Friction Coefficient and Compression Behavior of Particle Reinforced Aluminium Matrix Composites

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***Abstract*—Metal matrix composites (MMCs) are materials used in a large range of engineering applications. In this paper, the relatively low-cost stir casting is evaluated with the use for Silisyum Carbite (SiC) as reinforcement and Al7075 alloy as matrix to produce MMCs with varied reinforcement from 10% to 18%. The produced composites were examined, and their wear behavior was investigated. The results showed that the mechanical properties of the MMCs decrease with the increase of the mass percentage of reinforcement and compression.**

Keywords-metal matrix composites; stir casting; SiC; friction coefficient

I. INTRODUCTION

Aluminum and its alloys play an important role in the production of MMCs. These materials began to be used towards the end of the 20th century, especially in the automotive space and aviation industry. They attract attention due to their specific strength, light weight, heat insulation and high abrasion resistance. Composite material production and material properties can be improved by changing the types and amounts of matrix and reinforcement elements [1-3]. Today, methods such as infiltration, powder metallurgy, rapid solidification, plasma spray hot stamping [4, 5] and stir casting [6-8] are used on MMC material production. Stir method is the most economical and with higher product capacity process for production of MMCs. But, stir casting technique, is difficult to produce a homogenous and stable material due to inherent stir casting problems such as poor wetting, clustering and prosite [9-11]. The mechanical properties of MMCs are affected by the interface bond between the matrix and the reinforcing materials and the load transfer is decreased.

Authors in [12] studied aluminum alloy 6061 reinforced with Al_2O_3 particles with different mass ratio for the fabrication and characterization of AA 6061/ Al_2O_3 AMMC by stir casting process. They found some improvement about micro hardness and ultimate tensile strength in produced samples. Al7075 material was used as matrix due to its lightness and relatively high strength. Authors in [13] studied 7075 alloy as a matrix with whisker reinforced composites with squeeze casting method for manufacturing superplastic material and succeeded 260% total elongation. Authors in [14] used 7075 alloy as a matrix to produce (SiC+Ti) hybrid composites using squeeze casting method. They successfully produced hybrid composite material with increasing strength due to decreasing ductility. Authors in [15] studied 7075 alloy as matrix to produce nano hybrid composites using stir casting and squeeze casting improving the hardness of composites [15].

There are three types of composite reinforcements, long or fibers, finite length fibers and particulates. In our study SiC particles are selected as a reinforcement material. Authors in [16] used SiC particles as reinforcement. As a result the material strength increased along with a loose on ductility. Authors in [17] used SiC particles as a reinforcement with Al6061 matrix composites while investigating wear behavior and sliding speed in different SiC ratios. As a result, in increasing SiC ratio the wear decreases and friction coefficient increases. Authors in [18] used SiC as reinforcement with Al6063 matrix to produce composites with vacuum molding assisting stir casting method and to investigate the effect of reinforcement ratio and particle size on dry sliding wear. As a result they found optimum tribological behavior on 7.5% reinforcement ratio and 70AFS particle size. Authors in [19] used SiC particles with two different matrix alloys (A536, 6061) and studied reinforcement distribution and wettability improving the wettability of SiC. Authors in [20] used SiC and C nano tubes as reinforcements to the cooper matrix to produce hybrid self-lubricating composites, and investigated their wear and friction behavior. The resulted hybrid composites showed higher tribological behavior than monolithic copper [20]. Authors in [21] studied magnesium matrix composites

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reinforced with SiC particles using semisolid stirring assisted ultrasonic vibration method. They found that the composite mechanical properties mostly depend on grain refinement and particle distribution. Authors in [22] produced aluminum matrix composites with Al_2O_3 particles. The product microstructure and its mechanical properties were investigated via extrusion processes. They found that porosity increased by increasing reinforcement ratio and stirring speed and decreased by extrusion process. The samples' mechanical properties were usually increased.

