

International Journal of Innovative Research in Science, Engineering and Technology

(An ISO 3297: 2007 Certified Organization)

Website: www.ijirset.com

Vol. 6, Issue 6, June 2017

The Effect on Mechanical Properties and Microstructure of LM13 Aluminium Alloy Reinforced With Zirconium Silicate ($ZrSiO_4$)

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ABSTRACT: In the present days, the demand on composites are increasing day by day in the field of engineering, aerospace, automobile industry etc., because of their high strength, hardness and light weight compared to base metals. Many approaches have been made to study the behaviour of LM13 reinforced with $ZrSiO_4$ with a variation in particle size and percentage. In this an approach is developed to study the behaviour of LM13 reinforced with $ZrSiO_4$ in 0,2,4 and 6 wt%. Four tests were carried out on each composite. The tests included tensile test, Charpy test, microstructure study, SEM analysis and Rockwell hardness test. From these tests, it was observed that, the hardness value of the composite is increased as wt% of $ZrSiO_4$ increased. With increase in wt % of $ZrSiO_4$ in base metal matrix, results in increased impact strength, breaking strength and ultimate tensile strength. From the microstructure analysis, it was cleared that strength of composites are inversely proportional to the grain size. From SEM analysis it was concluded that, the distribution of $ZrSiO_4$ was uniform throughout the specimen.

KEYWORDS: stir casting, LM13 Aluminium alloy, Zirconium Silicate ($ZrSiO_4$)

I. INTRODUCTION

The metal matrix composite is composite material consist of at least two constituents, one should be metal and other may be any type of ceramics or organic compound like $ZrSiO_4$, SiC, Tin, etc are used. Metal matrix composite shows the combined properties like specific strength, stiffness, and wear over the conventional materials.

Aluminium matrix composite (AMC) have shown high mechanical properties like strength, good elevated temperature, wear resistance and stiffness, Hence AMC plays a significant role in automobile and aerospace industry. It also provides good flexibility in components design with a suitable reinforcement and manufacturing method.

LM13 is a aluminium alloy used in productions of pulleys and pistons for diesel and petrol engines. It has well mechanical properties like high resistances to wear, high bearing properties and low thermal expansion coefficient.

The reinforcement material zirconium silicate shows a low thermal coefficient and high wear resistance. The composite with a zircon as a reinforced material offers, high wear resistance compared with alumina reinforced composite because of its high particle- matrix bonding.

In the present work an approach was developed to fabricate a base metal matrix LM13 with 0, 2, 4, 6 wt% of $ZrSiO_4$ as a reinforcement, by stir casting method. Tensile test, Charpy test, Rockwell hardness test, microstructural analysis and SEM analysis were carried out to find out behaviour composite under the influence of $ZrSiO_4$ in LM13 alloy.

II. LITERATURE REVIEW

Mittal R et al. [2010] conducted an experimental method to find out the wear behaviour of composite, which consist zirconium silicate reinforced with LM13 alloy. Through spray forming technique the composites were

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produced. Through hardness test it was noticed that, the maximum value of hardness of a composites were found to be 43 HRB, with a composition of LM13+Zr106+10%Sn. The value of hardness was increased with reduced ZrSiO₄ particle size. From the wear test, it was concluded that lower the particle size of ZrSiO₄ lowered the wear rate and the same was found to be increased with increases in load.

Daniel S et al. [2015] made the study on sliding wear behaviour of LM13 reinforced with ZrO₂ produced by stir casting method. Experiments were conducted on composites with a variation in ZrO₂ particle size, to evaluate the good composition. It was observed that, the wear volume loss was increased slightly throughout the sliding length, for all loaded conditions. Wear resistance observed to be increased with increase in wt% of reinforcement and it decreased with increased load. Wear resistance is more in nano composites as compared to the matrix material.

Mallikarjun B. G et al. [2016] evaluated the wear and mechanical properties of LM13 with SiO₂ as reinforcement. Using stir casting method, the composites were manufactured. SiO₂ were used in composite with a particle size of 150 micrometre and 3, 6, 9 and 12 wt % of composition. From the tensile test, highest tensile strength was found in the specimen contained 12 wt% of SiO₂. Also it was concluded that, addition of SiO₂ in LM13 improved the mechanical properties compared with the unreinforced matrix.

