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Influence of Nickel Content on Mechanical Properties of Aluminium-Boron Carbide Hybrid Composite

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Abstract

In this work the influence of nickel (Ni) content on mechanical properties of aluminium matrix composite (AMC) was studied. Boron carbide was used as (B_4C) reinforcement with aluminium (6061-T6) alloy. The nickel content was varied from 2 wt. % to 8 wt. % keeping boron carbide as constant value of 10 wt. %. The composite blocks were produced by stir casting method. The flux (K_2TiF_6) was added during melting process to improve the wettability of boron carbide content in the matrix. The dispersion of boron carbide and nickel particles were found to be homogeneous in the matrix by studying the microstructure using an optical microscope. It was observed that as the nickel content increases from 2 wt. % to 8 wt. %, the hardness value correspondingly increases from 121 VHN to 193 VHN. Similarly, the tensile strength also increases from 192 MPa to 305 MPa. The % elongation decreases from 16 to 9 with respect to increase in nickel content. The tensile strength increases and % elongation decreases with hardness of the alloy.

Keywords: Aluminium matrix composite, Micro-hardness, Tensile Strength, Microstructure.

Introduction

Several approaches like coating [1], heat treatment [2], Shallow cryogenic treatment [3], alteration of compositions of the alloy [4, 5, 6] and addition of reinforcement materials [7] are used to achieve better mechanical and tribological properties of metal alloys. Aluminium matrix composites are very widely used in automobiles, aerospace and marine engineering applications [8]. The addition of boron carbide particles as reinforcement to the aluminium matrix improves the mechanical and tribological properties [9]. From the literature survey, it was known that a limited work was done on composites having boron carbide as reinforcement due to high raw material price and reduced wettability of boron carbide with molten aluminium. Further, it was reported that the addition of nickel content to pure aluminium will improve the mechanical properties of the alloy [10]. There are various manufacturing processes used to produce aluminium matrix composites, but the conventional stir casting is an attractive process to make the composites economically and also it offers wide range of materials to be processed.

Therefore, in this study 6061-T6 aluminium alloy was selected and it was reinforced with boron carbide particles at a constant wt. %. The nickel content was varied in order to study its influence on mechanical properties such as hardness, tensile strength and % elongation. In addition to this the microscopic examination was also studied. The conventional stir casting process was used to prepare the test blocks.

Experimental Procedure

CastingProcess

In this study, aluminium alloy (Al 6061-T6) was used as the base metal. Ni and B_4C of grain size 15 µm were used as the reinforcements. The proposed AMC was prepared with 2, 4, 6 and 8 wt. % of Ni and keeping the wt. % of B_4C constant as 10 wt. % for all the castings. The required compositions of the basemetal was melted in a graphite crucible using stir casting machine as shown in Fig. 1 and the preheated reinforcements along with K_2TiF_6 flux were added to the melt. The mechanical stirrer was used at 400 rpm for 4 minutes. The melt was then poured into a preheated metallic die of cavity size 100 × 100 × 10 mm. A typical casting for making specimens is shown in Fig. 2.

Fig. 1 Stir Casting Machine

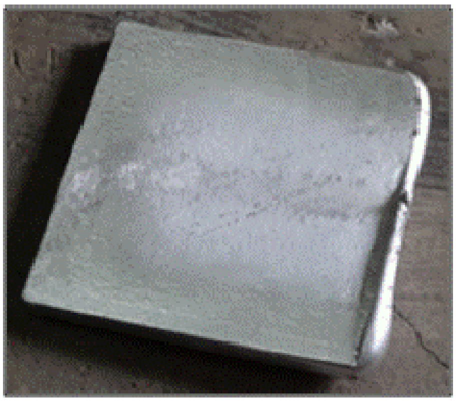

Fig. 2A Typical Casting of Al Composite

Microscopic Examination

Optical microscope was used to characterize the microstructure. The polished AMC specimens were etched for the metallographic study. The etchant used was 0. 5 vol. % HF aqueous solution. The optical microscope used for this study is shown in Fig. 3.

Fig. 3 Optical Microscope

Micro-hardness Testing

Micro-hardness testing of the polished specimens was carried out using Mitutoyo, MVK-H1, Vicker hardness Tester as shown in Fig. 4. The micro-hardness was measured at different locations at a load of 100 gf for 15 seconds and the average value was calculated.

Fig. 4 Micro-hardness Tester

Tensile Testing

The specimens prepared as per the ASTM E08 standard were used for conducting the tensile test. At room temperature, the ultimate tensile strength of the specimens was tested using computerized universal testing machine (Fig. 5). The photographic image of a typical tensile test specimen is shown in Fig. 6.

