]Department of Mechanical Engineering, Nitte Meenakshi Institute of Technology, Bangalore, India
[2]Department of Mechanical Engineering, SRM University, Kattankulathur, Kanchipuram, Tamil Nadu, India
[3]Department of Mechanical Engineering, Anurag Group of Institutions, Hyderabad, India
[4]Department of Mechanical Engineering, University of Johannesburg, Johannesburg, South Africa
Email: tushar.soni10@gmail.com, manish.sm52@gmail.com, harshavardhan_scorpio@yahoo.co.in sandeepramini92@gmail.com, rudranaik87@gmail.com, avinashlakshmikanthan01@gmail.com, mavvari@uj.ac.za

Abstract: In this investigation, A5083(Al-0.4%Si-4.5%Mg-0.4%Fe-0.4%Mn) alloy/Fly ash/SiCp Hybrid composites with various weight fractions of fly ash and SiCp were prepared by using electromagnetic stir casting process. Microstructure, hardness, tensile, compression and impact test properties of these composites were evaluated and compared with as-cast alloy. In addition, tribological properties of these composites were evaluated using a Pin-on-Disc apparatus at a constant sliding velocity of 2m/s and pressure of 0.35 MPa. Microstructural observation suggests that electromagnetic stirring action produces cast high performance hybrid Aluminium 5083/Fly ash/SiCp MMC with smaller grain size and there is a good particulate matrix interface bonding. The mechanical properties of composites increased with increasing the weight percentage of fly ash and SiCp upto certain percentage and then decreased. The present paper highlights the salient features of casting technique and characterization of aluminium alloy A5083 and alumina metal matrix composite.

Keywords: *A5083, Permanent Mould Casting, Sliding Velocity, Reinforcement, Microstructure, Tribology*

Introduction:

Aluminium Matrix Composite Material Advanced composite material like Al/SiCP metal material composite is gradually becoming very important materials in manufacturing industry i.e. Aerospace automobile and auto industry due to this superior property such as light weight low density High strength to weight ratio, high hardness high temperature, high fatigue strength etc.[1]Mohanty et al. [2] have studied the characteristics of aluminium 6061/SiCP and Al2O3 reinforcement particle metal matrix composite. In their work Aluminium MMCs are fabricated by melt stirring technique and the MMC bars are prepared with varying composition of SiCp reinforced by weight fraction ranging from 3% to 7%. The stirring process was carried out at 400 rpm /min rotating speed by ceramic coated starrier for 20 minutes. Samuel et al. [3] studied the effect of the solidification rate on the silicon carbide particle distribution in an A359 alloy they found that the inter-particle distance distribution for the silicon carbide particle composites proved that finer dendrites arm spacing produces a more uniform distribution, while higher spacing leads to particle clustering.L. Ceschini et al. [4, 5] studied on forging of the AA6061/23 vol. % Al2O3p & AA2618/20 vol. % Al2O3p composite, and its effects on microstructure and tensile properties. They have shown that forging process induced a slight increase in hardness, tensile strength. Ismail Ozdemir et.al [6] studied the effect of forging on the properties of particulate-SiC reinforced aluminium-alloy composites. They have shown that the forged samples had strength values superior to those of the as-cast counterparts. After forging, the yield strength and tensile strength increased and there has been tremendous improvement in ductility of the composite material. Studies on processing and properties evaluation of Al matrix reinforced composites are Scarce. In the present work Fabrication and characterization of A5083/ Flyash/SiCp hybrid MMCs, Micro structural, Mechanical and Tribological Properties are studied.

Materials and Methods:

Aluminum alloy A5083 of known materials was used and flyash and silicon carbide particles were used for the reinforcement materials. Some of the properties of matrix and reinforcement material are given in table1 and 2 respectively. SiC and flyash of average particle size ~400μm and 6 μm has been selected for the present investigation. Three types of composites were fabricated using permanent mould die casting. In addition, the alloy was also cast for comparison purposes. The mechanical properties of Alumina, designation of the alloy and composites is given in Table 3 and Table 4 respectively.