A limited number of studies is available on the development of AL7075 aluminum alloy based MMCs by a combination of stir casting method. In this work, different weight percentage of SiC particle reinforced AL7075 aluminum alloy matrix composites were produced by stir casting. Mechanical and microstructural observations between the aluminum alloy and SiC were described.

II. EXPERIMENTAL PROCEDURE

Al7075/10wt SiC, Al7075/14wt SiC, Al7075/18wt SiC, composite materials were produced. Al7075 was selected as matrix material. The chemical constituents of the material are listed in Table I. This alloy contains 2.7% Mg which increases wettability. SiC particles of 50-100μm in size were used as reinforcement elements. The production work was carried out in a specially prepared stir casting machine (Figure 1).

TABLE I. CHEMICAL COMPOSITION OF AL7075

Fe	Si	Cu	Mn	Mg	Zn	Cr	Zi	Ti	Rest
0.5	0.5	1.5	0.3	2.7	5.6	0.23	0.25	0.15	Al

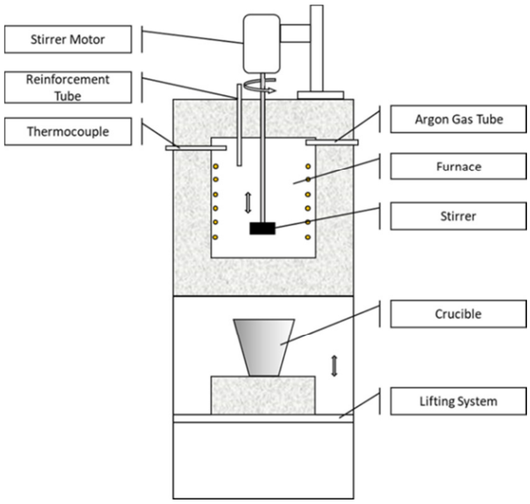

Fig. 1 Mixing casting machine

Al7075 was selected as the matrix material, and was heated to 690°C under argon gas, and then the SiC reinforcing particles, heated at the same temperature were added in packs. The addition continued for 10 minutes at a rate of 200rpm. During this mixing process the temperature dropped to around 590°C. We may say the study occurred in semi solid state rather than liquid state. After the mixing process, the temperature increased to 720°C to increase the fluidity of the composite material, and then it was poured into a pre heated at 350°C mold. When it was cooled to room temperature, 500g of composite material were produced. A produced test sample is shown in Figure 2. Samples were cut with a finger milling machine and a precision saw was used to give the same shape. For metallographic observation, they were prepared by grinding through 1000 grit papers followed by polishing with diamond paste. The samples were examined with SEM devices. The same samples were prepared as per ASTM E9 standard for compression testing at room temperature, with 20m/s velocity. To obtain friction coefficient a UTS TRIBOMETER T10/20 was used. Samples were prepared on ASTM G-33 standard. 20N, 30N, 40N forces were applied on the samples in 200m distance for wear test.

Fig. 2 Sample obtained after casting

III. RESULTS AND DISCUSSION

A. Friction Coefficient

The friction coefficients for different test loads and samples are listed in Table II and their graph is shown in Figure 3. Normally friction coefficient of aluminum - steel couples is 0.5-0.6 and increases with the test distance [23]. The result shown in Figure 4 is analogous to that. Also, an increase in load increases friction coefficient. Generally, in low loads composites shown good tribological characteristic [24]. The values obtained from the test were adjusted to a 6th degree curve to reduce noise. The increase in the ratio of the reinforcement element at a load of 40N obtained a lower drag coefficient. Friction coefficients increased due to the increase in distance and wear of the contact surface in the material.

B. Compressive Stres

Composite materials had different mechanical properties according to particle size and matrix alloy. The results of the test are given in Figure 4. When the SiC reinforcements increasedat room temperature, the strength of the composite material decreases [25, 26]. The 10% SiC-containing sample showed a sudden strain drop due to the progression of capillary cracks. It was observed that the increase in the SiC ratio caused a decrease in compressive strength due to the fact that the grain size is above 50 microns and porosity occurred in the microstructure during production.

