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Influence of B_4C on the tribological and mechanical properties of Al 7075–B_4C composites

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ABSTRACT

In the present investigation, the influence of B_4C on the mechanical and Tribological behavior of Al 7075 composites is identified. Al 7075 particle reinforced composites were produced through casting, K_2TiF_6 added as the flux, to overcome the wetting problem between B_4C and liquid aluminium metal. The aluminium B_4C composites thus produced were subsequently subjected to T6 heat treatment. The samples of Al 7075 composites were tested for hardness, tensile, compression, flexural strengths and wear behavior. The test results showed increasing hardness of composites compared with the base alloy because of the presence of the increased ceramic phase. The wear resistance of the composites increased with increasing content of B_4C particles, and the wear rate was significantly less for the composite material compared to the matrix alloy. A mechanically mixed layer containing oxygen and iron was observed on the surface, and this acted as an effective insulation layer preventing metal to metal contact. The coefficient of friction decreased with increased B_4C content and reached its minimum at 10 vol% B_4C.

1. Introduction

Metal matrix composites have many potential applications, because of the unique property combinations that can be achieved [1,2]. Metal matrix composites (MMCs) have been developed to respond to the demand for materials with high specific strength, stiffness, and wear resistance [3]. Aluminium is preferred as a matrix material in MMCs because of its low density, easy fabricability, and good engineering properties. Among the series of aluminium alloys heat treatable Al 6061 and Al 7075 have been much explored. Al 6061 alloy is highly corrosion resistant and exhibits moderate strength and finds many applications in the construction, automotive and marine fields. Al 7075 possesses very high tensile strength, higher toughness and are preferred in aerospace and automobile sectors [4]. The fabrication of MMCs can be achieved by the accumulation of reinforcement phase to the matrix. Certain suitable methods are powder metallurgy [5], spray atomization and co-deposition [6,7], plasma spraying [8,9], stir casting and squeeze casting [10]. In the engineering materials, the MMCs can be manufactured by a unique technique such as casting as it is inexpensive and proposes many other options for materials and processing conditions [11]. Straffelini et al. [12] reported that the matrix hardness has a strong influence on the dry sliding wear behavior of Al 6061–Al_2O_3 composites. A Martin et al. [13] from the studies of the tribological behavior of Al 6061–Al_2O_3 composites concluded, that a characteristic physical mechanism is involved in the wear process. Yu et al. [14] demonstrated the effects of applied load and temperature on the dry sliding wear behavior of the Al 6061–SiC composites, and concluded that the wear rate decreases with increased applied load. Reda et al. [15] and Clark et al. [16], in their studies on Al 7075 reported, that preaging at various retrogation temperatures improves the hardness, tensile properties and electrical resistivity. Kim et al. [17] concluded that the hardness of aged Al 7075 alloy increases. Doel and Bowen [18] reported the improved tensile strength and lower ductility of the Al 7075 reinforced with 5 and 13 μm SiC particles, than that of unreinforced material. Komai et al. [19] reported on the superior mechanical properties of Al 7075–SiC_W composites. It is thus observed that not enough data is available on the mechanical and wear resistance of particulate reinforced Al 7075 composites. Particulate reinforced aluminium matrix composites are alternative materials due to their strength, ductility and toughness as well as their ability to be processed by conventional methods. AMCs are applied successfully to structural components largely in automotive and aviation industries. AMCs can be reinforced with SiC, Al_2O_3, B_4C, TiC, TiB_2, MgO, TiO_2 and BN [3], while many researchers have used SiC and Al_2O_3 as reinforcing materials. Very limited research has been conducted on B_4C as the reinforcement because of the high cost of B_4C powders and complications in fabrication of composites [20,21].

B_4C is an attractive reinforcement material because of its good chemical and thermal stability. B_4C has lower density and higher hardness compared to Al_2O_3 and SiC [22–25]. Al–B_4C composites

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can be processed by low cost casting routes [26–29]. But it is difficult to fabricate Al–B_4C composites by mixing particles into the liquid phase, because of the poor wetting between Al and B_4C below 1100 °C. Besides wetting, controlling of the interface of the Al–B_4C is also important in the production of cast Al–B_4C composites. As such, in the present work Al–B_4C composites were processed through a casting route with the addition of K_2TiF_6 flux, to form a reaction layer containing TiC and TiB_2 at the interface, to increase wettability and interface bonding. Thus, the objective of this work is to investigate the effect of the B_4C particles on the mechanical properties and wear behavior of Al 7075–B_4C composites.

2. Experimental procedure

In this experiment, a commercial grade aluminium alloy Al 7075 was used as the matrix material, with B_4C particles as the reinforcement. The aluminium composites were manufactured with 5, 10, 15 and 20 vol% B_4C particles with particle size ranging from 16 μm to 20 μm were used as the reinforcement. The chemical composition of Al 7075 was analyzed and shown in Table 1. The base metal weighing 1000 g of aluminium was melted in a graphite crucible. The temperature control of the molten melt was taken care of, with thermocouples inserted into the melts to measure its temperature. The mixture of B_4C particles and the same amount K_2TiF_6 flux were added into the melt within 4 min

Table 1
Chemical composition of AA7075.