WCSET 2016039 Copyright © 2016 BASHA RESEARCH CENTRE. All rights reserved

Table 1: Properties of A5083

Properties	Values
Density	2.66g/cc^3
Melting Point	550-615^{o}C
Elastic Modulus	71.7GPa
Poisson Ratio	0.33

Table 2: Chemical Composition of A5083

Element	Weight %
Zn	0.03
Fe	0.17
Ti	0.04
Cu	0.01
Si	0.16
Pb	0.014
Mn	0.52
Mg	5.1
Cr	0.09
Al	Balance

Table 3: Properties of Silicon Carbide

Properties	Values
Density	3.21 g/cc^3
Melting Point	2730^{o}C
Elastic Modulus	410GPa
Poisson Ratio	0.4

Table 4: Chemical composition of flyash

MgO	5-6%
SiO_2	30-60%
Al_2O_3	11-19%
Fe_20_3	5-6%
CaO	2-45%
Trace Elements	Na,B,K,Mo,Cr

Table 5: Designation of Alumina reinforced Alloy

Sl. No	Alloy/ Composition	Alloy Designation
1.	Al5083+3%SiC+2%Flyash	5SF
2.	Al5083+5%SiC+2%Flyash	7SF
3.	Al5083+7%SiC+2%Flyash	9SF

The aluminium fly ash metal matrix composite was prepared by stir casting route. For this work we took 400gm of commercially pure aluminium 5% silicon carbide particles and desired amount of fly ash particles. The fly ash and SiCp particle was preheated to 400^{o}C for three hour to remove moisture. Commercially pure aluminium was melted in a resistance furnace. The melt temperature was raised up to 800^{o}C and it was degassed by purging hexa chloromethane tablets. Then the melt was stirred with the help of a mild steel turbine stirrer. The stirring was maintained between 5 to 7 min at an impeller speed of 200 rpm. The melt temperature was maintained 750^{o}C during addition of reinforcements. The dispersion of fly ash particles were achieved by the vortex method. The melt with reinforced particulates were poured into the preheated permanent metallic mold. The pouring temperature was maintained at 780^{o}C.The melt was then allow to solidify the moulds. The composites were made with a different amount of silicon carbide and flyash particles respectively (i.e.5, 7, 9, wt %(SiC) and 2 wt %(flyash) constant).Slow and steady addition of reinforcements was carried out at semi liquid state to improve wettability.

Composite mixture was poured into permanent cast iron moulds having diameter 22mm and length of 220 mm at a pouring temperature of 780^{0}C.

The prepared composites were characterized by microscopic studies. Specimens of 12mm diameter and thickness of 10mm were cut from the central portion of the casting for micro structural studies conducted using To investigate the mechanical behaviour of the composites the hardness and tensile tests were carried out using Brinell hardness tester and computerized uni-axial tensile testing machine and for each of the composite three tests were conducted and average value is reported and wear properties will be evaluated using pin-on-disc wear testing machine to note the extent of improvement. Finally, the improvement in the properties obtained was correlated with micro structural studies.

Results and Discussions:

Microstructure

It is observed from the microstructure that there is a fairly uniform distribution of the reinforcing phase in the matrix alloy. With quite a few agglomerations. Further it is observed that the size of the grain has reduced with increase in the percentage of the reinforcing phases. This can be attributed to the fact that fly ash of some extent acts as a grain refiner.

