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MECHANICAL PROPERTIES OF AS-CAST ZA-27/Gr/SiCp HYBRID COMPOSITE FOR THE APPLICATION OF JOURNAL BEARING

KIRAN, T. S.[1,*], M. PRASANNA KUMAR[2], BASAVARAJAPPA, S.[3], VISHWANATHA, B. M.[1]

[1]Department of Mechanical Engineering, Kalpataru Institute of Technology, Tiptur – 572 202, India
[2]Department of Mechanical Engineering, Bapuji Institute of Engineering and Technology, Davangere - 577 005, India
[3]Department of Studies in Mechanical Engineering, University B.D.T. College of Engineering, Davangere - 577 004, India
*Corresponding Author: kirants111@gmail.com

Abstract

The mechanical behavior of as-cast ZA-27 alloy and hybrid composite reinforced with graphite (Gr) of constant 3% by weight and silicon carbide particle (SiCp) varying from 0-9% by weight in steps of 3% was carried out. Vortex method of production was employed in which thoroughly mixed Gr and SiC particles were poured into the vortex created by means of mechanical stirrer. The melt was cast using a pre-heated permanent mold box. Microstructure showed fine distribution of the reinforcements in the specimen. Tensile and hardness tests were carried out as per ASTM standards. The results reveal that, as the percentage of SiCp was increased, UTS and hardness increased with reduction in ductility.

Keywords: ZA-27, As-cast, Hybrid, Mechanical property.

1. Introduction

Composite materials are in limelight nowadays which needs fewer introductions. Their applications range from automobile to aerospace industries. Metal matrix composites (MMCs) have received much research interests over several years due to their excellent mechanical and thermal properties compared with the conventional materials [1]. The modern composites are non-equilibrium combinations of metals and ceramics, where there are fewer thermodynamic restrictions on the

Nomenclatures

α	Aluminum rich phase
$\alpha+\eta$	Eutectoid phase
η	Zinc rich phase
ε	Metastable phase

relative volume percentages, shapes and size of ceramic phases. By carefully controlling the relative amounts and distribution of the ingredients constituting a composite as well as the processing conditions, MMCs can be imparted with a tailored set of useful engineering properties [2]. MMCs possess excellent mechanical and tribological properties and are considered as potential engineering materials for various tribological applications [3].

Aluminum based MMCs are finding more applications due to their low density, high corrosion resistance, ease of fabrication and low cost. Zinc-aluminum (ZA) based cast alloys by virtue of their excellent castability, wear resistance and good mechanical properties have found significant industrial usage [4]. The popular members of ZA alloy family are ZA-8, ZA-12 and ZA-27. The letter Z and A refers to zinc and aluminum respectively, and the preceding numbers 8, 12 and 27 refers to respective weight percentage of aluminum in each alloy. Among these alloys, ZA-27 is having the highest strength (400-440MPa) and ductility (3-6% elongation), that have inspired the investigators to reinforce them with ceramic dispersoids to obtain much more enhanced properties.

Particle distribution in the matrix material during the melt stage of casting process depends on the viscosity of the slurry, the extent to which particles can be successfully incorporated in the melt. The characteristics of the reinforcement particles themselves influence the settling rate and the effectiveness of mixing in breaking up agglomerates, minimizing gas entrapment and distributing particles [5].

Mechanical and microstructural properties of discontinuously reinforced metal matrix composites (DRMMCs) reinforced with SiCp, graphite (Gr), alumina (Al_2O_3), zircon particles are reported by various researchers. Seah et al. [6] reported that with the increase in composition of SiCp, significant increase in ultimate tensile strength (UTS) and hardness, with reduction in ductility and impact strength was observed. Heat treatment gave reverse results by reducing UTS and hardness, with increase in ductility and impact strength. Bobic et al. [7] found that, inclusion of smaller Al_2O_3 improved the strength than the larger particle size and as-cast alloy. Zircon particles were reinforced with ZA-27 by Sharma et al. [8] that showed an improvement in UTS, yield strength (YS), hardness and Young's modulus of composite, with a decrease in ductility and impact strength as the particulate percentage was increased.