Elements	Zn	Cu	Mn	Mg	Fe	Cr	Ti	Si	Al
Weight%	5.4	1.42	0.12	2.42	0.42	0.21	0.11	0.13	Remaining

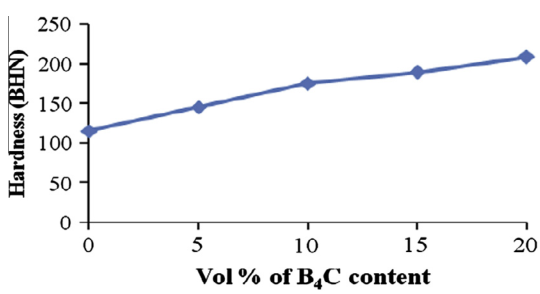

Fig. 1. Variation of hardness with varying content of the B_4C.

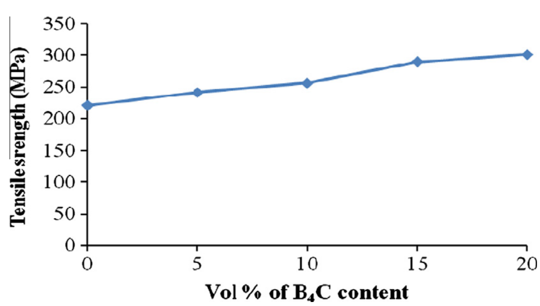

Fig. 2. Variation of tensile strength with varying content of the B_4C.

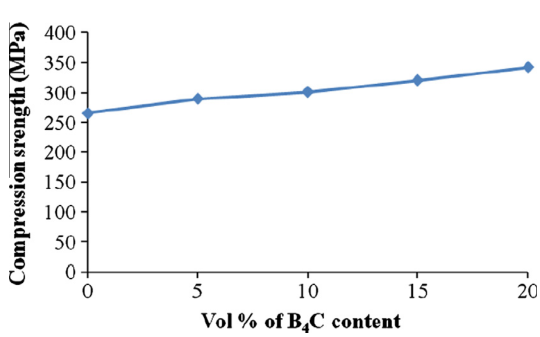

Fig. 3. Variation of compressive strength with varying content of the B_4C.

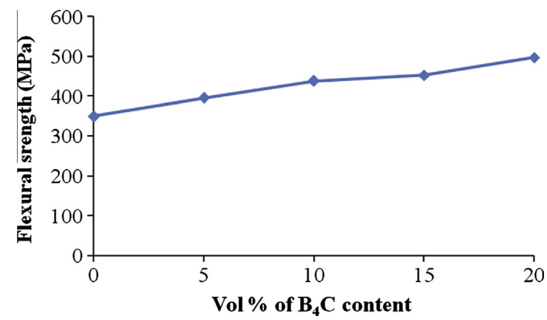

Fig. 4. Variation of flexural strength with varying content of the B_4C.

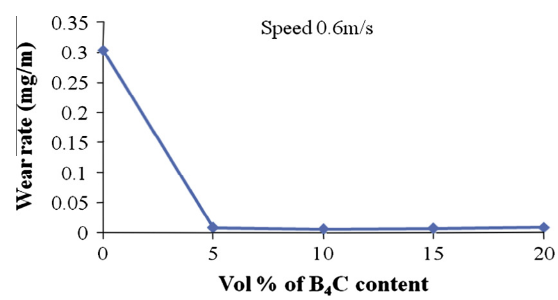

Fig. 5. Wear rate with varying B_4C content.

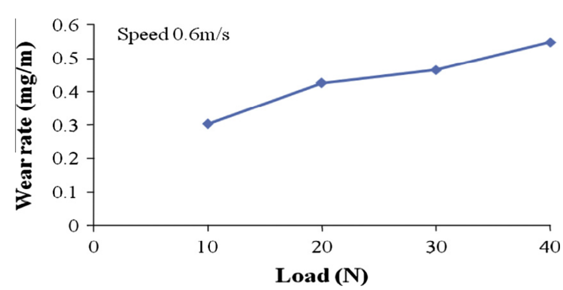

Fig. 6. Wear rate with varying applied load for Al 7075.

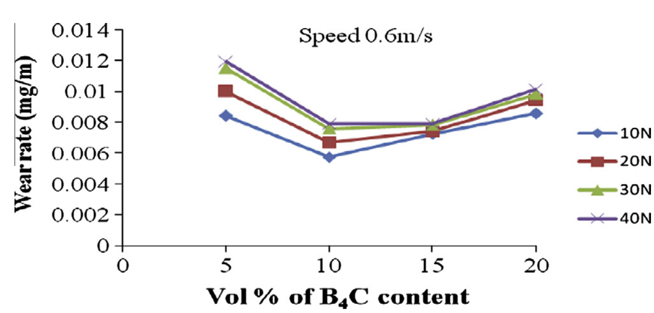

Fig. 7. Wear rate with varying applied load for Al 7075–B_4C composites.