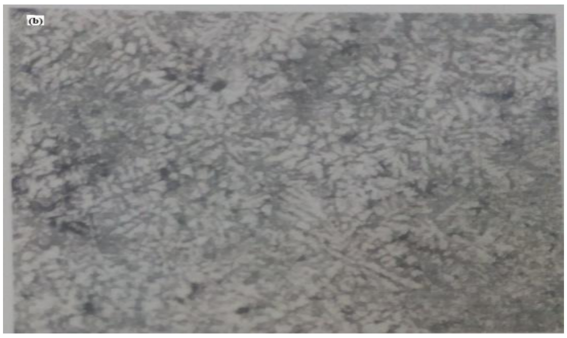

Fig.1 (a) Microstructure of 5SF (Al5083+3%SiC+2%Flyash)

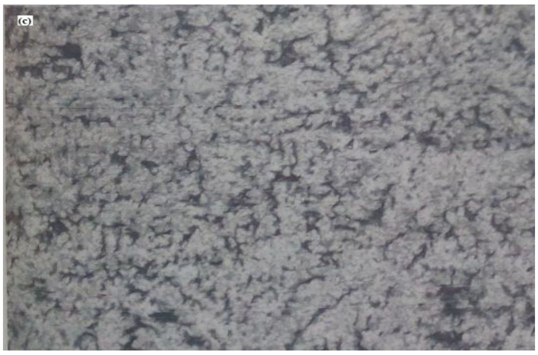

Fig.1 (b) Microstructure of 7SF (Al5083+5%SiC+2%Flyash)

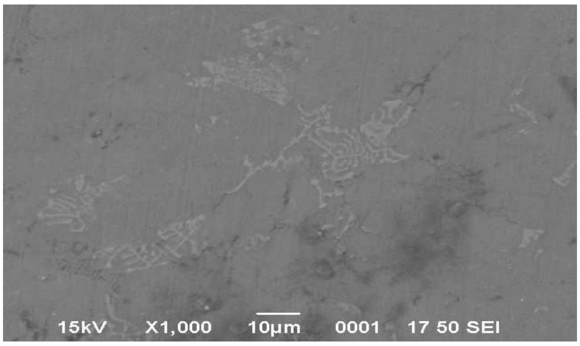

Fig.1 (c) Microstructure of 9SF (Al5083+7%SiC+2%Flyash)

Fig.1: Microstructure of as-cast and its Composites. SEM Microstructures

As the microstructure plays an important role in the overall performance of a composite and the physical properties depend on the microstructure, reinforcement particle size, shape and distribution in the alloy, prepared samples were examined using a Scanning electron microscope (SEM) to study the distributions pattern of Fly ash in the matrix. The micrograph shown in **Fig 2.** Intermetallic particles are formed due to reaction between silicon carbide and fly ash.

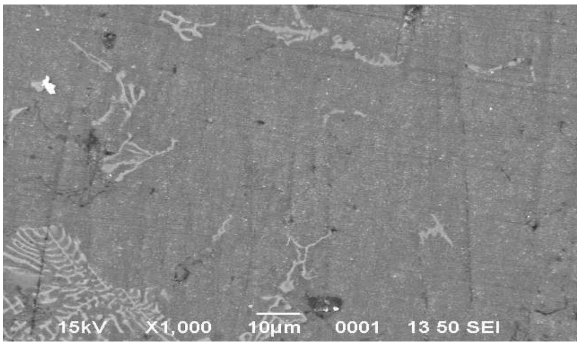

Fig.2 (a) SEM Image of 5 SF (Al5083+3%SiC+2%Flyash)

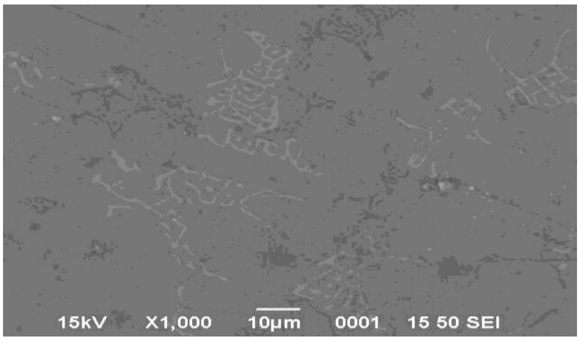

Fig.2 (b) SEM Image of 7SF (Al5083+5%SiC+2%Flyash)

