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Applicability of Boron Carbide reinforced Aluminium 7075 composites for Aircraft Wings and Engines

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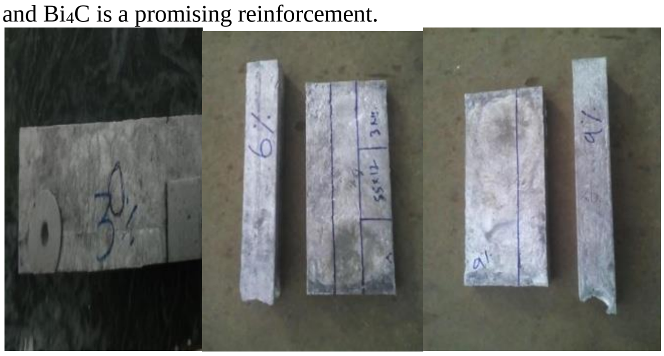
Abstract: It has become a prerogative of any industry to aim for lightweight materials, having promising strength for all of its major applications. Right from car manufacturers, aiming to incorporate lightweight materials, to substantial Space Research organizations, also aiming to reduce their functional weight, every organization puts forth voluminous efforts to achieve this goal. In such a scenario, Aluminium 7075 and Boron Carbide composites are found to be promising. This article briefs an experimental observation using these Aluminum-Boron Carbide composites which were synthesized using stir casting technique with varying particulate weight fraction (3%, 6%, and 9%). The experimental observation yielded promising outcomes of using this composite for lightweight applications. The composites are found to have greater strength and better weight ratio and are conveniently suitable for lightweight applications. This research work proposes this composite be applied in aircraft wings and engine.

1. Introduction

Aluminium 7075 is widely used in aircraft owing to its high strength, promising wear resistance and corrosion resistance [1]. Al 7075 is being employed in aircraft engines and wings. As the quantity of Al 7075 applications see a meteoric rise, there arises a need for reinforcement [2]. Aluminium Metal Matrix Composites (AMMC) owes attention due to its unique requirement for the reinforcement to be ceramic. In such a case SiC, B_4C, TiC, TiB_2 are found to be potential candidates for AMMCs [3]. Boron Carbide (B_4C) is further unique as it has been reported that the limitation of its mechanical properties can be reduced when percolated into a metal matrix [4]. This property of B_4C attracts for applying to be used with AMMCs. Boron Carbide is very hard and has low specific gravity and is sensitive to brittle fracture. On taking this hypothesis the next level, experimental observations with B_4C-2024 Al composites have yielded promising results. Microstructure observations have indicated strong interface bonding and no pores or cracks were detected [5]. Mechanical alloying is also a suitable process to produce B_4C-2024 Al composites [6]. Strong and lightweight bearing is also a need to be thought of. Researchers [7] have investigated the effect of strain sensitivity in the Linear Model Mockup Bearing (LMMB) using Digital Image Correlation (DIC) technique. Researchers have also addressed the lack of norms, standards, references for elastic and plastic deformation of bearing elements. Manufacturing of AMMCs using stir casting is found to be economical and is also technically sound [8]. Through stir casting, one can achieve a uniform distribution of the reinforcing material, meteoric reduction in the porosity and better wettability between the main entities [9]. Hence from this extensive literature search, it can be concluded that stir casting is a suitable method for AMMCs to induce reinforcements and Bi_4C is a promising reinforcement.



A B C

Fig. 1: Al- B_4C composite samples (A) 3% B_4C (B) 6% B_4C (C) 9% B_4C

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2. Fabrication of test specimens

Aluminium 7075 was mixed with B_4C composites at 3%, 6%, and 9%. Fluid Stir Casting method was employed to fabricate the composite.

