Studies on Tensile Properties of Titanium Carbide (TiC) Particulates Composites

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Abstract. The aim of this study is to determine the tensile properties of titanium carbide (TiC) particulate reinforced with aluminium alloy 11.8% silicon (LM6) alloy composite. In this experimental study, TiC particulates reinforced with LM6 composite were manufactured by sand and permanent metallic mould methods. Tensile properties of these composite materials were investigated by different weight percentages, 0%, 5%, 10%, 15% and 20%wt. The tensile tests were conducted to determine tensile strength and modulus young to investigate the effects of reinforce materials on weight percentages. The outcome of the investigations reveals that the tensile strength is enhanced from 0wt% to 10wt% of TiC and start to decrease after the addition of 10wt% of TiC. Good bonding and wettability between the composites ranging from 0%wt. to 10%wt. of TiC influence the close distribution of TiC particles in the LM6 alloy matrix. The addition of 10%wt. to 20%wt. of TiC in LM6 alloy matrix cause the lower resistance and load-bearing capacity and the particle are no longer isolated with the LM6 alloy matrix causing the worse value of tensile strength.

Introduction

With current trends of using lightweight, environment friendliness, quality, performances and economical materials for a variety engineering application, metal-matrix composites (MMCs) may find special application as they exhibit a wide range of mechanical behavior (e.g., tensile and compressive properties, creep, notch resistance, and tribology) and physical properties (e.g., intermediate density, thermal diffusivity) [1,2]. Parallel to this development, metal matrix composite (MMCs) have been attracting emergent interest [2]. A metal matrix composite (MMCs) are composite material combining two or more materials, one of which is a metal, where the tailored properties can be attained by systematic combination of different constituents to create strong and stiff materials [3]. It is composed of an element or alloy matrix in which a second phase is embedded and distributed for obtaining some property improvement [4]. Based on the size, shape and amount of the second phase, the composite property varies [5]. Particulate reinforces composites, often called as discontinuously reinforced metal matrix composites, constitute 5-20% of these new advanced materials. Good interfacial bonding yields high dislocation density in the matrix which increases the strength MMC's, while low fracture toughness due to cracking of the reinforcing particles is given by good interfacial bonding [6]. The toughness mechanicms of this kind of composites have been mainly due to the interaction between crack font and particles, crack deflections and crack-bridging [7-9]. The tensile test is used to evaluate the strength of metals and alloys. The mechanical properties that can be evaluated from the tensile test are modulus of elasticity, yield strength at 0.2% offset, ultimate tensile strength, and percent elongation at fracture and percent reduction in area at fracture. Dispersion of hard ceramic particles in a soft ductile matrix results in improvement in strength. This may be attributed to large residual stress developed during solidification and due to mismatch of thermal expansion between ceramic particles and soft aluminium matrix as corroborated also in. The increase in strength may also be result of closer packing of reinforcement with soft aluminium matrix. Wettability is one of the dominating factors to ensure good bonding between the matrix and reinforcement. A good bonding between reinforcement and soft aluminium matrix favors an enhancement of the ultimate tensile strength of the composite [10].

Experimental Work

In the study, LM6 alloy is used for the matrix and titanium carbide (325 mesh) as a particulates reinforced added in different weight percentages, %wt. LM6 is based on British specifications that conform to BS 1490-1988 LM6. In fact, LM6 alloy is a corrosion resistant aluminium casting alloy with the average durability and strength, as well as having high impact strength and ductility. Five composites were prepared for the tensile test by sand and permanent metallic mould process. The weight percentages of silicon particulates were selected from 0%, 5%, 10%, 15% and 20%wt respectively. The composite product pattern used in this research study is a cylinder shaped and the dimension of the cylinder is 40mm in diameter and 170mm in length as shown in Fig. 1 with the weight approximately 566.11grams.

The fabrication process starts by melting the LM6 alloy ingots until it reaches 700-750°C [11] and the particulates (TiC) were heated until 300°C in muffle furnace before being added in the LM6 alloy matrix by varying the weight percentages addition to the aluminium-11.8% silicon alloy [12]. The molten metal was mixed manually with the particulates in few seconds to make sure the particulates are distributed uniformly [13]. After that, the composite slurry is poured into the sand and permanent metallic mould and then allowed it to solidify and the cylindrical casting is broken out of the mould to complete the process. Specimens for tensile test were prepared according to ASTM B557 M-94 specification with the thickness 6mm [14] using CNC machine to match the specifications dimension. The speed control 2.00mm/min. Tensile test were performed using a 100 KN servo hydraulic INSTRON 8500 UTM testing machine. Each test result reported in this paper is the average obtained from at least three test specimens. The tensile specimens with 5% TiC particulates are shown in Fig. 2.

