Available online at www.sciencedirect.com

ScienceDirect

Procedia Materials Science 5 (2014) 550 – 557

Procedia Materials Science

www.elsevier.com/locate/procedia

International Conference on Advances in Manufacturing and Materials Engineering, AMME 2014

Effect of electromagnetic induction and heat treatment on the mechanical and wear properties of LM25 alloy

*Anil Kumar T, Gajanan Anne, N D Prasanna, M.K.Muralidhara

Asst. Professor, Dept of Mechanical Engg., M. S. Ramaiah Institute of Technology, Bangalore-54, India.
Research Scholar, Dept of Mechanical Engg., National Institute of Technology Karnataka, Surathkal-575025, India.
Professor, Dept of Mechanical Engg., M. S. Ramaiah Institute of Technology, Bangalore-54, India
Principal, RR Institute of Technology, Chikkabanavara, Bangalore-90, India

Abstract

Mainly for aluminum castings the properties depend on the grain structure, it is desirable to achieve a fine equiaxed grain structure. The formation of fine equiaxed grain structure depends on the rate of solidification, addition of grain refiners. Al-Ti-B master alloys are used in Al-Si alloys casting industries as a grain refiner to improve the casting properties. This research work investigates the combined effect of the addition of 2% Al-5Ti-1B and electromagnetic induction with T6 heat treatment on the mechanical properties and wear properties of LM25 alloy casting. The mechanical properties assessed are hardness and ultimate tensile strength (UTS), microstructure examination, fracture analysis of the castings are studied. It is found that mechanical properties and wear properties of LM25 alloy have been considerably improved by subjecting the alloy to combined effect of the addition of 2% Al-5Ti-1B and electromagnetic induction with T6 heat treatment.

Selection and peer-review under responsibility of Organizing Committee of AMME 2014

Keywords: LM25 alloy, grain refinement, electromagnetic induction, microstructure, heat treatment.

* Corresponding author. Tel.: +91-9663477722;
E-mail address: shohniadhi@gmail.com

2211-8128
Selection and peer-review under responsibility of Organizing Committee of AMME 2014
doi:10.1016/j.mspro.2014.07.299

1. Introduction

The excellent mechanical and tribological properties of aluminium-silicon alloys have led to extensive use of these alloys in engineering applications, particularly in the automobile and aerospace applications. Although aluminium-silicon alloys meet many of the service requirements, such as high strength-to-weight ratio, excellent corrosion resistance, good bearing qualities and lower expansion characteristics (Torabian et al.(1994)). Depending on the silicon concentration in the alloy and the cooling conditions, the structure of the casting will essentially comprise mixtures of aluminium grains, silicon crystals and aluminium silicon eutectic as well as various intermetallic phases formed from other alloying additions (Mg_2Si, $CuAl_2$) (Mohanty et al(1996)). The aluminium grains can grow very large, however, under slow cooling conditions, such as in sand castings or heavy sections, and this can lead to poor casting and mechanical properties. It is known that an equiaxed grain structure gives better mechanical properties than the columnar structure of the cast metal. In addition to that equiaxed grain structure exhibit better casting properties like improved feeding to eliminate the shrinkage porosity, decrease the hot tearing and reduced mold filling time. To achieve the grain refinement in the cast structures by adding inoculants to the melt in the foundry process(Mohanty et al(2002), Kashyap et al(2001), Zhu et al(2009)).

Grain refiners are materials added to alloys to aid in nucleation, and lead to the production of fine and uniform grain sizes. Grain refinement of aluminium alloys significantly improves the mechanical properties and susceptible to hot cracking is reduced (Kocatepe et al(2000)). There are several types of grain refiner available for Aluminium silicon alloys, which are based on aluminium- titanium or aluminium-titanium–boron master alloys, and titanium or titanium boron containing salt tablets (Mohanty et al(1995)). Several mechanisms take place in the formation of grains in a casting during solidification. There must be the presence of suitable substrates in sufficient amount to act as heterogeneous nucleation sites and there has to be sufficient undercooling to facilitate the survival and growth of the nuclei (Stefanescu et al(2008)). Both of these criteria have to be fulfilled to obtain a fine grain structure in a casting (Binney et al (2003)). Many methods have been introduced for microstructural control of cast alloys. Among these methods application of the external force like vibration during solidification give enhanced properties that have been considered by the investigators(Taghavi et al(2009)). Some of the investigators used ultrasonic waves as an external source to produce vibration and reported that it is more advantageous because cavitation and mass feeding act more effectively (Jian et al (2005)). Very meager information is available on the application of combination of addition of grain refiner with vibration through electromagnetic induction and T6 heat treatment.