Seah et al. [9] compared the hardness of as-cast and artificial aged specimens of ZA-27/Gr particulate composites that had effect only on the matrix rather than the alloy. Inclusion of Gr particles reduced the hardness considerably for as-cast, at the same time increased for aged specimens. Babic et al. [10] compared the as-cast and heat treated ZA-27 alloy with Gr reinforced composite specimens. The results for alloy showed reduced UTS and hardness with increase in elongation. Inclusion of Gr particulates with the alloy showed reduction in the hardness. Various sizes and wt% of SiCp were used as dispersoids in Al-2014 alloy showed

linear improvement in the hardness [11]. Ranganath et al. [12] studied the mechanical properties of ZA-27 reinforced with different % by wt. of TiO_2. The conclusion drawn was, with the inclusion of reinforced particles improved UTS, Young's modulus, yield strength and hardness in composites was observed while there was reduction in the ductility.

Prasad [13] evaluated the tensile property of ZA-27 and the effect of microstructure, composition and test conditions. Experiments were carried at different temperatures and strain rates. The tensile strength of the alloy improved with increase in the strain rate, but at higher temperature, reverse trend followed. Elongation had no effect on strain rate or temperature which kept increasing.

The chemical composition of zinc alloy matrix as per ASTM B669-82 used in the present work is shown in Table 1. Reinforcements used in the present work are Gr particles (45 µm) that are soft dispersoids with a property of self-lubrication, maintained constant at 3 % by weight and SiCp (25 µm) that are hard dispersoids varied from 0-9% by weight in step of 3%.

Table 1. Composition of ZA-27 Alloy.

Component	% Composition
Aluminum	25-30
Copper	2.06
Iron	0.065
Magnesium	0.012
Silicon	0.02
Zinc	Balance

2. Experimental Procedure

2.1. Preparation of composite

The composites were fabricated by liquid metallurgy technique ('vortex method'). The SiCp contents of 0-9% by weight in steps of 3% were thoroughly mixed with Gr particles of 3% by weight maintained as a constant (hereafter referred based on wt% of SiCp). The zinc alloy was melt above its liquidus temperature above 484ºC [14]. The melt was rotated at a speed of 500 rpm in order to create a necessary vortex using a mechanical stainless steel stirrer coated with aluminate (which prevents migration of ferrous ions from the stirrer material to the molten alloy) referred elsewhere [3, 4, 6, 8]. The mixture of reinforcements were preheated and poured into the molten slurry. A small amount of magnesium (Mg) was added that improves the wettability of the reinforcements with the molten alloy. The melt was degassed by addition of C_2Cl_6, as it reduces the porosity and helps in removal of entrapped gas. Further the melt was poured into permanent moulds of casting.

2.2. Testing of specimens

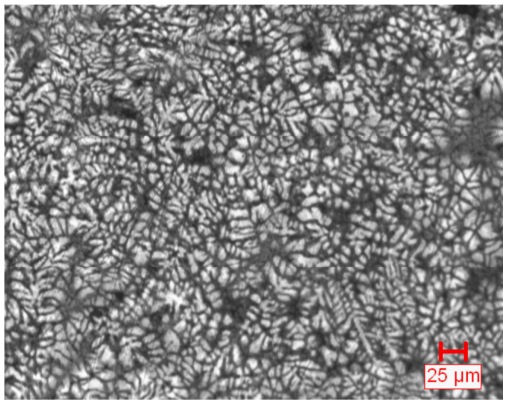
All tests were conducted in accordance with ASTM standards. Microstructural analysis were carried out by grinding the section of sample with a series of emery papers down to 600 grit size and polished with diamond paste of 1-2 microns size

and etched with Palmetron reagent. Tensile tests at room temperature were conducted using a Universal Testing Machine in accordance with ASTM E8-82. A gauge length of 50 mm was machined from the cast specimen with the gauge length parallel to the longitudinal axis of the castings. For each specimen, the UTS and ductility (in terms of percentage elongation) were measured. Hardness test were conducted in accordance with ASTM E10 using Brinell hardness tester.

