Proc. of Int. Conf. on Current Trends in Eng., Science and Technology, ICCTEST

Mechanical Characterization of ZA-27 Reinforced with Silicon Carbide MMC

Bhaskar Raju S A[1], Hemanth Kumar C[2] and Jayasimha SLN[3]
[1]Asst. Prof., Don Bosco Institute of Technology, Bangalore
[2]Asst. Prof., B.N.M Institute of Technology, Bangalore
[3] Asst. Prof., Acharya Institute of Technology, Bangalore
[1]bhaskarrajusa@gmail.com
[2]hemanthkumar.sh17@gmail.com
[3]jysmh_simha@yahoo.com

***Abstract*—Zinc alloys with higher aluminum content (25-27 wt. %) obtained by conventional processes of melting and casting, are applied in various fields, specifically in automobile industry, because of their good mechanical, technological and economical properties.**
Ceramic phase reinforcement comeout with an effective method for improving the properties of zinc based alloys at high temperatures. Some researchers are shown that the mechanical properties of Zn-25Al-3Cualloys (ZA27 alloys) at high temperatures could be improved considerably with the incorporation of SiC particles. An effort has been made to fabricate ZA-27 reinforced with through Die casting process by varying the percentage of SiC particle from 0, 3, 6 & 9% wt. For each specimen produced, Mechanical properties like hardness, tensile strength, compression strength and Impact strength are studied and compared.

***Index Terms*— ZA27 alloy, Die casting, Tensile strength and Compression strength.**

I. Introduction

Composite materials have successfully replaced the traditional materials in several ways like lightweight and high strength applications. The selection of composite material is due to their high strength to weight ratio, high tensile strength at high temperatures, high toughness and high creep resistance. In composite material the reinforcing materials are tough with lesser densities, the matrix materials are usually tough/ductile material. If the composite is fabricated in a proper way, it combines the strength of the reinforcing material with the toughness of the matrix material to reach the goal of obtaining desired properties in a single material, which is not available in a single traditional material.
Zinc-aluminium-27 alloy i.e. ZA-27 is used as the matrix material. Zinc aluminum alloys 8, 12, and 27 comprises a new family of zinc casting alloys, they have proven themselves in a wide variety of applications. The alloys design at edas 8, 12, and 27 are based on the approximate amount of the aluminum content. Alloy contains copper and magnesium to attain a combination of properties.

Grenze ID: 02.ICCTEST.2017.1.39

II. Literature

E Delannay et al., [1] have studied about improvement of mechanical properties of Al, Zn and Cu-based matrix composites, strengthend with continuous fibers of carbon, Sic, A1203. Interface bond has been represented from the disposal of fiber pull-out lengths on fracture surfaces. The results of this work revealed that, if the processing conditions were properly controlled, composites present attractive properties from the point of view of thermal expansion and creep strength. In composites with low melting point matrices, the reduction of fracture toughness and ductility typically of metallic composites can be alleviated without affecting the other properties by replacing the ceramic fibers by ductile fibers such as steel fibers.

G. B. Veeresh Kumar et al., [2] have done an investigation on variations on mechanical properties of Al6061-SiC and Al7075-Al2O3 MMCs with the variation in the reinforcement content. Castings of the base alloys were carefully shaped to prepare the test specimens for density, hardness, mechanical, wear tests and for the microstructural studies. The SiCp and Al2O3 resulted in improving the hardness and density of their respective composites. Further, the increased percentage of the reinforcements, contributed to an raise in the hardness and density of the composites. The microstructural studies revealed the orderly distribution of the particles in the matrix system.

G. Ranganath, S.C. Sharma et al., [6] have reported an investigation on the mechanical properties and the fracture mechanism of ZA-27 alloy composites containing titanium-di-oxide (TiO2) particles 30-50μm in size and in contents ranging from 0-6wt.% in steps of 2wt.%. Compo-casting technique was selected to fabricate the composites. Improvements in mechanical properties such as Young's modulus, ultimate tensile strength, yield strength, and hardness of the composites, but at the cost of ductility. Titanium dioxide particles influenced the fracture behaviour. Propagation of crack through the matrix and therein forcing particles resulted in the final fracture.