III. EXPERIMENTAL DETAILS AND METHODOLOGY

Stir casting

Stir casting method is a well-known method for fabricating the composites. The composites used in this work were manufactured by this method. First The LM13 ingots were made into small pieces and transferred into the crucible and the same was placed into electric resistance furnace. Where the heating of LM13 pieces took place at a temperature of 750 °c, which caused the phase conversion of LM13, from solid to liquid. The melt of LM13 was held for 10 minutes, Then the reinforcement material ZrSiO₄ was added into the melt. The stirring of the molten metal was carried out for uniform distribution of ZrSiO₄. C₂Cl₅ was added to the mixture, to remove the moisture content. Then the electric furnace was switched off and the mixture was poured into die box for cooling. After cooling, the specimens were removed from the die box. Finally, the specimens were machined as per the standard dimensions.

IV. RESULTS AND DISCUSSION

4.1 Tensile test

Table. 4.1 Results of Tensile test for different composition of specimen

Sl. No	Material composition	Ultimate load (kN)	Breaking load (kN)	Ultimate strength (N/mm ²)	Breaking strength (N/mm ²)
1	LM13 (as cast)	1.6	0.8	56.6	28.29
2	LM13 + 2 wt% ZrSiO ₄	2.52	1.2	89.14	42.49
3	LM13 + 4 wt% ZrSiO ₄	3.2	1.6	113.19	56.65
4	LM13 + 6 wt% ZrSiO ₄	4.8	3.64	169.79	128.75

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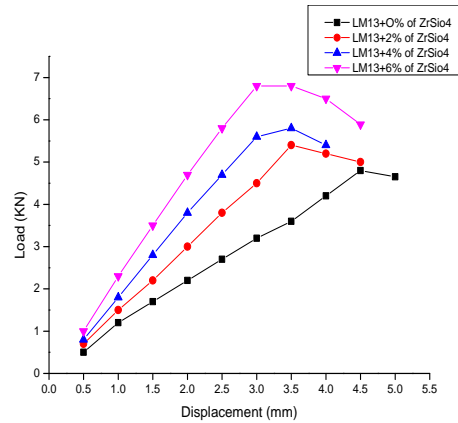


Fig. 4.1 Load vs displacement curve

4.2 Charpy test

Table. 4.2 Results of charpy test

Sl. No	Material composition	Initial reading (K ₁)	Final reading (K ₂)	Total energy absorbed (K ₁ -K ₂)	Impact strength (N-m/mm ²)
1	LM13 (as cast)	300	298	2	0.02
2	LM13 + 2wt% ZrSiO ₄	300	296	4	0.04
3	LM13 + 4wt% ZrSiO ₄	300	294	6	0.06
4	LM13 + 6wt% ZrSiO ₄	300	290	10	0.10

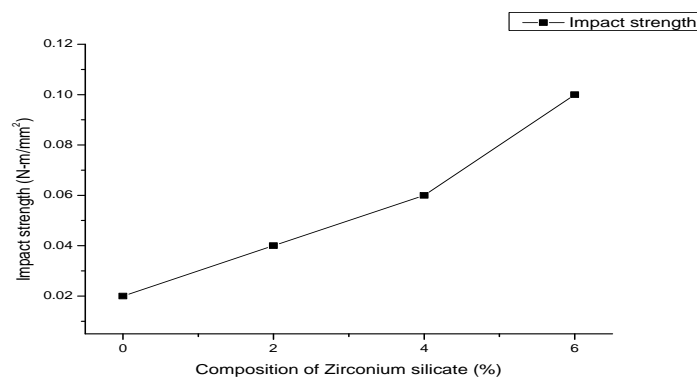


Fig. 4.2 Impact strength vs wt% ZrSiO₄

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It was observed that, energy absorbed and the impact strength offered by the specimens increased, with increases in wt % of ZrSiO₄ in LM13. Hence it was concluded that, LM13 with 6 wt% of ZrSiO₄ exhibited higher impact strength compared to other specimens.