In the present investigation, an attempt is made to study the effect of addition of grain refiner on LM25 alloy, when it is subjected to the combined effect of 2% grain refiner (Al-5T-1B) addition and subjected to electromagnetic induction and T6 heat treatment.

2. Experimental procedure

The composition of the alloy was determined by subjecting the alloy to a chemical test by the optical emission spectrometer.

Table 1: Composition of LM 25 alloy

Elements	Cu	Mg	Si	Fe	Mn	Ni	Zn	Pb	Sn	Ti	Al
% by wt.	0.04	0.41	6.81	0.34	0.003	0.02	0.07	0.01	0.03	0.08	Rem

The melting of the LM-25 alloy was carried out in an electrical resistance melting furnace. The temperature of the furnace was maintained at 756^0C. Degassing was carried out using hexachloroethane degassing tablets. The dross was skimmed off and the clean molten metal was transferred into the mould. Following treatment of the molten alloy were carried out in different stages:

- Without adding grain refiner and without inducing mechanical vibration.(as-cast)
- By inducing the electromagnetic induction to the molten metal with the addition of 2% (Al-5Ti-1B) refiner and T6 heat treatment.

2.1 Electromagnetic induction

The permanent die was placed in the electromagnetic induction coil arrangement; voltage supply was varied at various levels across the coil to effect the value of induction and intern rate of vibration to the molten alloys. The supply voltage of 80,120 and 200volts is supplied to the melt for a period of 3minutes during solidification.

Figure 1. Electromagnetic induction coil assembly

2.2 T6 heat treatment

The solution treatment was carried out at 540^0C for 6h followed by quenching immediately in still water maintained at 60^0C and then artificial aging was carried out at 170^0C for a period of 5 hours and followed by air cooling.

2.3 Microstructure examination.

After the T6 heat treatment the casting sample was prepared for microscopic examination according to ASTM-E407-2002 standard s. The size of the grains were measured using linear intercept method.

2.4 Mechanical testing

The influence of grain refinement and electromagnetic induction with T6 heat treatment on the mechanical properties of LM25 alloy was investigated. Properties like, tensile strength (UTS) and hardness of the alloy was assessed (using Brinell hardness testing machine).

2.5 Wear tests

Dry sliding wear tests were carried out using pin on disk type wear testing machine. The specimens were tested for constant load of 20N for different speeds viz.. 400, 800, and 1200rpm (time duration of 10mins).

3 Experimental results and discussion

3.1 Microstructure Examination

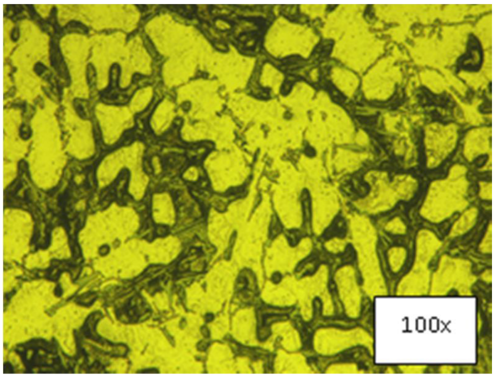

Figure2. microstructure of the as cast LM-25 alloy

Figure 2. shows the structure of the as cast LM-25alloy (without refiner addition and without inducing vibration). It is observed that the structure of the alloy is comprised of coarse aluminum matrix and by large and needle shaped Si particles near the grain boundaries. As per the linear intercept method, the secondary dendrites arm spacing (SDAS) was found to be 68.03μm.