III. Experimental details

A. Matrix material

Zinc-aluminium-27 alloy i.e. ZA-27 is used as the matrix material. Zinc-aluminum alloys 8, 12, and 27 comprises of a new class of zinc casting alloys, they have resulted themselves in a wide range of applications. The alloys designated as 8, 12, and 27 are based on the approximate amount of the aluminum content. Alloy contains copper and magnesium to attain a combination of properties. Because of the popularity as a commercial materials, these alloys have emerged in delivering national and international standards.

Chemical composition of this ZA-27 alloy according to ASTM E 8M-04 ingot specification.

TABLE I Chemical composition of zinc-aluminium-27 alloy (ZA-27)

Material	%by Weight
Al	25.5-28
Cu	2.0-2.5
Mg	0.012-0.02
Fe	0.072max
Zn	Balance

B. Reinforcement – SiC (50-60μm)

Silicon carbide is composed of tetrahedral carbon and silicon atoms with strong bonds in the crystal lattice. This produces a very hard and strong material. Till 800°C Silicon carbide will not react with any acids or alkalis or molten salts. At 1200^{o}C SiC is protected by silicon oxide till the temperature reaches 1600^{o}C. The high thermal conductivity, low thermal expansion and high strength gives this material exceptional thermal shock resistant qualities.

Some typical uses of silicon carbide are found in fixed and moving turbine components, seals, bearings, heat exchangers etc.

Melting of matrix alloy ZA-27 is separately carried out in a muffle furnace, using a graphite crucible at about 500^{0}c. Then it is superheated at approximately 650^{0}c. After melting, the required amount of filler material SiC (0, 3, and 6 % wt.) is preheated to around 400^{0}c in a separate crucible. Preheating is done to avoid amalgamation (clustering) of SiC particles.

Then, this melt is stirred manually about 2-3minutes in order to get a vortex of the molten metal. The extent to which the stirrer was immersed was approximately one third of the molten metal from the bottom of the crucible.

After this, the preheated SIC particles discharged into a vertex. The stirring is continued until a systematic distribution of SiC particles is seen in the mixture during stirring. In order to enhance the Wettability, a small amount of magnesium is added to the melt. Then, the molten mixture is degassed using degassing tablets (Hexachloroethane). This is done to avoid the formation of blow holes in the castings. The molten metal is then drained into a preheated cast iron die of size 22 mm diameter and 170 mm length. Then the temperature will be lowered deliberately.

Fig. 1 Stages in casting

IV. RESULTS AND DISCUSSIONS

A. Microstructure studies

Fabrication of metal–matrix composites with SiCp particles by casting processes is sometimes difficult because of the very low wettability of SiCp particles and agglomeration phenomena, which results in a non-uniform distribution and poor mechanical properties.

An attempt has been made to prepare ZA-27aluminium alloy matrix composites with micro size SiCp particles by stir casting method with a novel three stages mixing, incorporated with preheating of the reinforcing particles and adding magnesium at 0.1 ratio to the reinforcement.

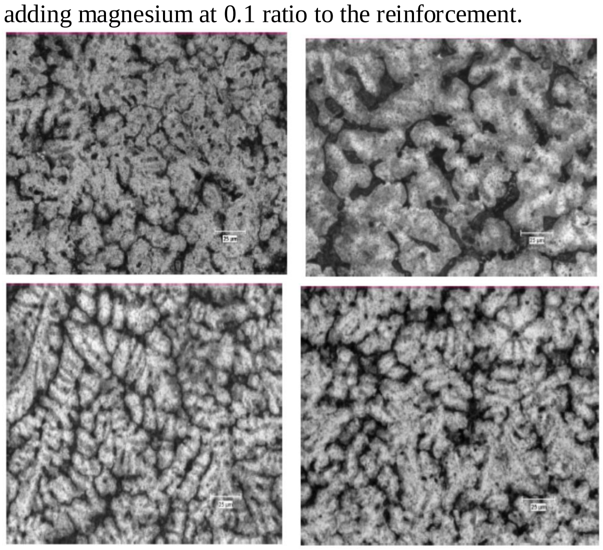

Fig. 2 Microstructure consists of zinc rich dendrites in the matrix of alpha+ η phase & ε-phase. Particles are dispersed in the matrix

