THE POSSIBILITY OF OBTAINING COMPOSITE AL18WT%SI/SIC BY COMPOCASTING PROCESS

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Abstract: The aim of this study was to investigate the influence of various process parameters on the microstructure of composite materials based on alloys Al18Wt%Si with the addition of 10Wt%SiC. The effect of stirring speed (1000 and 1500 rpm), stirring time 15 min and casting temperature 565 °C on the structural and mechanical properties are discussed. It was found that applying the stirring speed of 1500 rpm in semisolid state the best distribution of SiC particles in the matrix was achieved, which gave satisfying mechanical properties. In order to evaluate the quality of obtained composites and their possible application in the practice, tests were carried out under conditions of cavitation. Cavitation damage to the composite samples was determined using modified vibratory cavitation equipment. Mass loss and surface analysis of composite samples during the experiment were used as an indicator the level of cavitation damage. The results showed very good cavitation resistance which gives the possibility of using these materials in condition where cavitation resistance is needed.

Key words: Al–Si alloys, composite, composasting process, cavitation resistance.

1. INTRODUCTION

Aluminium-silicon alloys are a part of the group of important alloys for automotive industry. Piston alloys, with reference to application conditions, must show good thermal stability, good heat conductivity, corrosion resistance and satisfactory tribological properties. Within the exploitation life time, these alloys are subject to mechanical and heat stresses and to aggressive environmental application conditions. Piston alloy properties greatly depend on a proper choice of a melting technology, melt treatment, casting process and thermal treatment of castings. A basic limit factor affecting application of these alloys is the presence of coarse and brittle Si crystals in a soft Al base. One of important parameters influencing piston alloys properties is a modification procedure, i.e. the choice of type and quantity of modification agent. With Al-18wt%Si alloy, a modification process is mostly limited to modifying primary Si crystals. These procedures are aimed at a break and proper distribution of Si particles in a soft aluminium base. As a modifier, phosphorus is commonly used. A basic imperfection concerning application of this modifier is the fact that eutecticum remains needle-shaped and coarse, which is manifested by poor mechanical properties. Usage of Sr as a modifier significantly improves alloy properties and this modifier was used in the tests shown [1-6].

In order to obtain materials with advanced performances based on Al-Si alloys, procedures such are rheocasting, tixosasting and compocasting are used. Designing composite materials based on Al-Si alloys with application of SiC, Al_2O_3, ZrO_2 based reinforcement enables production of entire new specter of materials with good structural and mechanical properties. This paper presents detail description of producing method of Al18%Si/SiC composite by means of compocasting process [7-10].

Cavitation resistance is also important property when using them in contact with high velocity liquid subjected to pressure changes.

Cavitation represent the formation and collapse of the bubbles in a liquid due to local pressure changes. When the liquid that contains bubbles is subjected to higher hydrostatic pressure, the bubbles can collapse suddenly. This collapse can cause cavitation fatigue of material surface through shock waves and microjets [7,11-15].

The cavitation mechanism of AlSi alloys was discused. It showed that the material removal was mainly by plastic deformation and ductile fracture of the aluminium. In this study, the cavitation resistance of rheocasting alloy Al18Wt%Si and aluminium alloy composite with 10wt%SiC was investigated.

2. EXPERIMENT

Al-18wt%Si alloy which was used for the experiment had the following chemical composition: 18 % Si; 0.8-1.5 % Cu; 0.8-1.3 % Mg; 0.8-1.3 % Ni; 0.7 % Fe; 0.2 % Zn; 0.2 % Mn; 0.2 % Ti; balance to 100 % Al. Two series of testing were conducted.