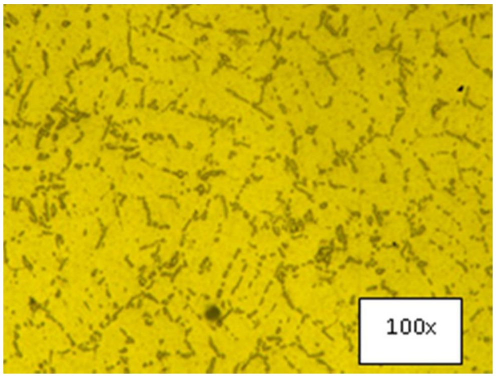

Figure 3. Supply voltage of 80V with 2% GR (Al-5Ti-1B) and T6 heat treatment

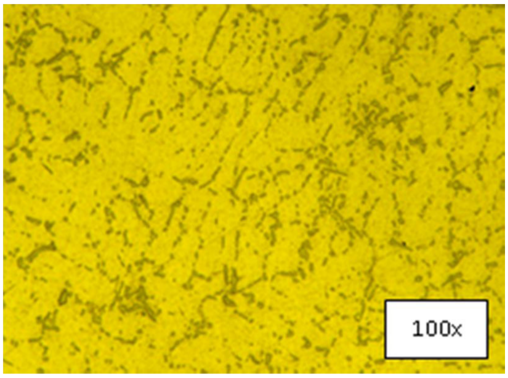

Figure 4. Supply voltage of 120V with 2% GR (Al-5Ti-1B) and T6 heat treatment

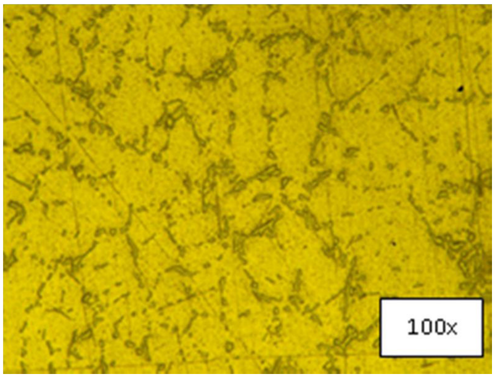

Figure5. Supply voltage of 200V with 2% GR (Al-5Ti-1B) and T6 heat treatment

Figures 3, 4 and 5 show the photomicrograph of the specimen subjected to addition of 2% grain refiner and electromagnetic induction (80, 120 and 200volt) for 5hrs of artificial aging. The SDAS of 80, 120 and 200 volt are found to be 47, 42.5 and 53.3µm respectively.

3.2 Hardness test

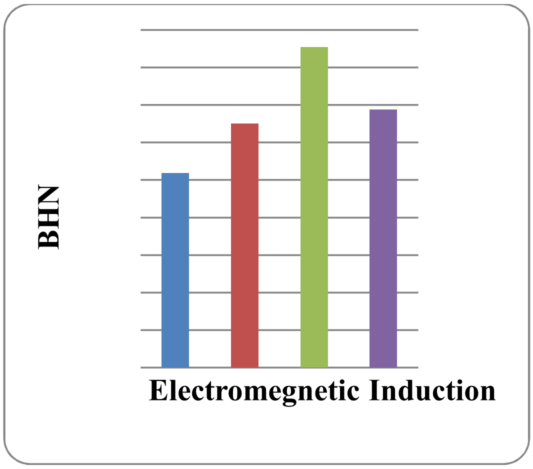

Figure 6. Electromagnetic induction with 2% GR (Al-5Ti-1B) with T6 heat treatment

Figure 6 shows the variation of hardness values with Electromagnetic induction with 2% GR (Al-5Ti-1B) and with T6 heat treatment. it can be seen that a maximum BHN value is observed in specimen subjected to the combined effect of 120volt of electromagnetic induction and with 2% grain refiner addition along with T6 heat treatment for the period of 5hrs of artificial aging. An improvement of 39.8% is seen with the specimen subjected to combined 2% grain refiner addition and 120volt electromagnetic induction and T6 heat treatment as compared with as-cast condition.