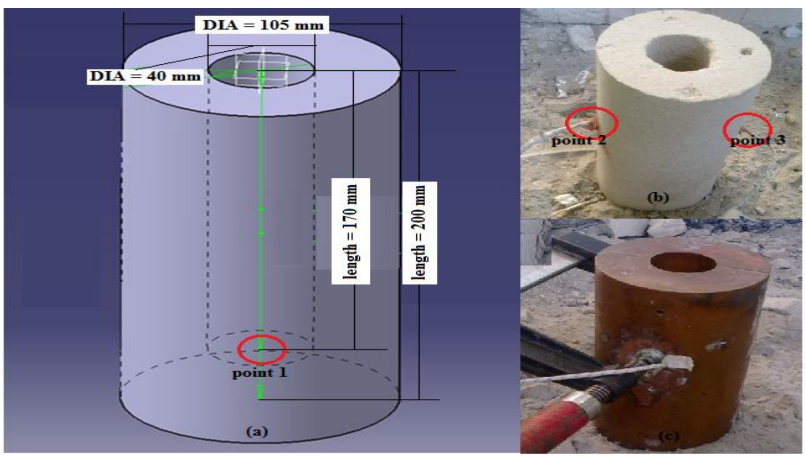

Fig. 1: (a) shape and dimensions for mould (b) sand mould and (c) permanent mould.

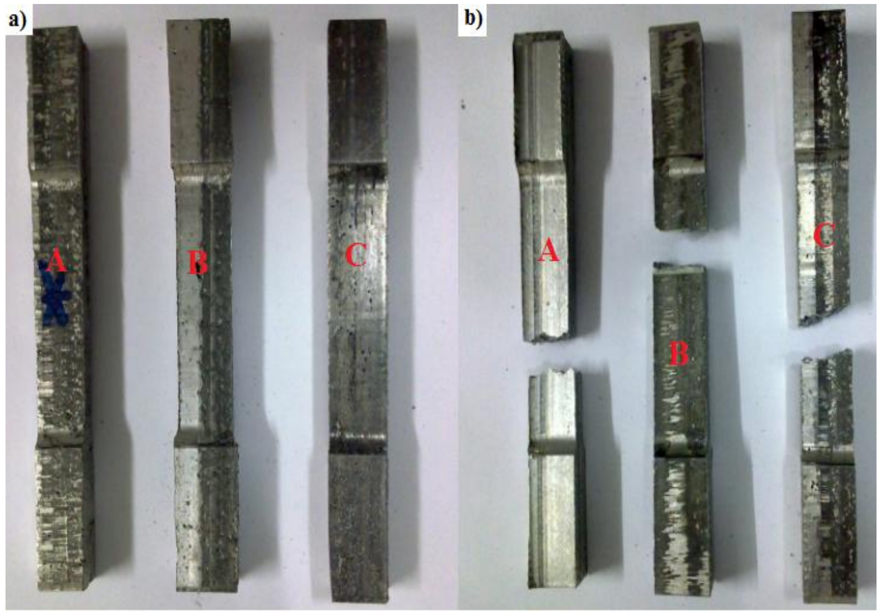

Fig. 2: Tensile specimens with 5% TiC particulates, shows a) the specimens before test and b) specimens after failure for sand casting.

Results and Discussion

The values of tensile strength and Young's modulus are tabulated at Table 1 for two types of moulds. All the data in this table were presented in average and the results is between 0 to 20%wt. of TiC particulates. Based on below tables, it shows that composite made in sand mould having 5%wt. TiC particulates has the highest value of tensile strength i.e. 107.52MPa followed by 10%wt. TiC particulates by (103.94MPa) 15%wt. TiC particulates 84.50MPa and 20%wt. TiC particulates (82.71MPa). Composite of aluminium alloy LM6 without TiC particulates exhibited tensile strength of 82.29MPa. It can be seen from Fig. 3 a similar graph pattern for permanent metallic mould but the values for tensile strength for this mould is higher than using sand mould. Tensile strengths of the composites with outfit, 0%wt., 5%wt., 10%wt., 15%wt., 20%wt. TiC particulates using permanent metallic moulds are 121.81MPa, 140.34MPa, 139.33MPa, 132.55MPa, and 123.83MPa. However, the improvement of the tensile strengths of the composites of a different LM6 added with a different percentage of titanium carbide is not uniform.

From the observation for both moulds, it is clearly seen that the value of tensile strength is increased until 5%wt. TiC particulates and starts decrease gradually after this percentages. The explanation for the increasing value is probably due to the dispersion of second phase in LM6 alloy matrix having higher TiC particulates content. During the solidification process, there were discrepancies of thermal expansion between the TiC particles and LM6 alloy matrix and attributed to large residual stress. The factors that contributed the increasing the strength of these composites are the closer packing of the TiC particles with LM6 alloy matrix and the wettability to ensure good bonding between this materials.

Table 1: Tensile strength and modulus young without and 5 to 20% weight percentages of titanium carbide particulates.