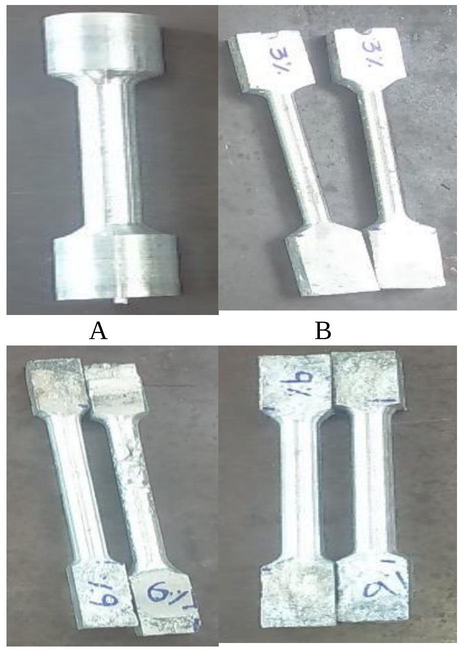

Fig. 2: Fabricated Al- B_4C composite samples (A) Al 7075 alone (B) 3% B_4C (C) 6% B_4C (D) 9% B_4C

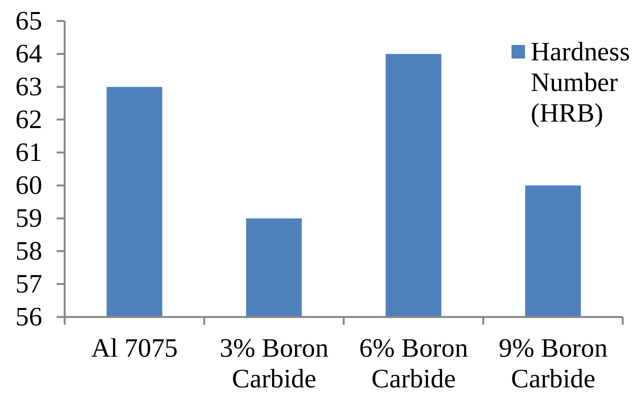

Fig. 3: Variation in the hardness of the composite samples

3. Experimental Observation on AMMC composites

3.1 Rockwell Hardness Test

A Rockwell hardness Test was performed with an indenter of size 1/16th inch and 100 kgf load. From figure 3, the observation, it can be inferred that the specimen with 6% B_4C is harder than the others. But still, the validation for the hypothesis that 6% B_4C is better than the others cannot be validated as this test is just a precursor to more of further investigations. Hence, the specimens were subjected to a torsion test.

3.2 Estimation of Modulus of Rigidity of the specimens

Modulus of Rigidity is tantamount to hardness as the former visualizes the rigid behavior of the material. To estimate the modulus of rigidity, a torsion testing machine was wielded for a specimen of length 175 mm and diameter 12mm.

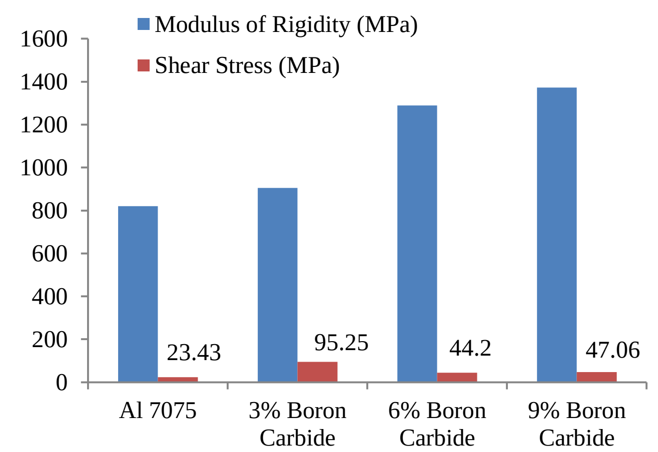

Fig. 4: Variation in the Modulus of rigidity and corresponding shear stresses of the composite samples

From the observation, it can be inferred that specimens with B_4C are more rigid than the mediocre 7075. This validates the hypothesis that with increasing B_4C, the rigidity of the specimen increases. These results of this experiment cannot be set aside as a conjecture or as a hypothesis. But, the experimental observation is not specific and further optimization requires to be done to customize the ratio for the suitable application. Hence a series of tensile tests were conducted to assess the performance of the specimens.