3.3 Fractography

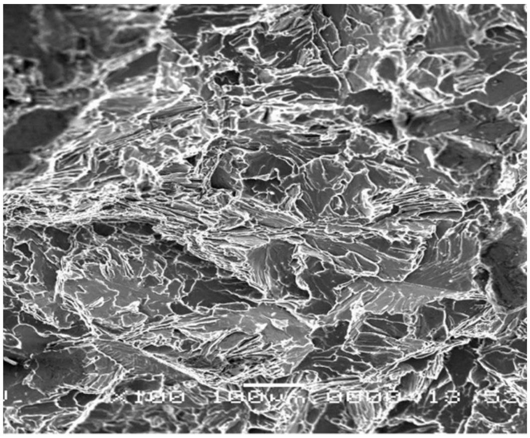

Figure7. As-cast specimen

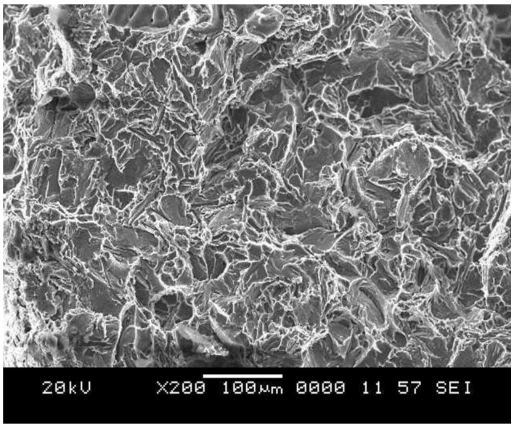

Figure 8. Supply voltage 80 volts with 2% GR (Al-5Ti-1B) and T6 heat treatment

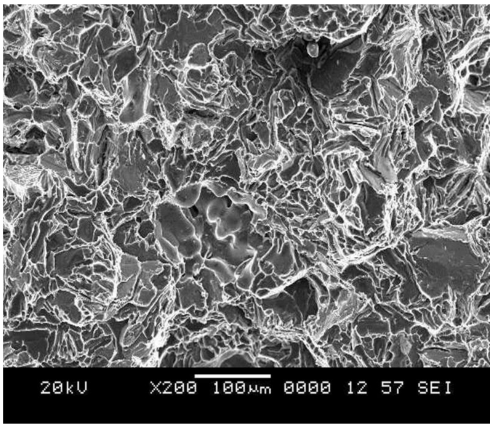

Figure9. Supply voltage 120 volts with 2% GR (Al-5Ti-1B) and T6 heat treatment

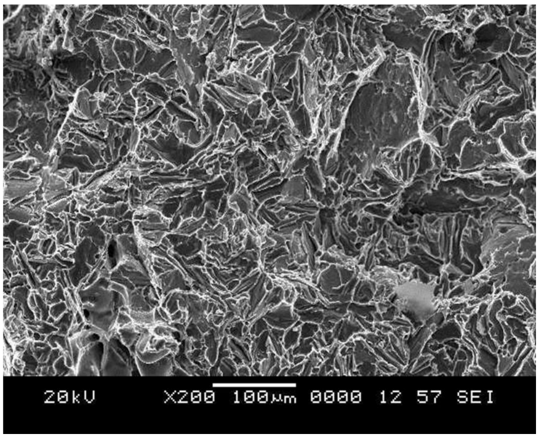

Figure 10. Supply voltage 200 volts with 2% GR (Al-5Ti-1B) and T6 heat treatment

Figures 7-10 shows the SEM fractography of tensile fractured samples of ascast and specimens subjected to supply voltage 80,120 and 200volts respectively. From the study, in comparison with ascast one , more fine and much uniform dimple mode of fracture was noticed in the specimens subjected to supply voltage of 80, 120 and 200 volts indicating ductile mode of fracture. Dimples have been formed arround cracked silicon particals as a result of plastic deformation of the alloys. Also more shrinkage defects are observed in Ascast specimen than that of others ..

3.4 Tensile test

Figure 11 shows the variation of UTS values with Electromagnetic induction with 2% GR (Al-5Ti-1B) and with T6 heat treatment. It can be seen that a maximum UTS value of 181.6 N/mm^2 is observed in specimen subjected to the combined effect of 2% grain refiner addition and supply voltage of 120 volts along with T6 heat treatment. An increase of 20.4% is seen with the specimen subjected to combined effect of grain refiner addition and T6 treatment in comparison with the as cast condition. The reason could be the due to minimum SDAS and almost evenly distributed silicon particles.

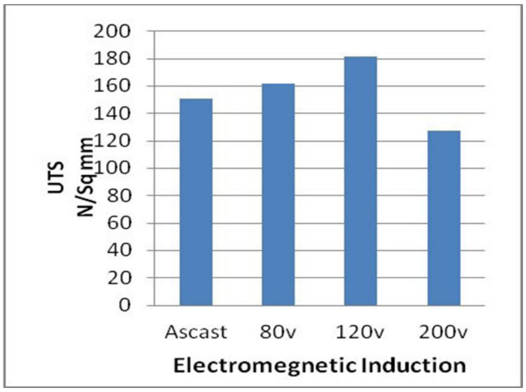

Figure 11. Electromagnetic induction with 2% (Al-5Ti-1B) GR with T6 heat treatment

3.5 Wear test (Dry sliding wear)

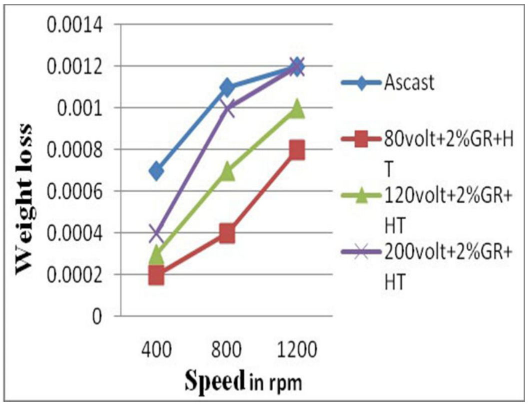

Figure 12. Weight loss V/s speed of the electromagnetic induction specimens.