Weight percentage (%wt.)	Sand casting		Permanent metallic mould	
	Tensile Strength, σ (MPa)	Modulus Young, E (MPa)	Tensile Strength, σ (MPa)	Modulus Young, E (MPa)
0	82.29	8023.32	121.81	8762.04
5	107.52	9493.18	140.34	8393.39
10	103.94	9022.05	139.33	8409.78
15	84.50	10485.62	132.55	7760.79
20	82.71	8382.71	123.83	13278.85

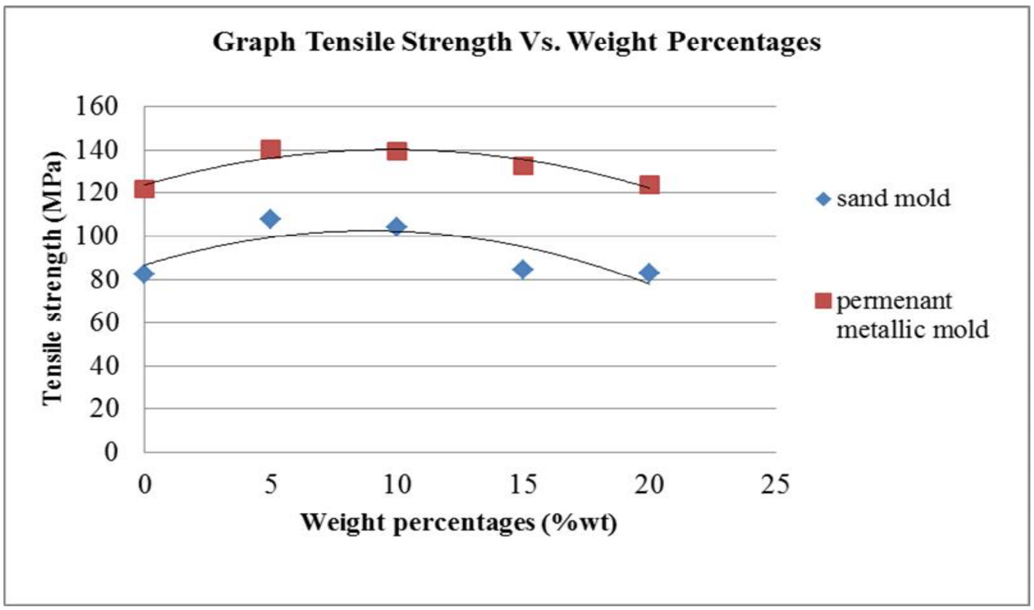

Fig. 3: Average tensile strength versus weight percentages of TiC

The graph shows the value of tensile strength is gradually decreases with the increasing 10 to 20%wt. particle reinforcement. The decreases in strength of both type of the cast composites is attributable to lower resistance and more sites for crack initiation valid due to increased TiC reinforcement, and hence lowering the load-bearing capacity of the reinforcement [4]. The presence of higher quantity of TiC particulates content leading particles are no longer isolated with the ductile LM6 alloy matrix and make it more prone to tensile failure [14,15]. As a result, the cracks are not arrested by the ductile matrix and would propagate easily between titanium carbide particulate [10-16].

The variations of this result are affected by the experimental error which also depends on the cooling rate during the solidification process. Another factor that caused influencing this phenomenon may originate from dislocations of particles due to the distribution of non-uniform TiC particulates in the LM6 alloy matrix under deformed condition. It is known that larger difference in the thermal expansion values between LM6 alloy matrix and the reinforcing particulates guides the mismatch. The elastic stresses generated due to the thermal mismatch put the particle into compression and the matrix into tension. This residual stress affects the material properties around in and the crack tips and the fracture toughness values are altered. Consequently, these residual stresses would likely contribute for the brittle nature of composites [4, 13-17].

Summary

Through this study, LM6 alloy matrix composites have been successfully developed with fairly dispersion of TiC particles. Addition of TiC particles significantly improves the value of tensile strength of LM6 alloy matrix reinforced with TiC particulates, when compared with that of unreinforced matrix, the tensile strength of LM6 alloy matrix reinforced with TiC particulates composites is increased. However, the value of tensile strength and hardness begins to decrease above 10 wt% of TiC particles. Addition of TiC particles to LM6 alloy matrix clearly improves the result of tensile strength. This is due to hard TiC particles dispersion in soft aluminium alloy matrix and enhanced the value of results due to distribution of the TiC particles are close with the LM6 alloy matrix and the wettability ensure a good bonding between composites. The addition of 10%wt. to 20%wt. of TiC in LM6 alloy matrix cause the decreasing value of tensile strength and hardness due to the lower resistance in the composites. These particles are no longer isolated with the LM6 alloy matrix and will create more sites for crack initiation and decreased load-bearing capacity of the reinforcement.

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