3.3 Estimation of Critical parameters through tensile testing

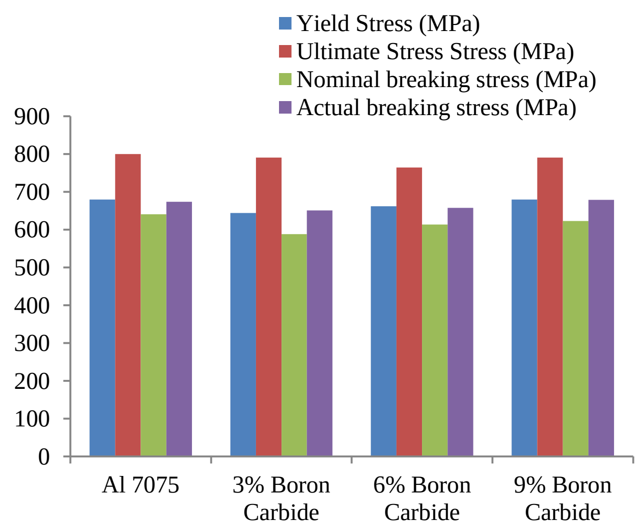

Fig. 5: Variation in the critical parameters during tensile testing

All specimens were subjected to a tensile strength test which operates on the principle of controlled tension until failure. The average diameter of all specimens was 12mm and their corresponding gauge lengths were 95mm. A Universal Testing Machine was wielded to observe the change in length for periodical loads

From Fig.5, it can be observed that the yield stress, nominal breaking stress, actual breaking stress increases with an increase in the boron composition. However, the ultimate stress values have played a fair deal, remaining fairly constant over the trials. Hence, the tensile tests also prove that B_4C is a potential candidate for AMMCs. Fig. 6 to Fig 13 visualizes the variation of crucial parameters during the tensile test.

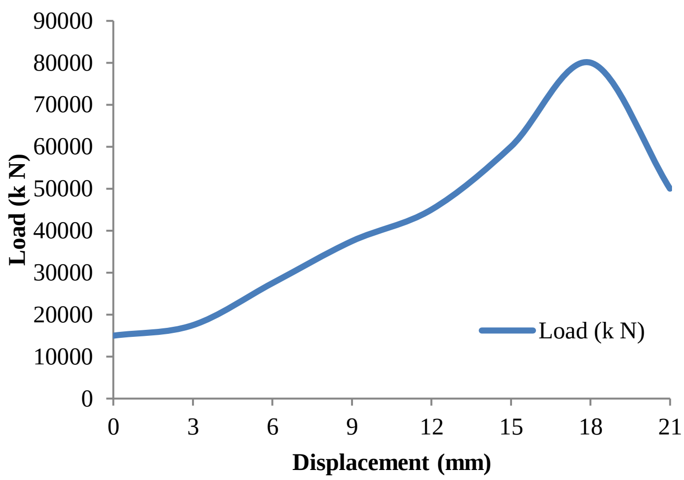

Fig. 6: Force vs Displacement (Al 7075)

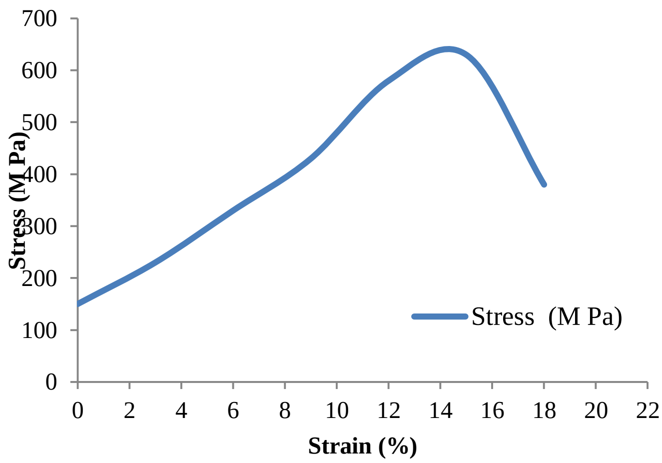

Fig. 7: Stress vs Strain (Al 7075)

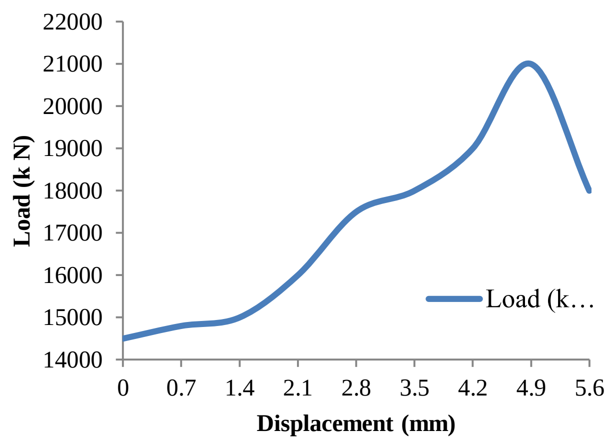

Fig. 8: Force vs Displacement (3% Boron)