4.3 Rockwell hardness test

Table 4.3 Results of hardness test

Sl. No	Material composition	Applied load (Kgf)	Hardness Number (HRB)			
			Test 1	Test 2	Test 3	Average
1	LM13 (as cast)	100	43	49	42	44.66
2	LM13 + 2wt% ZrSiO ₄	100	58	51	55	54.66
3	LM13 + 4wt% ZrSiO ₄	100	62	60	59	60.33
4	LM13 + 6wt% ZrSiO ₄	100	75	80	73	76

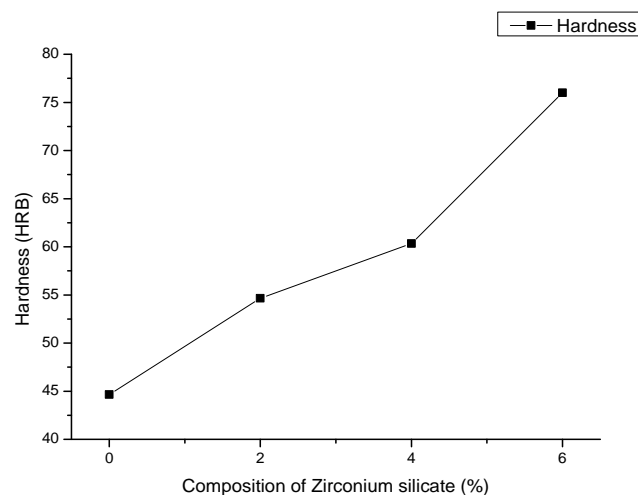


Fig. 4.3 Hardness vs weight % ZrSiO₄

It is clear that the hardness of the composites increased with the increase in wt% of ZrSiO₄. The composite with 6 wt% ZrSiO₄ exhibited highest hardness of 76 HRB.

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4.4 Microstructural analysis

