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Air Jet Erosion Study on Stir Casted Metal Matrix Composite Aluminum-SiC

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Abstract. For equipment that operates in high-speed abrasive media, erosion will be the major factor for its failure. Metal Matrix Composite (MMC) Aluminum-Silicon Carbide has been developed for improving the lifetime for such application.
In this research, MMC Al-SiC has been made using Al-7075 scrap with 5%, 10%, and 15% SiC powder addition. This MMC was manufactured using stir casting technique with 1% Magnesium addition. Optical metallography has been done to know the SiC distribution homogeneity. Erosion resistance of the MMC was studied using Air Jet Erosion Test with Alumina powder as abrasives.
The microstructural study showed that MMC Al-SiC has been successfully manufactured although the SiC particle distribution has not been fully homogeneous yet. Air Jet Erosion Testing revealed that the addition of 5% SiC powder was optimal in increasing its erosion resistance. The SiC addition from 10 to 15% did not improve its erosion resistance significantly.

Keywords: Metal Matrix Composite; Al-7075; SiC; Stir Casting; Air Jet Erosion Test

1. Introduction

Technology development in materials has made a way to help reducing working cost and increasing efficiency in industries. Metal Matrix Composite (MMC) Al-SiC is a composite material with aluminum matrix reinforced with silicon carbide (SiC) particles [1]. This composite has been used in energy and aviation industries because it is relatively easy to produce, light weight and has good mechanical properties.

Good MMC Al-SiC has been manufactured with stir casting process using Aluminum Al7075, SiC powder grit 220 and the addition of 1 wt.% of magnesium powder [2, 3]. Even though stir casting is the simple way to produce composite, this process has some drawbacks that reduce the quality of product, i.e. the presence of porosity and particle agglomeration. There are some factors that influence the MMC product quality, such as interface reaction, wettability, and porosity. At the interface region, reaction between SiC powder and molten aluminum must be controlled to avoid unnecessary reaction that can produce more harmful compound like Al_4C_3 [4]. Wettability is the tendency of a certain fluid to spread on a solid surface. To increase the wettability of the fluid, there are three main things that must be accomplished which are increasing surface energy of solid particle, decreasing surface tension of fluid, and decreasing interfacial energy of solid-fluid [5]. Porosity is a void or an opening space between grains or trapped gas in grains in microstructure. The presence of porosity in manufacturing products cannot be avoided but can be reduced. Porosity was formed by the presence of impurities of hydrocarbon or entrapped gas because of vigorous stirring [6].

In some applications, parts made from MMC Al-SiC may operate in environment that contains high-pressure fluid. This high-pressure fluid may bring particles that can cause erosion on the composite and may reduce its life-time. It is our aim in this research to investigate the effect of SiC content to the erosion resistance of MMC Al-SiC.

2. Materials and Methods

Before the stir casting process, 50 μm SiC powder was heated at 1050^0C for 8 hours to develop thin SiO_2 oxide layer at the surface of SiC particles. This SiO_2 oxide layer will prevent the formation of Al_4C_3 whenever molten Al reacts with the surface of the SiC particles [7]. This brittle Al_4C_3 will reduce the interface bond strength of the MMC. The stir casting process was done by mixing aluminum Al7075 scrap and oxidized SiC powder with the addition of 1 wt.% magnesium powder. SiC and 1 wt.% magnesium was preheated before introduced to the molten aluminum at 700°C, then stirred for one minute outside the furnace. The melted composite was then reheated before poured into a 33 mm diameter cylindrical steel container with 120 mm height. This sample was then cut and characterized for optical metallography to know the homogeneity of the MMC Al-SiC sample. The observation was done for the un-etched samples at nine different locations as described in Figure 1.

Resistance to erosion was studied with air jet erosion tester that was in the Metallurgy and Materials Laboratory, Institute of Technology, Bandung. The 2.5 cm × 2.5 cm specimen were placed in a jet erosion testing machine with 45° contact angle, then the erodent particle of 50 μm alumina powder was impacted to the specimen with fluid velocity of 70 m/s. The erosion test was conducted for 20 minutes with 2 grams/minute of erodent discharge. The difference in weight before and after the erosion test will then be determined for different percentage of SiC. The weight loss was then divided by specimen density to obtain volume loss in cubic millimeter. Erosion resistance will be presented in the erosion value that is the volume loss divided by total mass of alumina erodent that used to erode specimen. The erosion jet testing is schematically presented in Figure 2.