Fig.2 (c) SEM Image of 9SF (Al5083+7%SiC+2%Flyash)

Fig.2: SEM Images of as-cast and it's Composites

Mechanical Properties

The mechanical properties values of hardness, tensile (UTS, YTS, % Elongation), Compression and impact strength were obtained as averages of several trials are presented in the Figures below

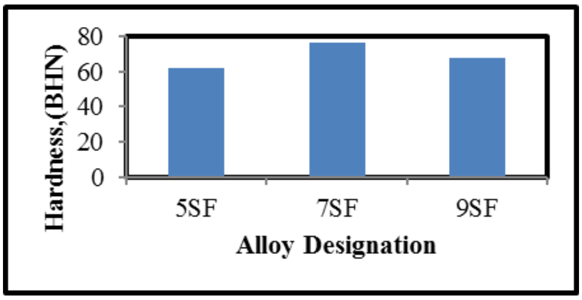

Fig.3: Hardness values of As-Cast and its composites

Brinell hardness test was carried out on Al 5083 SiC, Fly Ash composites and average of three reading for each specimen was calculated and reported in and **Fig 3** shows the variation of Brinell hardness number respect to different percentage of reinforcement. Al 5083 reinforced with 5% SiC shows greater Brinell hardness number compared to Al 5083 (3% SiC+ 2% Fly Ash). As the reinforcement percentage has increased Brinell hardness number has increased up to 5% SiC Composition Composite beyond which it decreases for Al (7% SiC).which is about 22.5% improvement over that of Al5083(3% SiC).

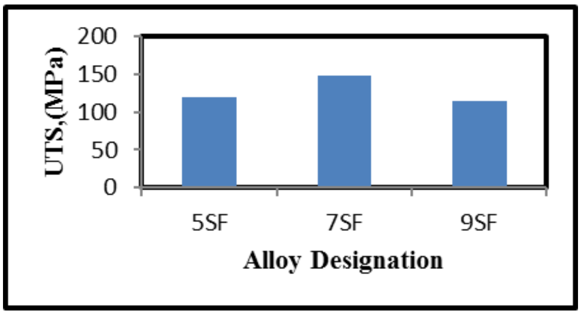

Fig.4: UTS values of As-Cast and its composites

To investigate the mechanical behaviour of the composites the tensile tests were carried out using computerized uni-axial tensile testing machine as per ASTM E8-95 standards. Three specimens were used for each test and average value is reported. The tensile properties, such as, tensile strength, yield strength and % elongation were extracted from the stress-strain curves and are represented in **Fig.4** It is clear ultimate tensile of composite having 5% SiCp is higher when compared to composites having 3% and 7% SiCp . This is due to the hard and lighter microsphere of fly ash, which acts as barriers to the movement of dislocation and refines the structure of matrix [7].

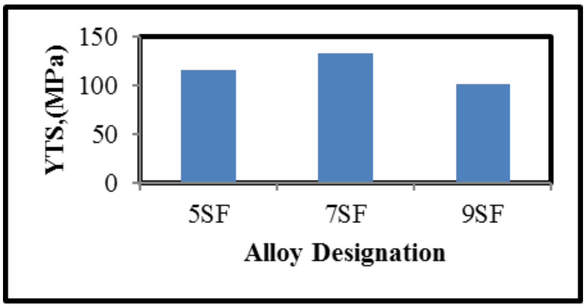

Fig.5: YTS values of As-Cast and its composites

Fig.5 shows the comparison of yield strength of Al 5083 alloy and SiC, Fly Ash hybrid composites. It is observed that the yield strength increases up to 5% SiC particles beyond which it decreases. Yield strength of Al (3% SiC) is 116.8 MPa and this value increases to 132.45Mpa for Al (5% SiC) which is about 15.65% improvement over that of Al (3% Sic).