Figure 12 shows the variation of weight loss of the specimen with Electromagnetic induction with 2% GR (Al-5Ti-1B) and with T6 heat treatment. It can be seen from the figure that with an increase in speed, the weight loss also increases. Maximum weight loss is seen in the as-cast specimen. There is a 33.3% improvement in the resistance to wear upon the alloy subjected to electromagnetic induction and with the addition of grain refiner and T6 heat treatment.

4. Conclusions

From the investigation carried out on LM25 castings subjected to combination of vibration and addition of 2% grain refiner with T6 heat treatment, the following observations were made.

- From the photomicrograph it is observed that, the as-cast specimen is comprised of coarse aluminium matrix and a dispersion of silicon platelets/needle particles and the grain structure gets reduced and a closed structure is observed when the alloy is subjected to combination of vibration and addition of 2% grain refiner and with T6 Heat treatment.
- Maximum hardness value of 85.5 BHN is observed in the specimen when it is subjected to combination 2% grain refiner addition with a supply voltage of 120volt electromagnetic induction and with T6 heat treatment. An improvement of 39.8% hardness values is observed.
- Maximum ultimate tensile strength value of 181.6 N/sq mm is seen in the specimen subjected to supply voltage of 120volt electromagnetic induction and the addition of 2 % grain refiner and T6 heat treatment. (An improvement of 20.5% in UTS value is noticed).
- Considerable improvement in the resistance to wear is seen upon subjecting the alloy to combined effect of grain refiner addition, electromagnetic induction with T6 heat treatment. (An improvement of about 33.3% in the resistance to wear is observed).

Acknowledgements

Authors express their sincere gratitude to the Management, Principal, HOD, Mechanical Engineering department, M.S.R.I.T. Bangalore for the support and the encouragement.

References

Binney, M. N., StJohn, D. H., Dahle, A. K., Taylor, J. A., Burhop, E. C., & Cooper, P. S. (2003). Grain refinement of secondary Aluminium-Silicon casting alloys. In *LIGHT METALS-WARRENDALE-PROCEEDINGS-* (pp. 917-922). TMS.

Jian, X., Xu, H., Meek, T. T., & Han, Q. (2005). Effect of power ultrasound on solidification of aluminum A356 alloy. *Materials letters*, *59*(2), 190-193.

Kashyap, K. T., & Chandrashekar, T. (2001). Effects and mechanisms of grain refinement in aluminium alloys. *Bulletin of Materials Science*, *24*(4), 345-353.

Kocatepe, K., & Burdett, C. F. (2000). Effect of low frequency vibration on macro and micro structures of LM6 alloys. *Journal of materials science*, *35*(13), 3327-3335.

Mohanty, P. S., & Gruzleski, J. E. (1995). Mechanism of grain refinement in aluminium. *Acta Metallurgica et Materialia*, *43*(5), 2001-2012.

Mohanty, P. S., & Gruzleski, J. E. (1996). Grain refinement mechanisms of hypoeutectic Al- Si alloys. *Acta materialia*, *44*(9), 3749-3760.

Murty, B. S., Kori, S. A., & Chakraborty, M. (2002). Grain refinement of aluminium and its alloys by heterogeneous nucleation and alloying. *International Materials Reviews*, *47*(1), 3-29.

Stefanescu, D. M. (2008). *Science and engineering of casting solidification*. Springer.

Taghavi, F., Saghafian, H., & Kharrazi, Y. H. (2009). Study on the effect of prolonged mechanical vibration on the grain refinement and density of A356 aluminum alloy. *Materials & Design*, *30*(5), 1604-1611.

Torabian, H., Pathak, J. P., & Tiwari, S. N. (1994). On wear characteristics of leaded aluminium-silicon alloys. *Wear*, *177*(1), 47-54.

Zhu, M., Yang, G., Yao, L., Cheng, S., & Zhou, Y. (2009). Influence of Al-Ti-B addition on the microstructure and mechanical properties of A356 alloys. *Rare Metals*, *28*(2), 181-186.