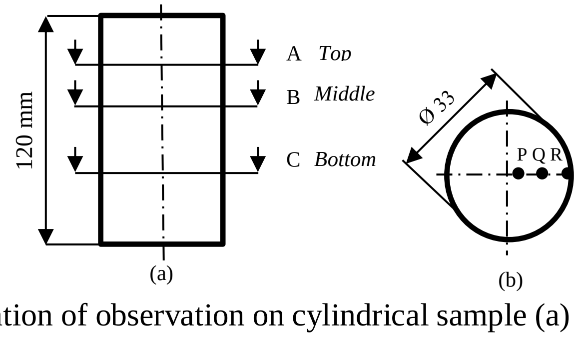

Figure 1 Location of observation on cylindrical sample (a) side view and (b) cross section view

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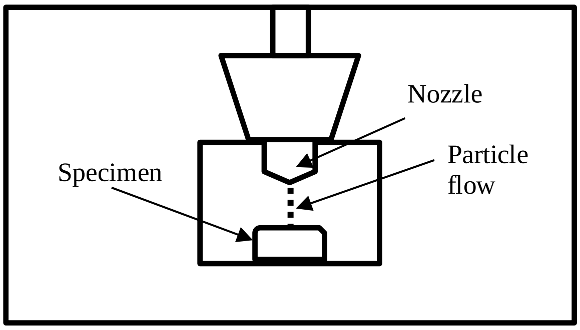

Figure 2 Air jet erosion test scheme

3. Results and Discussion

The result of optical metallography of the un-etched sample of MMC Al-15 wt.% SiC in Figure 3 shows the homogeneity of SiC distribution. It presents the microstructure of the nine observation locations at the cross sections of the cylindrical sample as schematically shown in Figure 1. It can be demonstrated that the SiC particles have been mixed nicely in the cylindrical sample from the upper part to the lower part of the cylinder although the distribution of SiC particles for each location were not homogeneously distributed. In the mixing process, SiC powder will tend to form clusters following the flow of the melted aluminum. Because the stirring process was done outside of the furnace, there was not a lot of time to do the mixing before the temperature reached the liquidus temperature of the Al-7075 and solidified. This will result in the SiC particles distribution that was still locally clustered, although the SiC particles still could be distributed all over the cylinder. The SiC particles apparently were quite intact at the aluminum matrix due to the addition of 1 wt.% Mg. Without the addition of magnesium, it has been proven that the SiC powder would tend to float at the surface of the molten aluminum due to the high surface energy of the molten aluminum. The addition of 1 wt.% magnesium has made the SiC powder not to float when the stirring process was done. This shows that the magnesium addition has reduce the surface tension of aluminum, reducing the interfacial energy between molten aluminum and SiC particles, and improving the surface energy of the solid, in accordance with the investigation for MMC Al-SiC by Singh et.al. [5] This happened due to the formation of $MgAl_2O_4$ at the surface of the oxidized SiC particle which improved the wettability of the SiC particles towards aluminum.

The amount of SiC particles in Figure 3 was counted to know the homogeneity of the SiC distribution from the upper part to the lower part of the cylinder. The result is presented in Figure 4. In general, the outer cylinder has lower density of SiC particle. SiC particles tend to be at the center of the cylinder. After stirring, the molten MMC was casted to the steel cylinder die. It will solidify starting from the outer part that was closer to the steel wall. Due to the surface energy of the molten metal, the SiC particles will tend to flow up to the surface. This can only happen at the aluminum that has not been solidified yet. Therefore, the SiC particle then will be pushed upwards and try to move to the area that was still melted at the center of the cylinder. This explains why the SiC particles to be more at the center and less at the outer part of the cylinder. This also explains why the upper part of the cylinder has more SiC particles than the lower part.