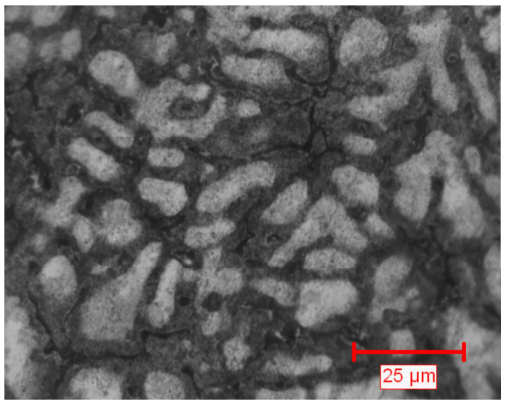
3. Results and Discussion

3.1. Microstructure

To study the overall performance of alloys and composites, microstructure plays an important role. Microstructure of the as-cast alloy and composites are presented in Figs. 1 and 2. The as-cast alloy is shown in Fig. 1, exhibiting dendritic structure comprising α dendrites surrounded by $\alpha+\eta$ eutectoid, residual η phase and metastable ε phase in interdendritic regions. In Figs. 1(a) and (b), the white particles are rich in aluminum (α phase), while the dark regions are zinc rich phase (η phase). Grey color shows the mixture of α and η phase.

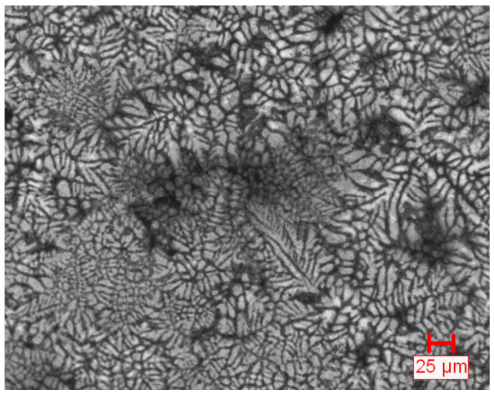


(a) 100 X

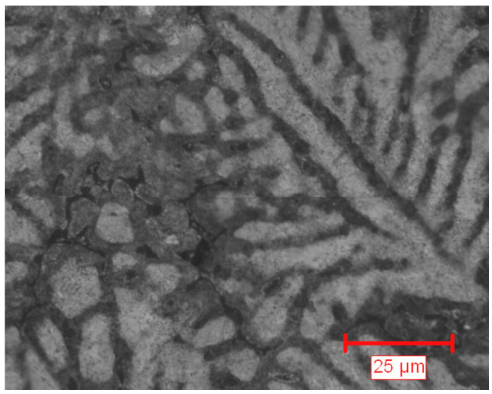


(b) 500 X

Fig. 1. Microstructure of ZA-27 Alloy.



(a) 100 X



(b) 500 X

Fig. 2. Microstructure of ZA-27/3Gr/9SiCp.

The uniform distribution of the 9% SiCp in the ZA-27 matrix alloy are clearly evident from the micrographs shown in Figs. 2(a) and (b). The uniform distribution in case of 3 and 6% of SiCp was also observed. In Fig. 2(a), bonding between the interphase of alloy and reinforcement can be observed (SiCp gray in color and Gr as dark black) with fine cored dendrites of Al rich (α) solution and zinc rich (η) phase.

3.2. Ultimate tensile strength

Figure 3 shows the effect on UTS for composites containing various percentage of SiCp. It can be seen that as the SiCp content is increased, the UTS of the composite material also increases. Various researchers [6, 8, 11, 12] have reported tests on DRMMCs and found remarkable improvement in UTS by incorporation of reinforcements. Improvements are seen in UTS by addition of 9% SiCp to ZA-27. Seah et al. [6] compared the improvement in UTS of as-cast and heat treated for alloy and SiCp reinforced composite. Heat treatment reduced the UTS for both

alloy and composite samples. As SiCp was increased from 0 to 5% by weight, UTS was also improved by 11.2%. In the present investigation, as SiCp content is increased from 0% to 9%, the specimen shows improvement in UTS. This increase in UTS is due to the reinforcements that act as barriers to the dislocations in the microstructure [15].

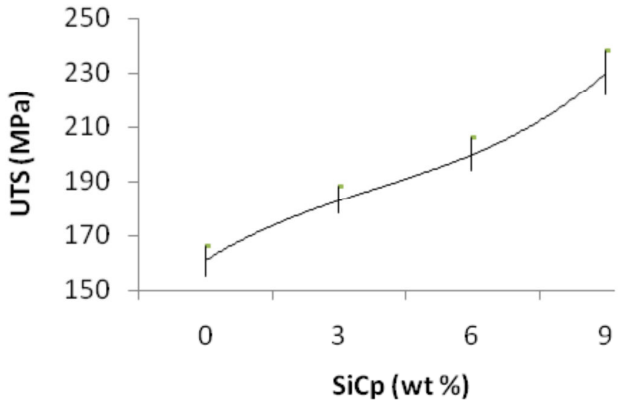


Fig. 3. Variation of UTS for Different Percentages of SiCp.