B. Hardness Properties

Micro-hardness values of the ZA-27MMC (with and without particulate fillers) have been acquired by Brinell hardness tester.

TABLE II. MEASURED HARDNESS VALUES

Composition	Hardness BHN
ZA-alloy	91.21
ZA27+3%wt SiCp	109.2
ZA27+6%wt SiCp	152.89
ZA27+9%wt SiCp	209.23

The maximum hardness value is noticed for ZA-27 filled with 9wt% of SiCp. The test results shows that, with the presence of hard ceramic particles, hardness of the ZA-27 metal matrix composites is improved from91.21BHN to 209.23BHN, SiCp filled ZA-27 metal matrix composites.

C. Impact Test

The impact strength of a material is its capacity to absorb and dissipate energies under shock or impact loading. The selection of a composite for certain applications is determined not only by usual design parameters, but also by its impact or energy absorbing properties. Thus, it is significant to have a valuable perceptive of the impact behavior of composite, for both safe and efficient design of structures.

The measured impact energy values of the ZA-27MMC are filled with SiCp particulate fillers respectively. It is noticed the table that, the impact energies of the composites, increases deliberately with the increase in filler content, increasing from 0 to 9 wt.%.

TABLE III. MEASURED VALUES OF IMPACT STRENGTHS

Composition	Energy Observed in Joules	Impact Strength (KJ/m^2)
ZA-alloy	3.2	40
ZA27+3%wt SiCp	3.7	46.25
ZA27+6%wt SiCp	4.2	52.5
ZA27+9%wt SiCp	5	62.5

D. Tensile Properties

It is witnessed that in all the specimens samples, tensile strength of the composite increases with an increase in the filler content. The unfilled ZA-27 metal matrix composite has a strength of 114.4 MPa in tension and be able to notice that, this value improves to 149.33 MPa with an addition of 9 wt.% of SiC.

TABLE IV. TENSILE PROPERTIES OF ZA27/SICP MMC

Composition	Peak Load(kN)	Percentage Elongation	Yield Strength(MPa)
ZA-alloy	8	1.11	114.4
ZA27+3%wt SiCp	6.68	0.44	91.14
ZA27+6%wt SiCp	7.56	1.91	103.5
ZA27+9%wt SiCp	10.64	0	149.33

Presence of hard particulates, the load on the matrix gets transferred to the reinforcing elements and thereby increasing the load bearing capability of the composites. With the increase in amount of the filler material, more loads get transferred to the reinforcement, which starts to an increase in the tensile strength. Moreover, with the presence of hard ceramics like SiC, there is a control of the plastic flow as a result of distribution of these hard particles in the matrix, thereby providing intensified tensile strength in the composite.

E. Compression Properties

The test results for compression strengths of the composites with SiC reinforcement is shown that in all the samples, compression strength of the composite increases with addition of the filler content. The unfilled ZA-27 metal matrix composite has a strength of 662MPa in compression and it may be noticed that this value improves to 1376MPa with addition of 9 wt.% of SiC.

With the inclusion of hard particulates, the load on the matrix gets transferred to the reinforcing elements and thereby increasing the load bearing capability of the composites. With the increase in amount of the filler material, more loads get transferred to their reinforcement which leads to an improvement in compression strength.

Moreover, with the presence of hard ceramics like SiC, there is a control of the plastic flow as a result of distribution of these hard particles in the matrix, thereby providing intensified compression strength in the composite.