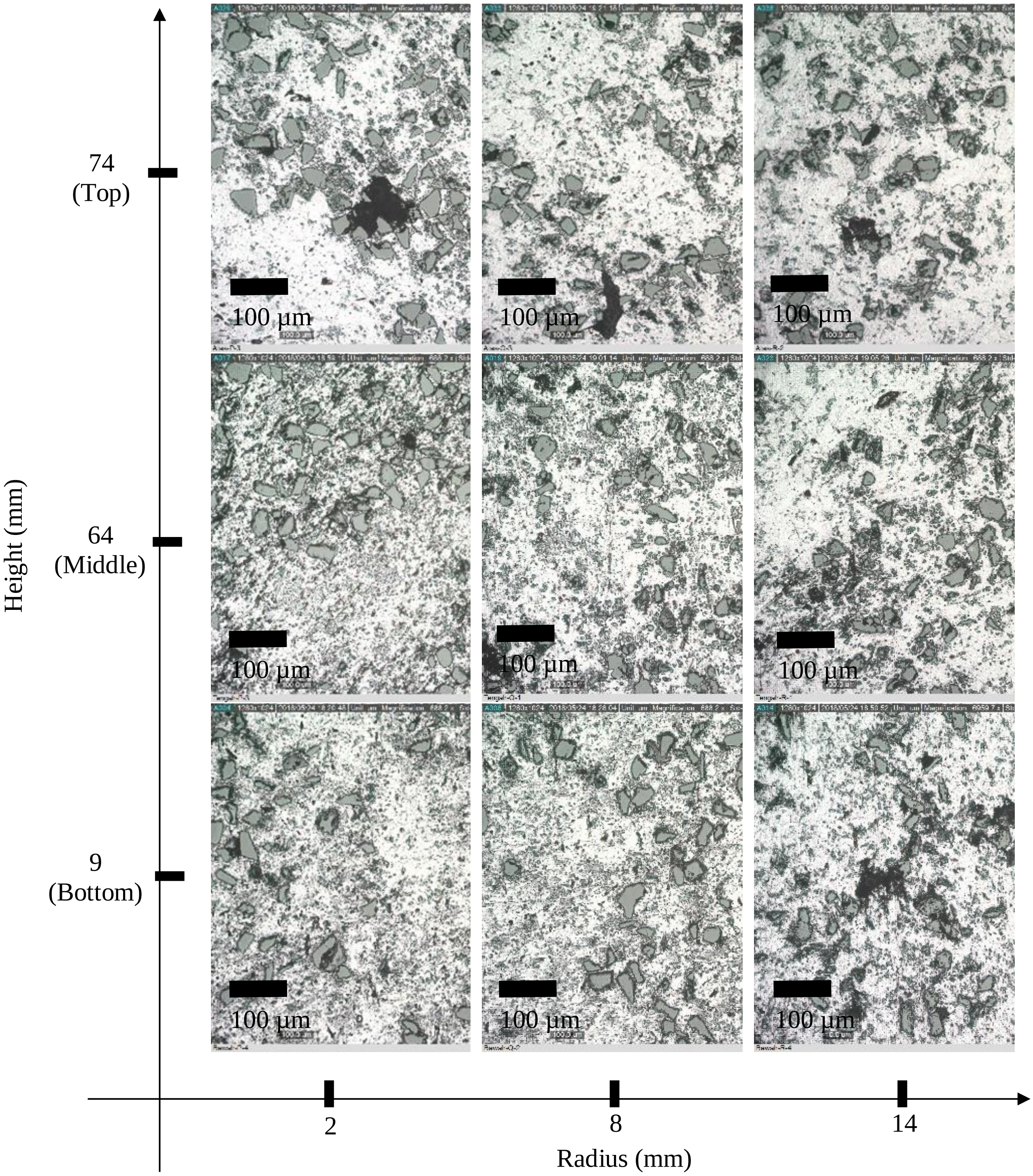

Figure 3 The distribution of SiC particle in MMC Al-15 wt.% SiC

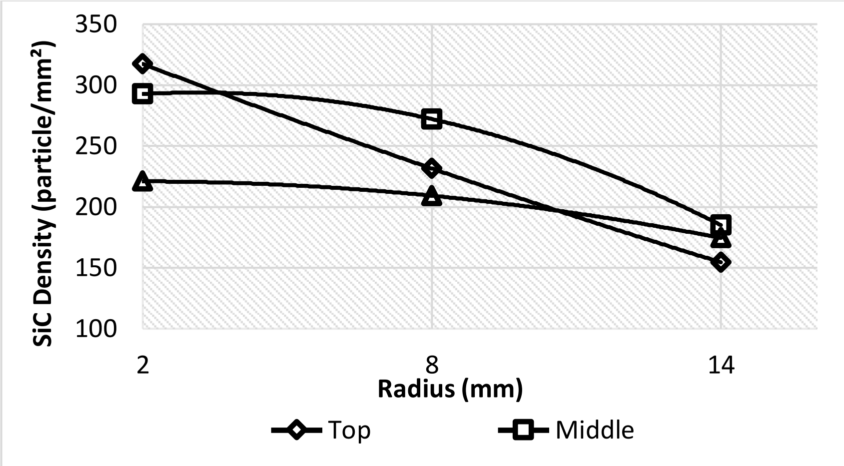

Figure 4 Particle density of SiC in Aluminum matrix

Figure 5 presents the result of the jet erosion testing for four different addition of SiC powder to aluminum, i.e. 0 wt.%, 5 wt.%, 10 wt.%, and 15 wt.% SiC. The result shows that the addition of SiC will decrease the erosion value which means improving the erosion resistance of MMC Al-SiC. The SiC particles apparently act as a shield to the jet flow of fluid that contains the alumina erodent in jet erosion testing. This will protect the aluminum matrix to the erosion wear due to the jet flow. However, the addition of more than 5 wt.% SiC will not make a statistically significant difference in erosion value. This is due the presence of the porosities that tend to be more at higher percentage of SiC addition. These porosities will make the SiC to be easier to be pulled out when it was impacted by the jet flow. The porosities will be getting bigger and the weight loss will be more. This results in the reduction of the erosion value such that there is no statistically significant difference in erosion value after 5 wt.% SiC.

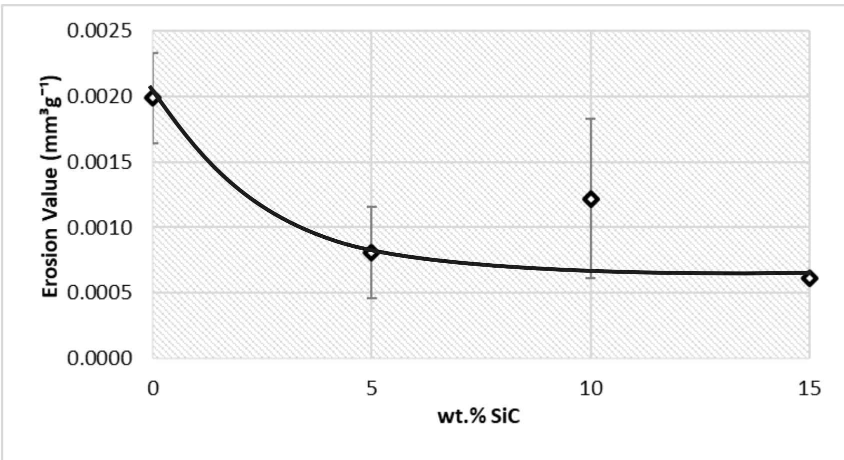

Figure 5 Erosion value variation from air jet erosion test

4. Conclusions

Metal Matrix Composite Al-SiC can be produced using the stir casting procedure with 1 wt.% magnesium addition. Even though SiC particle was not distributed homogenously in Al matrix, the addition of SiC powder in aluminum matrix makes MMC Al-SiC to have better erosion resistance. The test showed that the optimum erosion resistance can be accomplished with 5 wt.