Fig. 5 Universal Testing Machine

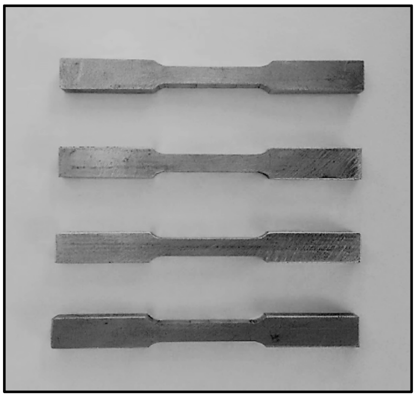

Fig. 6 Photographic image of the Tensile Test Specimens

Results and Discussion

Microstructure

It was observed from the optical photo-micrographs (Figs. 7-10) that B_4C and Ni contents are distributed uniformly in the Al-matrix at all wt. % of Ni content. In case of B_4C, the same value of density of base metal and reinforcement (B_4C) caused the elements neither float nor settle down in the mixture [9] helping it to get distributed uniformly. The Ni particles are found to have a homogenous distribution in the matrix. This proved that Ni is having good wettability with B_4C reinforced AMC. The interface bonding structure between the aluminium matrix and Ni particles consists of Ni_xAl_y inter-metallic and provides higher mechanical properties to the aluminium. The inter-metallic formed here may be Al_3Ni which are having very high hardness values. Most of the small Ni particles were consumed completely and converted into inter-metallic [10].

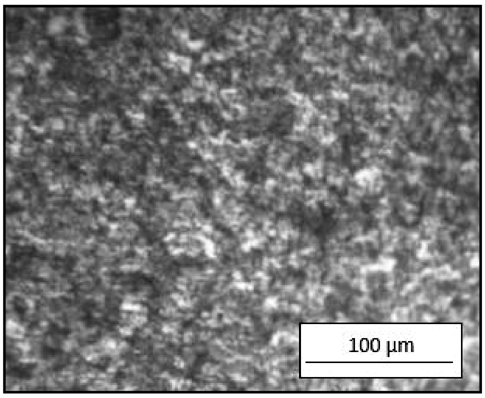

Fig. 7 Optical Micrograph of the cast AMC with 2 wt. % Ni

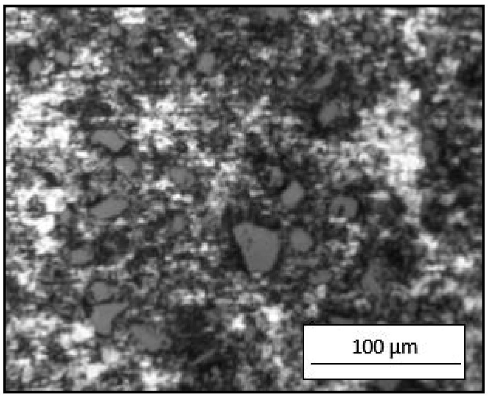

Fig. 8 Optical Micrograph of the cast AMC with 4 wt. % Ni

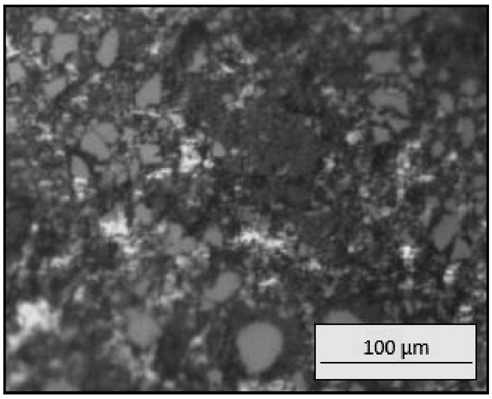

Fig. 9 Optical Micrograph of the cast AMC with 6 wt. % Ni

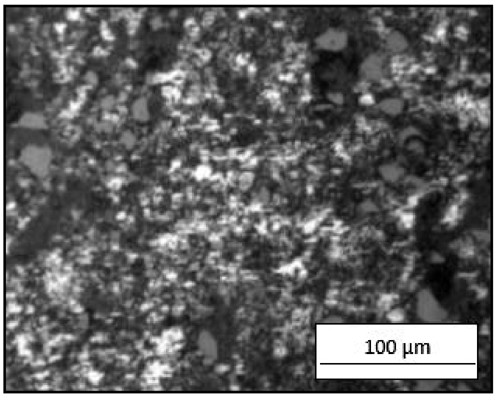

Fig. 10 Optical Micrograph of the cast AMC with 8 wt. % Ni

Hardness

Fig. 11 shows the micro-hardness of the AMC with increasing wt. % of Ni. It was observed that the hardness increased with increase in Ni content. The hardness value obtained is higher than the pure matrix (107 VHN) and B_4C reinforced aluminium matrix (75 VHN) with the same composition. This is due to, (a) B_4C-a hardest ceramic particle and (b) Ni which is having a low solubility in aluminium increases the hardness of composites by offering more resistance to plastic deformation. The Al_3Ni inter-metallic compounds play the major role in the substantial increase of the hardness. It is also reported that due to decrease of ductile particles content, the ductility of composites are reduced with the occurrence of hard ceramic phase in the aluminium matrix. This significantly increases the hardness value [12].