3.3. % Elongation

Ductility of composites containing various amounts of SiCp is compared in Fig. 4. It can be seen that as the SiCp content is increased, the % elongation of the composite material decreases. As SiCp content is increased from 0% to 9%, keeping Gr content constant of 3 wt%, the specimen shows decrease in % elongation by 42%. This decrease in the property may be due to the presence of reinforcements which cause increased local stress concentration sites. These reinforcing particles resist the passage of dislocations either by inducing large differences in the elastic behavior between the matrix and dispersoids. Ductility of the composites reduced with an increase in reinforcements can be related to the increasing porosity in composites. The formation of porosity is due to the large co-efficient of thermal expansion between the reinforcement and the ductile matrix. Porosities serve as stress concentration zones, which can promote crack initiation and may result in reduction of ductility. These results are inline with the other researchers [6, 8, 16], who have demonstrated that composite failure was associated with particle cracking and void formation in the matrix.

The tensile property of materials will depend on contribution of sound and defective portions of gauge area. The areas that comprise the strain raiser points like microconstituents with sharp edges and tips, inclusions, microporosity and the phases that poorly compatible with matrix are weaker/defective portions. These regions enhance the tendency towards cracking of material and allow them to fail at lower stress level. As the strain rate is increased, the defects negative contribution of weaker sections reduces, but with slow strain rate, these defects contribute more which affects the UTS values.

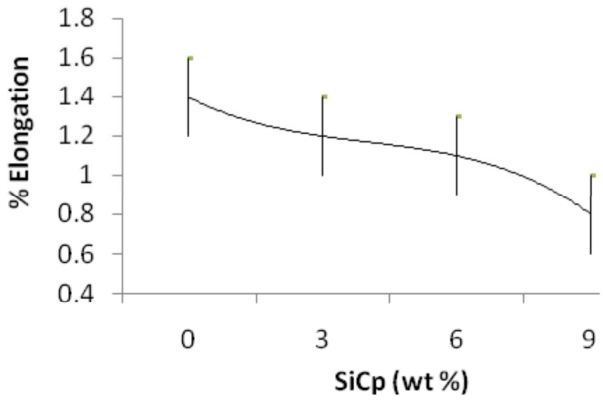


Fig. 4. Variation of Elongation for Different Percentages SiCp.

3.4. Hardness

Figure 5 shows the variation in hardness of the specimens containing various amounts of SiCp. The resistance of a material to indentation under standard testing condition is termed as hardness. It can be seen that as the SiCp content is increased, the hardness of the composite material also increases. As SiCp content is increased from 0% to 9%, the specimen shows less improvement in hardness of 8%. This limited increase in the hardness is due to the fact that, SiCp is harder while Gr is a soft dispersoids, which may have decreased the improvement in hardness. Inclusion of Mg also reduces the hardness, therefore it should be kept a minimum [8]. Seah [6 and 9], studied separately the effects of reinforcing SiCp and Gr with ZA-27. Inclusion of the former reported an improvement of 21.1% while the latter reported an reduction of 37.5%. Addition of TiO_2 ranging from 0-6 % by weight in steps of 2 % with ZA-27 also showed improvement in hardness by 10% [12].

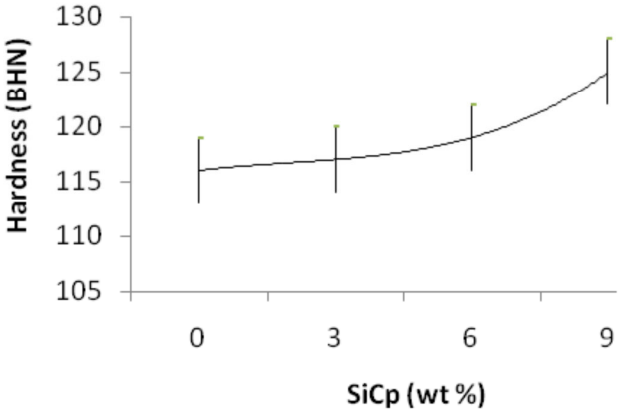


Fig. 5. Variation of Hardness for Different Percentages of SiCp.