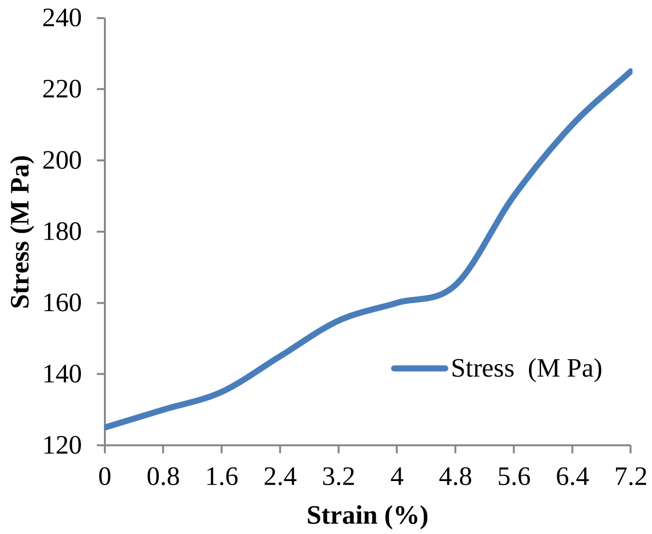

Fig. 9: Stress vs Strain (3% Boron)

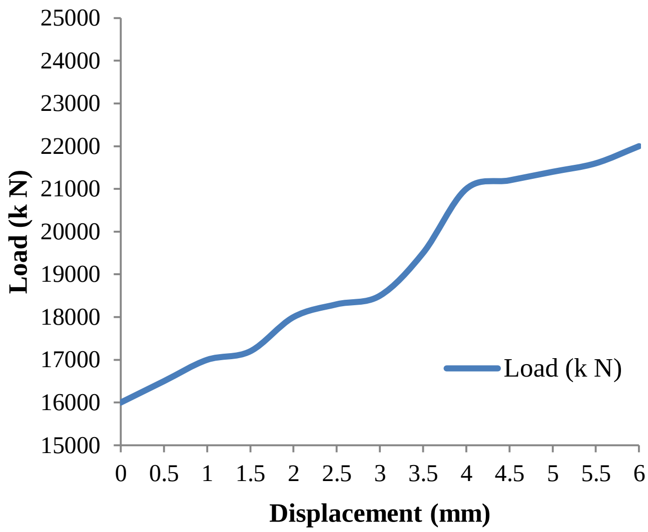

Fig. 12: Force vs Displacement (9% Boron)

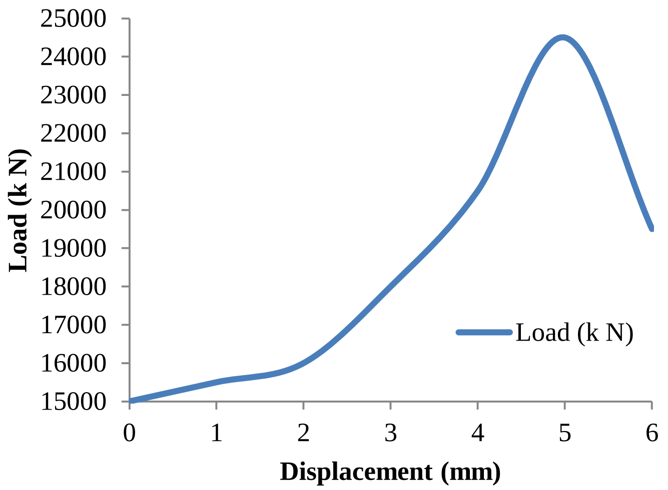

Fig. 10: Force vs Displacement (6% Boron)