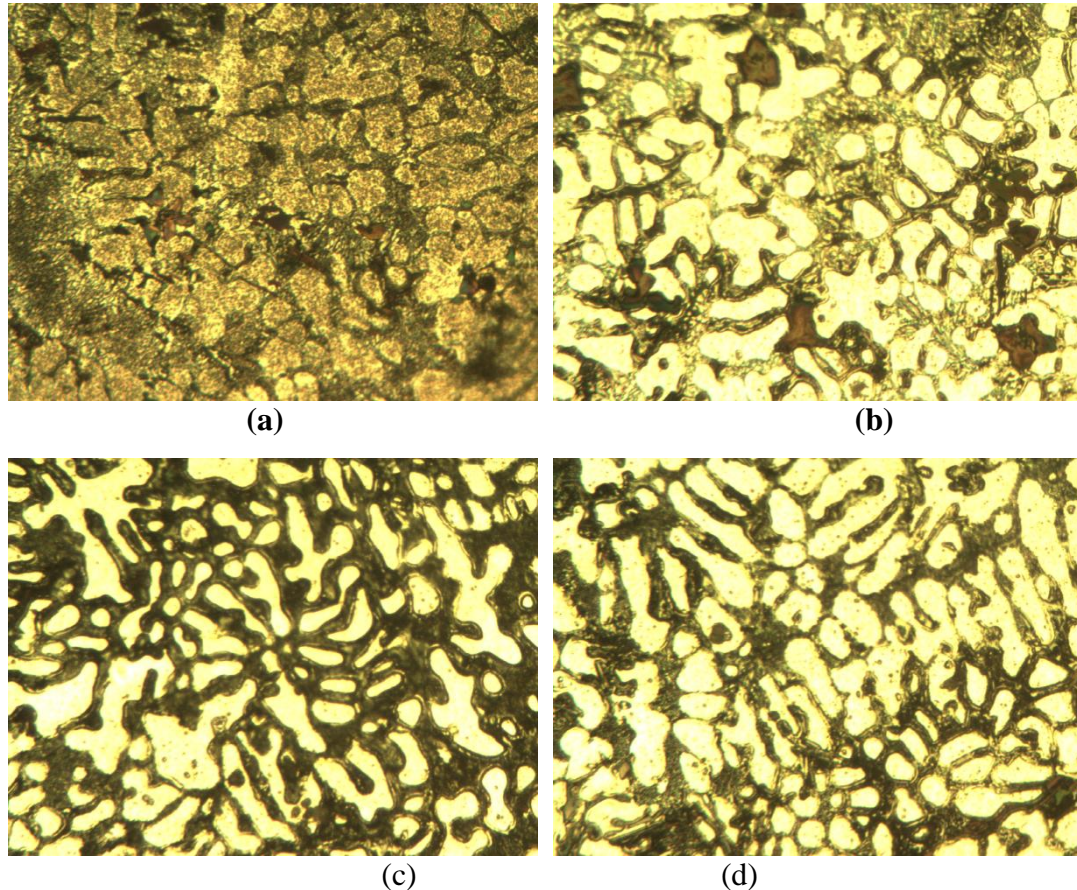


Fig. 4.4 Dendrite formation in (a) as-cast, (b) 2 wt% ZrSiO₄- LM13 (c) 4 wt% ZrSiO₄- LM13 and (d) 6 wt% ZrSiO₄- LM13

It was noticed that, dendrite formation in 2 wt% ZrSiO₄-LM13 and 4 wt% ZrSiO₄-LM13 were almost similar but 6 wt% ZrSiO₄-LM13 had more dendrite growth. Formation of dendrite growth was increased due to greater wt % of ZrSiO₄.

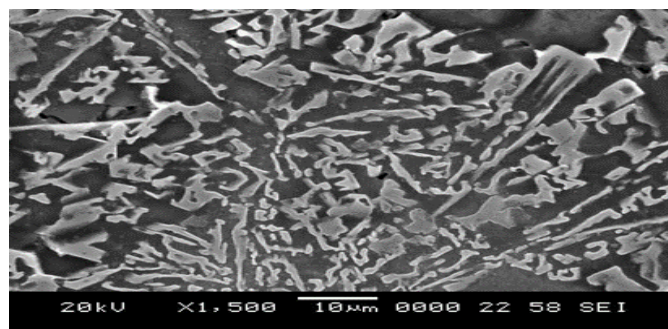


Fig.4.5 Grain formation in 2 wt% ZrSiO₄-LM13

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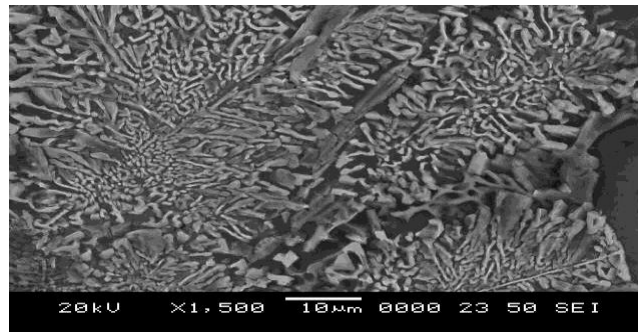


Fig. 4.6 Grain formation in 6 wt % ZrSiO₄-LM13

The images (Figs. 4.5 and 4.6) were captured at 1500 X. It was noticed that, dendrite growths were cellular in nature. The blue parts in the figures show that rejection of solute from solidified alloy in liquid phase. The degree of microstructure increased with increase in addition of ZrSiO₄.

V. CONCLUSIONS

From this study, the following results were obtained.

- Hardness and impact strength of the composite increased with addition of ZrSiO₄ in LM13.
- Tensile strength increased with increase in wt% of ZrSiO₄. LM13 with 6 wt% ZrSiO₄ exhibited highest tensile strength
- Breaking strength and tensile strength were found to be highest in the composite having 6 wt% ZrSiO₄.
- From the microstructure analysis, it was inferred that tensile strength values of the composites were inversely proportional to the grain size.
- From SEM analysis it was concluded that distribution of ZrSiO₄ was uniform. This uniformity was observed in 6wt% ZrSiO₄-LM13.

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