% SiC. In the future study to ensure the homogeneity of SiC particle distribution, it is suggested to increase the stiring time of the molten MMC using an externally heated container.

5. References

[1] T. W. Clyne and P. J. Withers, An Introduction to Metal Matrix Composite, E. A. Davis and I. M. Ward, Eds., Oakleigh, Melbourne: Press Syndicate o the University of Cambridge, 1993.

[2] E. B. Kohara, "Study of the Effect of Aluminum Types and SiC Powder Oxidation in the Making of Al-SiC MMC," Intitute of Technology Bandung, Bandung, 2016.

[3] P. K. Sudarsono, "Study of the Effect of SiC Concentration and Magnesium Addition on Hardness of Aluminium Matrix Composite," Institute of Technology Bandung, Bandung, 2017.

[4] Amitesh and V. C. Kale, "Aluminium Based Metal Matrix Composite for Aerospace Application: A Literature Riview," *IOSR Journal of Mechanical and Civil Engineering,* pp. 31-33, November-Desember 2015.

[5] V. K. Singh, S. Chauhan, P. Gope and A. Cahudhary, "Enhancement of Wettability of Aluminum Based Silicon Carbide Reinforced Particulate Metal Matrix Composite," *High Temperature Materials Processes,* p. 2, 2004.

[6] X. G. Chen and E. S., "Formation of Gas Porosity in Aluminium Alloys," *American Foundry Society Transactions,* Vols. 92-94, pp. 673-682, 1993.

[7] J. Hashim, M. Looney and M. S. J. Hashmi, "The Enhancement of Wettability of SiC Particles in Cast Aluminium Composites," *Journal of Material Processing Technology,* no. 119, pp. 329-335, 2001.