TABLE II. DIFFERENT STATES FOR THE SAMPLES.

Sample	Mass% SiC	Method
Al7075 - SiC	10	Free Casting
Al7075 - SiC	14	Free Casting
Al7075 - SiC	18	Free Casting

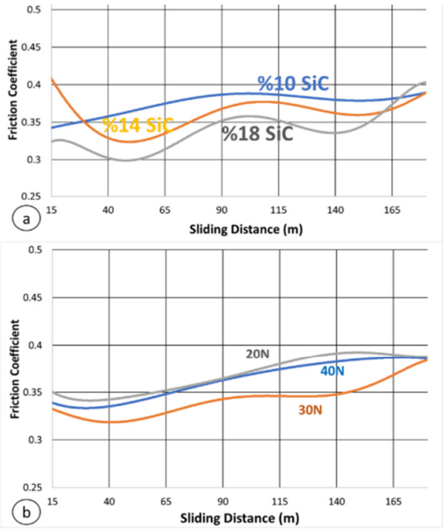

Fig. 3 Friction Coefficient: (a) on 40 N load for samples 1-3, (b) on 20N, 30N, 40N laod for 10% SiC content composites.

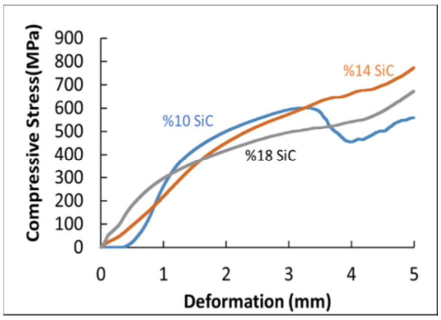

Fig. 4 Compressive stress

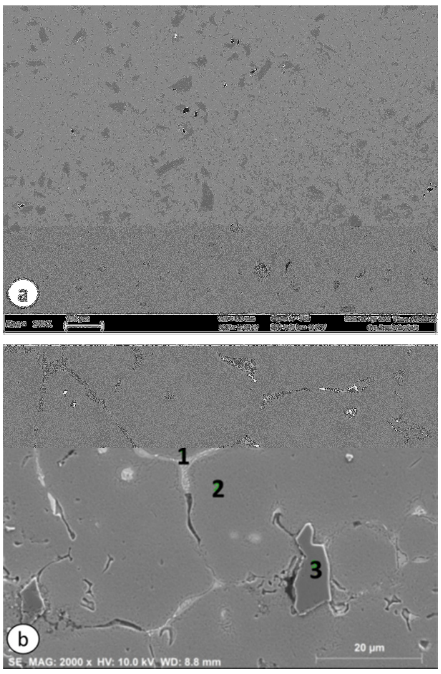

Fig. 5 (a) SEM 1-3, (b) XRD samples

C. Microstractural Characterization

The microstructure of 14% SiC-containg composites by SEM is shown in Figure 5(a). The microstructure can be counted as having homogenous distribution and interconnection. But at some points porosity is also observed. XRD images give the structure of the particles (Figure 5 (b)). The results of spectrum analysis are listed in Table III.

TABLE III. CONTENTS OF XRD SPECTRUM

	C	O	AL	Si	Cu	Zn
1	4.49	2.69	44.2	45.3	69.5	3.18
2	2.74	1.17	87.8	0.23	1.64	6.47
3	29.2	0.73	0.48	69.5	0.05	0

IV. CONCLUSIONS

AA7075 alloys reinforced with SiC aluminum matrix composites were manufactured by stir casting method. SEM figures show the nearly uniform distribution of SiC particles in the matrix and a good bonding. Some porosity was noticed in the micrograph. The mechanical properties of the aluminum matrix composites change with respect to their SiC content.

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