Rheocasted samples (serie A) were casted at temperature 565 ^{o}C and with mixing time 15 min. In order for compocasted sample (serie B) to be obtained the following procedure was applied: mixing rate was 500 rpm; afterwards the mixing rate was increased until 1000 rpm was reached. At the end of the procedure mixing rate was 1500 rpm. In both experiments, A and B, the alloy was heated up to 720 ^{o}C. Afterwards the alloy melt underwent cooling procedure with rate of cooling $0.16\pm0.05^{o}Cs^{-1}$. At temperature 560-565 ^{o}C mixing with special alloy mixer was performed. The mixing of the melted alloy at the rate of 500 rpm lasted for 5 min, and the goal of the procedure was to transform morphology of dendrite of α-Al into non-dendrite one. Particles of SiC reinforcement, before its infiltration into the solution, were dried in drying chamber and then heated at temperature 500 °C. Time of SiC particles infiltration was 3 min. After infiltration, the mixing was proceeded at the constant increment of mixing rate up to 1500 rpm. The mixing lasted for 7 min.

All samples were being prepared for microstructural tests applying standard metalograhic procedure of polishing and etching of the samples (by Keler's agent). Microstructural tests were carried out by applying microscope REICHERT – JANG with JVC color video camera. The microscope is connected to the computer LEICA.

Cavitation damage to the composite samples was determined using modified vibratory cavitation equipment.

Mass loss and surface analysis of composite samples during the experiment were used as an indicator the level of cavitation damage.

Quality mineral analysis of the samples SiC was carried out under polarizing microscope for reflected and transparent light, of type JENA POL-U, Carl Zeis, by immersion method, with qualitative identification of present minerals, magnification 50 x.

Analysis of the particle size and shape factor was conducted by means of the software application package OZARIA 2.5 (0-1 range), shape factor for 0-section corresponding to needle shape, for 1-section corresponding to circle, grain size given in microns.

Vickers hardness was measured by using a universal hardness tester (WPM Leipzeg), under 5 N load. Hardness was measured at four points and the average was taken for study.

3. RESULTS AND DISCUSSION

Qualitative mineralogical analysis of SiC sample are shown that particles mostly had a uniform size and morphology and that the grains were more oval, Fig.1. Grain size was 25-30 μm, Fig.2.

Grain shape factor was 0.6-0.7 (particles was roundness), Fig.3.

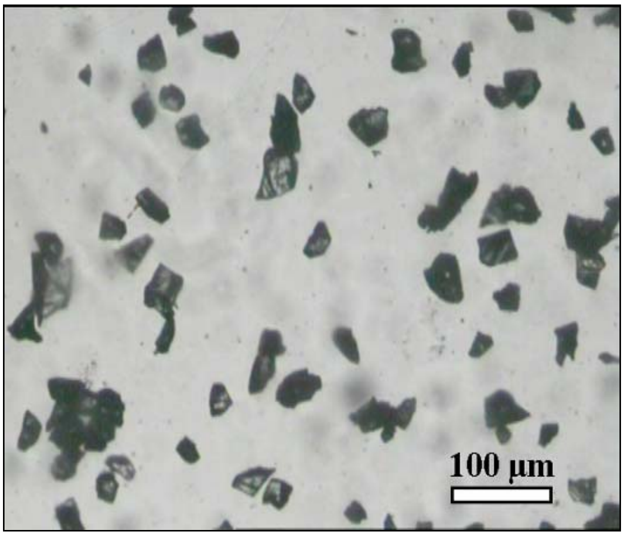

Fig. 1. Microphotography of SiC sample.

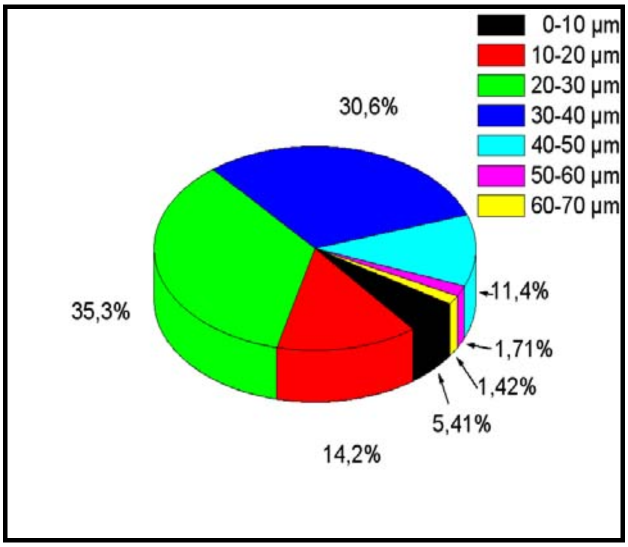

Fig.2. Histogram of grain size of SiC

Fig. 4. shows the structure of the samples A created during the rheocasting process.