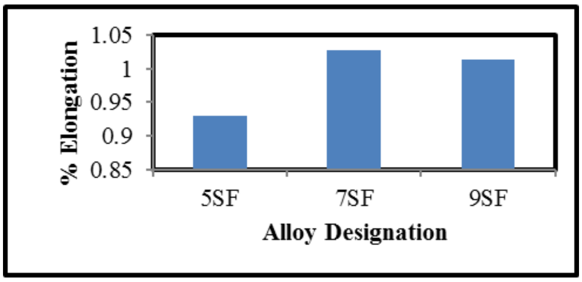

Fig.6: % Elongation values of As-Cast and its composites

Fig. 6 shows the comparison of elongation of Al 5083 alloy and SiC, Fly Ash hybrid composites. It is experimentally observed that the elongation of the composites is gradually decreased in Al (7% SiC) than that obtained in Al (5% SiC). Elongation of Al (5% SiC) is 1.028 % this value is decreased to 1.0137% for Al (7% SiC) which is about 16.16%

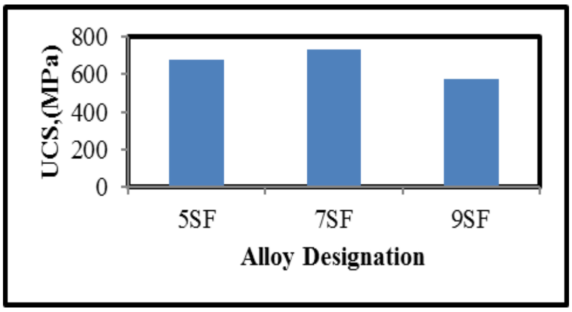

Fig.7: UCS values of As-Cast and its composites

As seen from the **Fig 7** and increasing trend of compressive strength was observed with increase in weight fraction of SiC, Fly Ash and their mixtures. This is due to the hardening of the base alloy by fly ash particulates. It is observed that the maximum compressive strength is observed at Al/ (5% SiC+2% Fly Ash). It is also observed that compressive strength increases up to Al (5% SiC + 2% Fly ash) beyond which it decreases for Al (7% SiC + 2% Fly ash). Compressive strength of Al(3% SiC + 2% Fly ash) is observed as 697.25 Mpa and this value increases to 729.29 Mpa for Al (5% SiC + 2% Fly ash) composite which is about 32.04% improvement over that of the Al(3% SiC + 2% Fly ash) composite.

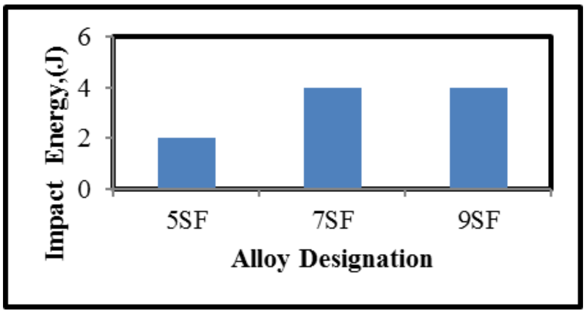

Fig.8: Impact Energy values of As-Cast and its composites.

From **Fig.8** maximum charpy impact energy was observed for Al 5083(5% SiC + 2% Fly) and Al 5083(7% SiC + 2% Fly). Which are about 50% improvements over that of Al 5083(3% SiC + 2% Fly ash) composite.

Wear Properties:

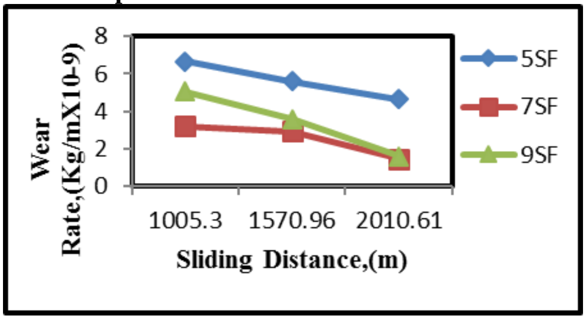

Fig9: Wear rate of As-Cast alloy and its composites.