TABLE V. COMPRESSION PROPERTIES OF ZA27/SICP MMC

Composition	Max Force(kN)	Max Displacement(mm)	Compressive Strength (MPa)
ZA-alloy	138.3	3.8	662
ZA27+3%wt SiCp	179.8	3.7	861
ZA27+6%wt SiCp	254.05	5.2	1217
ZA27+9%wt SiCp	273.3	5.4	1376

V. CONCLUSIONS

- The composites possess improved hardness (from 91 to 209.23 BHN) and Impact strength (from 40 to 62.5 KJ/m^2). It is noticed that, as the amount of filler material increases, both hardness and impact strength increases.
- The SiC reinforced ZA27 alloy has shown maximum strength. Whereas, the unreinforced ZA27 alloy is found to be less in strength.
- The various tension properties like yield strength, UTS, and toughness increases with an increase in the filler content, at the cost of decrease in ductility.
- Tensile strength of prepared composites is higher in the case of composites, in analogous to ZA-27 alloy.
- Compressive strength of prepared specimens is higher in the case of composites, in analogous to ZA-27 alloy.
- Finally this experimental work showed that, the mechanical properties increases with an increase in the inclusion of silicon carbide content.

REFERENCES

[1] E Delannay, C. Colin, “Processing and properties of metal matrix composites reinforced with continuous fibres for the control of thermal expansion, creep resistance and fracture toughness”, Volume 3, November1993.

[2] G. B. Veeresh Kumar, C. S. P. Rao, “Studies on Al6061-SiC and Al7075-Al2O3 Metal Matrix Composites”, Vol. 9, No.1, pp.43-55, 2010.

[3] Angeliki Moustatsou, Grigorious S, “Synthesis aluminum based composite with flu ash reinforcement” USA.

[4] G. Ranganath, S.C. Sharma, M. Krishna, and M.S. Muruli, “A Study of Mechanical Properties and fractography of ZA-27/Titanium-Dioxide Metal Matrix Composites”, JMEPEG (2002) 11:408-413 ©ASM International.

[5] K.H.W. Seaha, J. Hemanthb, S.C. Sharmac, “Mechanical properties of aluminum quartz particulate composites cast using metallic and non-metallic chills”, Materials and Design 24 (2003) 87–93.

[6] S. K. Nath and Uttam Kr Das, “Effect of Microstructure and cracks on the Fracture Toughness of Medium Carbon Steel”, Journal of Naval Architecture and MarineEngineering-3, 2006, pp. 15-22.

[7] Neelakantha V Londe, Dr. T.Jayaraju and Dr.P.R.Sadananda Rao, “Use of circular specimen in Fracture Toughness Test of Metallic Materials”, International Journal of Engineering Science and Technology, Vol. 2(9), 2010, pp. 4130-4136.

[8] Vikram Singh and R C Prasad, “Tensile and Fracture Behavior of 6061 Al-Sicp Metal Matrix Composites”. International Symposium of Research Students on Materials Science and Engineering December 20-22, 2004.

[9] Xicong Liu and Yue Zhuo, “Fracture Surfaces of Al2o3/Al-Alloy Composites”, Department of Materials Engineering and Applied Chemistry, National University of Defense Technology, pp.1-8.

[10] Fumiyoshi Minami, Masuo Iida and Wataru Takahara, “Fracture Mechanics Analysis Of CharpyTest Results based On The Weibull Stress Criterion”, OMAE2001/MAT-3130.

[11] G.G. Vanian, A.K. Hellier, K. Zarrabi and B.G. Prusty, “Fracture toughness determination for aluminum alloy”, Int J Fract (2013) 181:147–154 DOI 10.1007/s10704-013-9827-22011-t6 using tensile notched round bar (nrb) test pieces.

[12] G. L. Heness1 and Y-W Mai, “The fracture toughness of some metal matrix composites - comparison of techniques, ICF100239PR.