During subcooling created by introducing the stirrer into the melt, first α- Al particles are formed locally around the stirrer in a globular form. The particles are mutually separated. As the stirring time increases, roundness of α-Al particles is changed and the particle congregating and their mutual agglomeration is noticed. Stirring speed increment influences increased fragmentation of dendrite arms and creation of a larger number of particles for α-Al phase nucleation. Thus increased number of small fragments influences low possibility of their further increment, which is in accordance with the fragmentation-agglomeration mechanism of the change of phase morphology during the solidification process of the rheocasting alloy. In this work, the shape factor of α-Al particles was not determined, but it can be noticed that roundness degree is more distinct at the stirring speed of 1500 rpm.

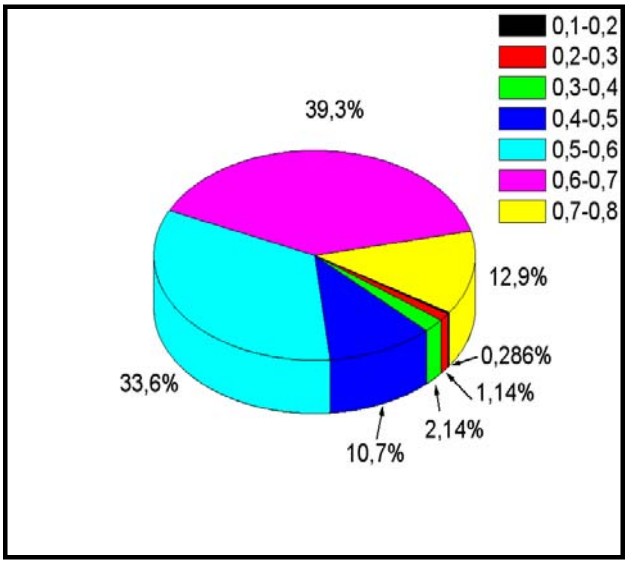

Fig.3. Histogram of grain shape factor of SiC

The tests showed that gathering rate of primary Si particles is increased with an increment of the melt stirring speed, Fig.5. Gathering rate of Si particles is not noticeable at lower stirring speeds, i.e. at the stirring speed of 1000 rpm, while segregation of Si particles is more noticeable at higher stirring speeds. The process of gathering primary Si crystals in clusters-blocks, consisting of a number of individual Si particles mutually connected, is a consequence of shearing forces appearing during melt stirring.

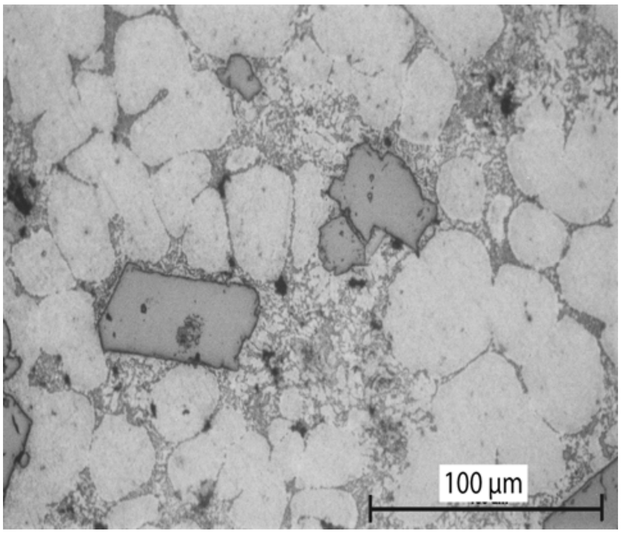

Fig. 4. Microstructure of α- Al particles (sample A).