A pin-on-disc apparatus was used to perform the wear experiment. The wear track, alloy and composite specimens are cleaned thoroughly with acetone prior to each test. After that the specimen is mounted on the pin holder of the tribometer ready for wear test. For all experiments, wear track diameter 80mm, load 10N and total time is 10 minute.

Fig 6.9 shows the result of wear rate as a function of sliding distance for varying composition of SiCp (3%, 5%, 7%), with 2% Fly Ash as a common reinforcement. It is clear from **Fig.9** that the wear rate decreases as the sliding distance increases.

Conclusion:

The following conclusions are arrived based on the experimental investigation on the Distribution of fly ash and silicon carbide particles in the stir casting and Its effect on mechanical properties of the as cast MMCs at a constant weight fraction of 2% fly ash and varying weight fraction of silicon carbide in the range of 3% to 7%

(a) Micro structural observation suggests that electromagnetic stirring action produces cast high performance hybrid Aluminium 5083/Fly ash/SiCp MMC with smaller grain size and there is a good particulate matrix interface bonding.
(b) The hardness of the high performance hybrid MMCs increases linearly with increasing the weight fraction of SiC particulates up to 5% beyond which it decreases.
(c) The tensile strength of the hybrid composites increases on increasing the weight fraction of Silicon carbide particulates up to 5% beyond which it decreases since addition of silicon carbide after certain limit increases brittleness of the material.
(d) The yield strength of the hybridized Aluminium Metal matrix composites with fixed weight fraction of fly ash and varying weight fraction of Silicon carbide increases with Increase in the weight fraction of silicon carbide up to 5% beyond which it decreases drastically due to the phenomenon of embrittlement of the material with increased Addition of Silicon carbide particles.
(e) The compression strength of the hybrid composites increases initially with the addition of silicon carbide particulates up to 5% but decreases substantially beyond 5% due to increases addition of silicon carbide.
(f) It was found that the wear resistance of composites increase with an increase of particle weight fraction up to 5% and then decreases.

Acknowledgement:

We thank Dr. H. C. Nagaraj, Principal and Management of Nitte Meenakshi institute of Technology, Bangalore, India for motivating and providing research facilities at the institute.

References:

[1] Process for preparation of composite materials containing non-metallic particles in a metallic matrix, and composite materials made by, US
[2] Patent No. 4 786 467, 1988. 2006. Metal matrix composites in automotive applications. Adv. Mater. Processes. 164: 29-31.
[3] Doel, T.J.A., M.H. Lorretto and P. Bowen, 1993. Mechanical properties of aluminium-based particulate metal-matrix composites. Composites, 24: 270-275. DOI: 10.1016/0010-4361(93)90174-7.
[4] Metal Matrix Composites-Thermomechamcal Behaviour, Pergamon Press, Oxford, 1989, pp 41-156
[5] Ceschinia, L., Minakb, G. and Morri, A., “Forging of the AA2618/20 vol. % Al2O3p composite: Effects on microstructure and tensile properties”, Composites Science and Technology, 69(2009) pp.1783–1789.
[6] Ismail Ozdemir Lloyd D J , Factors Influencing the Properties of Particulate Reinforced Composites Produced by Molten Metal Maxing, in 12th Riso International Symposium In Materials Science, Roskilde, Denmark, 1991, pp 81-99
[7] Suresh N,Venkateshweran S ,Seetharamu S, Influence of cenosphere of fly ash on mechanical properties and wear of permanent moulded eutectic Al-Si alloys,Material-science-Poland, Vol28. No.1 2010 PP.55-65.