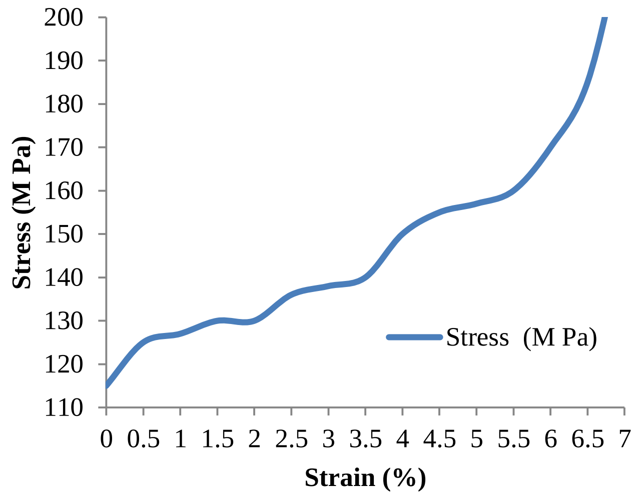

Fig. 13 Stress vs Strain (9% Boron)

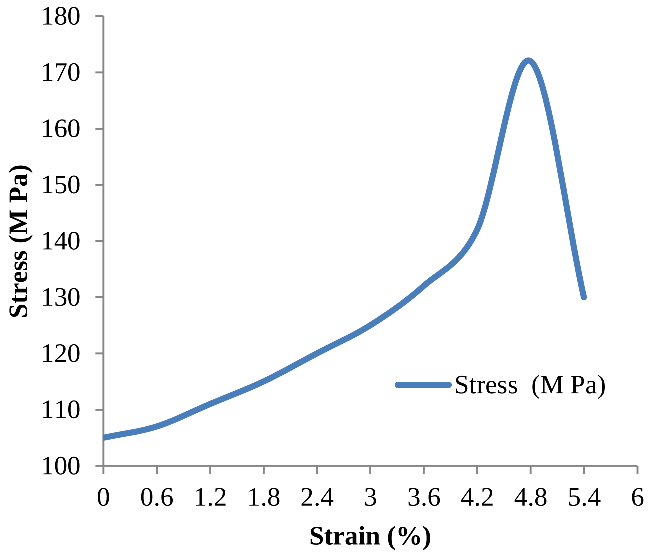

Fig. 11: Stress vs Strain (6% Boron)

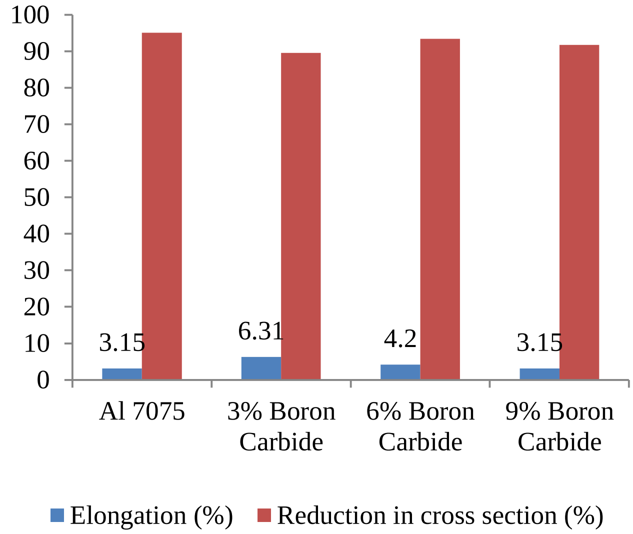

Fig. 14: Variation of elongation and reduction in cross section during tensile testing

4. Conclusions

This research work commenced with a hypothesis that B_4C based AMMC composite will find applicability in aircraft wings and engines. The experimental observation on B_4C – Al 7075 alloy is found to be a promising option for the application owing to the following observations,

1. The hardness test yields an observation that the hardness levels of the composites are satisfactory. In B_4C 6% case, the hardness level sees a meteoric rise.
2. The torsion test has estimated the modulus of rigidity of the composite specimens. It is apparent that the modulus of rigidity increases with an increase in the B_4C composition. Hence it can be inferred that B_4C is a rigidity inducing agent.
3. The tensile tests indicate that there is a rise in the yield stress, ultimate stress and actual breaking stress of the composite. The stress-strain relationships and the elongations are also satisfactory and could scale up.

Hence it is recommended that B_4C-Al 7075 composite are suitable for lightweight application and specifically for aircraft applications. The stir casting process is also found suitable for the process.

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