Fig. 6. shows microstructure of composite material. It can be noted that microstructure is consisted of primary particles of silicium, Al - matrix, as well as SiC particles. Silicium particles (light gray) surround SiC particles (dark) and they are mutually connected. SiC particles are basis for nucleation of primary particles of silicium. Depending on melt-stirred conditions, shape of primary particles of silicium can vary and they manifest tendency for agglomeration as they are making connection with surface of SiC particles.

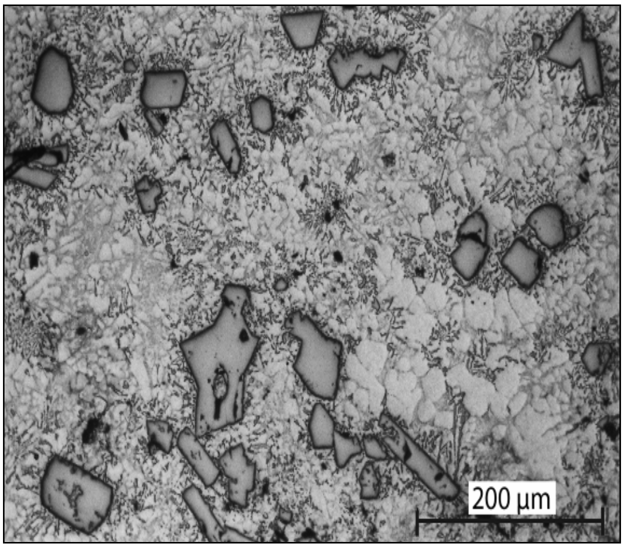

Fig. 5. Microstructure of Si particles (sample A).

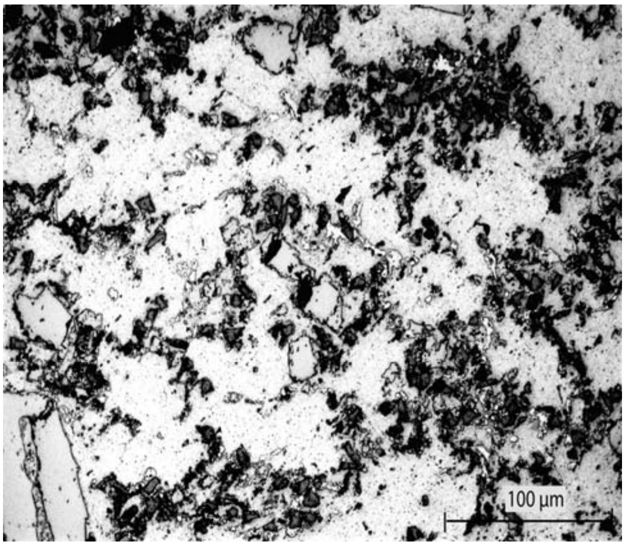

Fig. 6. Microstructure of sample B

The results of the cavitation resistance testing of the materials subjected to cavitation are shown in Fig.7.
The diagram shows relation between mass loss and testing time, where the lines were drawn by least-square method and data can be expressed by a straight line. The slope of the straight line represents the cavitation rate. The calculated slope for AlSi18% + SiC10% was 0.047 mg / min.
Regression analysis showed excellent correlation, with coefficient of correlation of R^2=0.9926 for AlSi18% + SiC10%. Loss of ignition was between 2 and 11 mg which can be seen in Fig. 7.