4. Conclusions

The hybrid composites were cast successfully with liquid metallurgy technique. The micrographs showed uniform distribution of fine particles with α dendrites surrounded by $\alpha+\eta$ eutectoid, residual η phase and metastable ε phase in interdendritic regions. Mechanical properties of the as-cast specimens were improved by varying the percentage of SiCp. It was observed that, as the SiCp content was increased, the UTS and hardness values increased with ductility taking the opposite direction.

References

1. Aldas, K.; and Mat, M.D. (2005). Experimental and theoretical analysis of particle distribution in particulate metal matrix composites. *Journal of Materials Processing Technology*, 160(3), 289-295.
2. Pradeep, K.R. (1993). Metal-matrix composites. *Defence Science Journal.* 43(4), 323-349.
3. M. Prasannakumar, K.; Sadashivappa, K.; Prabhukumar, G.P.; and Basavarajappa, S. (2006). Dry sliding wear behaviour of garnet particles reinforced zinc-Aluminum Alloy Metal Matrix Composites. *Material Science* (*Medžiagotyra*), 12(3), 209-213.
4. Sharma, S.C.; Satish, B.M.; Girish, B.M.; Kamath, R.; and Asanuma, H. (1998). Dry sliding wear of short glass fibre reinforced zinc-aluminum composites. *Tribology International*, 31(4), 183-188.
5. Hashim, J.; Looney, L.; and Hashmi, M.S.J. (2002) Particle distribution in cast metal matrix composites-Part I. *Journal of Materials Processing Technology*, 123(2), 251-257.
6. Seah, K.H.W.; Sharma, S.C.; Rao P.R.; and Girish, B.M. (1995). Mechanical properties of as-cast and heat-treated ZA-27/silicon carbide particulate composites. *Materials & Design*, 16(5), 277-281.
7. Bobić, I.; Jovanović, M.T.; and Ilić, N. (2003). Microstructure and strength of ZA-27-based composites reinforced with Al_2O_3 particles. *Materials Letters*, 57(11), 1683-1688.
8. Sharma, S.C.; Girish, B.M.; Somashekar, D.R.; Kamath, R.; and Satish, B.M. (1999). Mechanical properties and fractography of zircon-particle-reinfored ZA-27 alloy composite material. *Composite Science and Technology*, 59(12), 1805-1812.
9. Seah, K.H.W.; Sharma, S.C.; and Girish, B.M. (1995) Effect of artificial ageing on the hardness of cast ZA-27/graphite particulate composites. *Materials and Design*, 16(6), 337-341.
10. Babic, M.; Mitrovic, S.; and Ninkovic, R. (2009). Tribological Potential of Zinc-Aluminum Alloys Improvement. *Tribology in industry*, 31(1-2), 15-28.
11. Sahin, Y. (2003). Preparation and some properties of SiC particle reinforced aluminum alloy composites, *Materials and Design*, 24(8), 671-679.
12. Ranganath, G.; Sharma, S.C.; Krishna, M.; and Muruli, M.S. (2002). A study of mechanical properties and fractography of ZA-27/Titanium-dioxide metal

matrix composites. *Journal of Materials Engineering and Performance*, *JMEPEG*, 11(4), 408-413.

13. Prasad, B.K., (1998). Tensile properties of some zinc-based alloys comprising 27.5% Al: effects of alloy microstructure, composition and test conditions. *Materials Science and Engineering: A*, 245(2), 257-266.
14. ASM (1990). *Properties and selection: Nonferrous alloys and special-purpose materials*. ASM Handbook, Volume 2, ASM International.
15. Dieter, G. (1986) *Mechanical Metallurgy*. (SI Metric 3rd Ed.), McGraw Hill, New York.
16. Abou El-khair, M.T.; Lotfy, A.; Daoud, A.; and El-Sheikh, A.M. (2011) Microstructure , thermal behavior and mechanical properties of squeeze cast SiC, ZrO_2 or C reinforced ZA27 composites. *Materials Science & Engineering: A*, 528(6), 2353-2362.