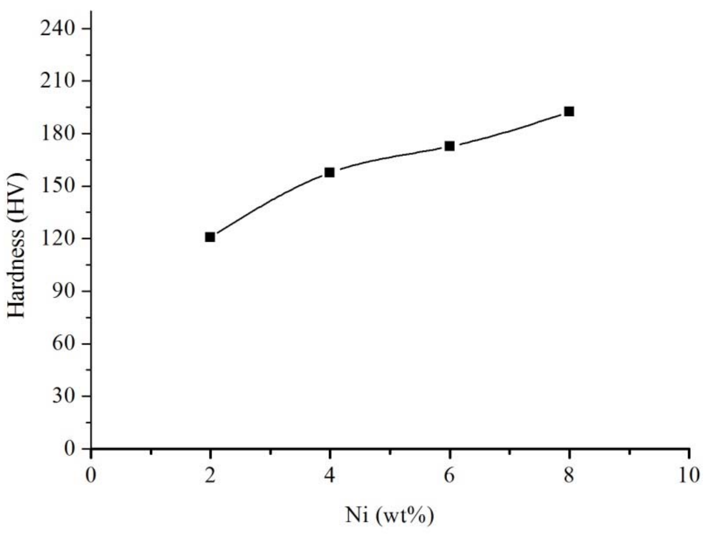

Fig. 11 Variation of Hardness with Ni Content

Tensile Properties

Fig. 12 shows the increase in UTS with the increase in nickel content. The UTS of AMC was improved from 192. 1 MPa to 305. 1 MPa. This may be due to the presence of extremely hard reinforcements like B_4C and Ni content. Hence, from these observations we may conclude that nickel particles were very much effective in improving the UTS of the hybrid composite.

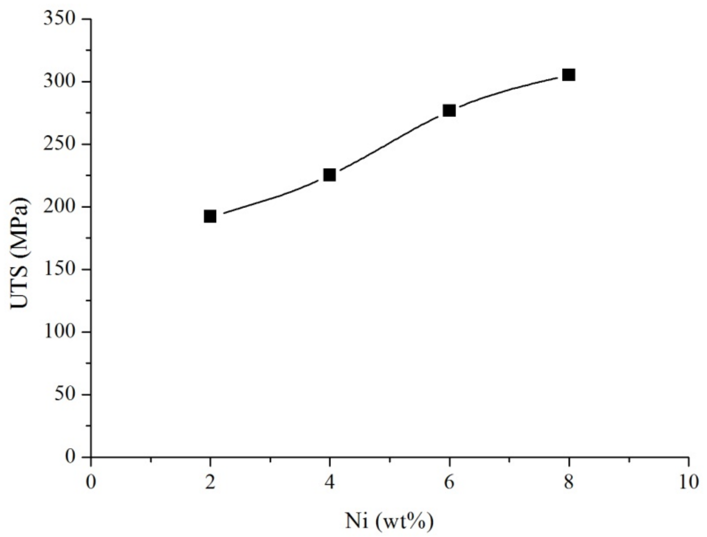

Fig. 12 Variation of UTS with Ni Content

Fig. 13 shows the variation of % elongation with respect to the Ni content and was found to be decreasing with the increase in Ni content. The B_4C particles in the matrix offer more resistance to tensile stresses thus inducing ample strength to matrix alloy [9]. This strengthening mechanism of the reinforcements helped in decreasing the % elongation of the AMC.

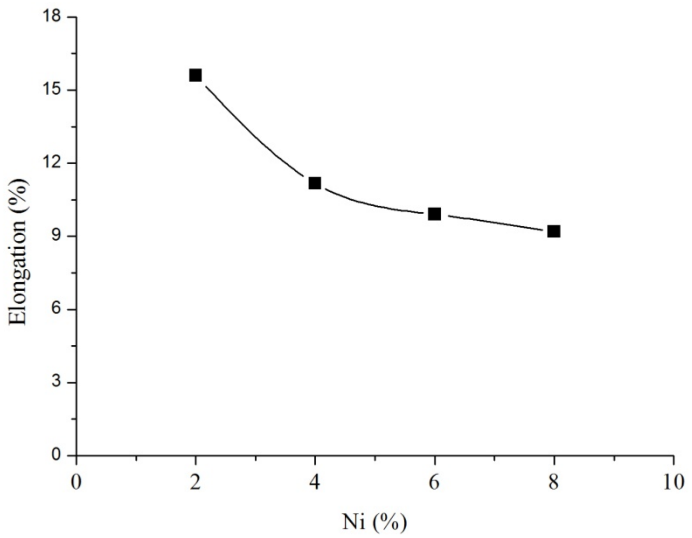

Fig. 13 Variation of % elongation with Ni Content

Conclusion

The hybrid AMC was successfully produced by casting method with varying nickel content. The mechanical properties and microstructure were evaluated. The following conclusions are derived based on this study.

- Nickel particles are found to have wettability with the B_4C reinforced aluminium matrix.
- Optical photo-micrograph revealed the presence of B_4C & Ni contents in the composite with uniform distribution.
- Addition of reinforcements improved the hardness of base metal and the micro-hardness of the AMC was found to increase with increase in Ni content.
- The presence of Ni in the Al-B_4C composite enhanced the tensile strength of the AMC.
- The UTS of the AMC also was found to increase and the % elongation was found to decrease with increase in Ni content.

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