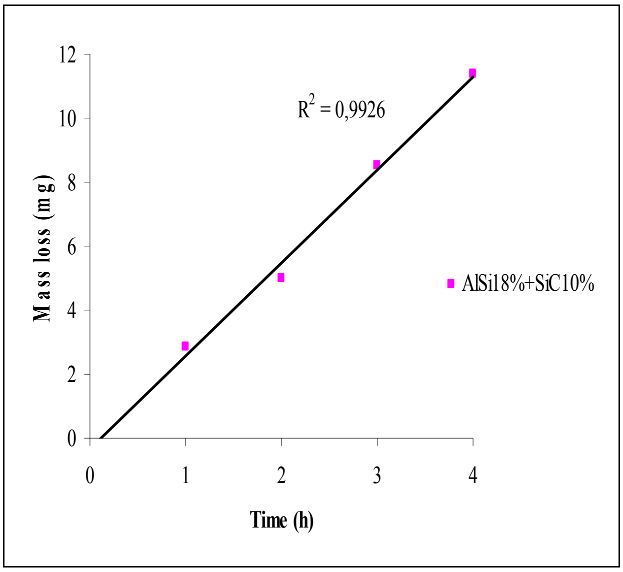

Fig. 7. Cavitation erosion of tested sample as a function of time

Wearing-out resistance of B composite reinforced with 10 % of SiC particles depends on inter-superficial connection between Al matrix and reinforcement.

When connection between particles and Al is strong, they protect surface from destructive cavitation actions. Investigation results show that obtained composites have satisfying quality and that mixing time was punctually projected for strong bonds between Al matrix and SiC particles to be created.

4. CONCLUSION

Results of investigation showed that by application of compocasting procedure a Al18wt%Si/SiC composite was obtained, which showed excellent structural and mechanical properties and also better cavitation resistance in comparison with same alloys obtained by rheocasting procedure.

5. ACKNOWLEDGEMENTS

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6. REFERENCES

1. Cosic, M. et al., (2011). *Possibility to use Rheocasting process for manufacturing parts in automotive industry*, 10th Anniversary International conference on accomplisments in Electrical and Mechanical Engineering and Information Technology, DEMI 2011, Banja Luka, Proceedings, pp.405-408.
2. Tomida, S. et al., (2003). *Improvement in wear resistance of hypereutectic Al – Si cast alloy by laser surface remelting*, Surf.Coat.Technol.169 – 170, pp. 468 – 471.
3. Gupta M. and Ling S., (1999). *Microstructure and mechanical properties of hypo/hyper – eutectic Al – Si alloys synthesized using a near – net shape forming technique*, J.Alloys Compd. 287, pp. 284 – 294.
4. Kim T. et al., (2001). *Microstructure of rapidly solidified Al – 20Si alloy powders*, Mater.Sci.Eng.A 304 -306, pp. 617 – 620.
5. Bai Qing, X. at al., (2003). *The study of primary Si Phase in spray forming hypereutectic Al –Si alloy*, J.Mater.Process.Technol.137, pp.183 -186.
6. Agarwal, A. and McKecchnie, (2001). *T. Spray – forming aluminium structures,* Adv.Mater.Processes 159 (5), pp. 44 – 46.
7. ASTM Standard G32-92, (1992). Annual Book of ASTM Standards, Vol. 03.02, ASTM, Philadelphia.
8. A.Agarwal and T.McKecchnie, (2001). *Spray – forming aluminium structures,* Adv.Mater.Processes 159 (5), pp. 44 – 46.
9. Tamer Obzen at all, (2008). *Investigation of mechanical and mechinability properties of SiC particle reinforced Al- MMC,* Journal of materials processing technology, 198, pp. 220-225.
10. Sahin. Y, (2003). *Preparation and some properties of SiC particle reinforced aluminium alloy composites*, Mater. Des. 24-28, pp. 671-679.
11.J.H.N.Yoshimuro at all, (1997). *The effect of SiC clusters and porosity on the mechanical properties of PMAL matrix composites,* Key Eng.Mater. 127 – 131, 985 – 992.
12. K. Kondoh at all, (2009). C*avitation resistance of powder metallutgy aluminum marix composite with AlN dispersoids,* Materials Science and Engineering A, 499, pp. 440-444.
13. T.Zeuner at all, (1998). *Developing trends in disc brake technology for rail application*, Mater.Sci.Technol.14, pp. 857 – 863.
14. C.E. Brennen, (1995). *Cavitation and Bubble Dynamics*, Oxford University Press, pp.123.
15. F.G. Hammitt, (1980). *Cavitation and Multiphase Flow Phenomena,* McGraw-Hill, New York, pp. 255.

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