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Fracture Toughness and Brinell Hardness of AL7475-NbC and AL7575-MoS_2 Composites

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Abstract

The proposed work investigates the effect of micro-particle reinforcement of Niobium Carbide (NbC) and Molybdenum disulphide (MoS_2) with AL7475 alloy. Mechanical properties, including fracture toughness and Brinell hardness, are studied for the composites AL7575-Nbc and AL7575-MoS2. The preparation of aluminium metal matrix composites is done by using the liquid metallurgical technique by varying the weight percentage (wt%) of Niobium Carbide (NbC) and Molybdenum disulphide (MoS_2) from 2 to 10%. The reinforcement compounds are analyzed using Scanning Electron Microscope. The fracture toughness and Brinell hardness are determined using ASTM E10 and ASTM E23 standards, respectively. The Brinell hardness of the composites increased with reinforcement compounds, whereas the fracture toughness decreased with an increase in NbC and MoS_2.

Keywords: *Alluminium Alloy (Al7475), Niobium Carbide (NbC), Molybdenum disulphide (MoS_2).*

1.0 Introduction

Composites are becoming incredibly popular in replacing ferrous metals. The unique properties, including lightness, low density, high strength, and resistance to corrosion of aluminum, have proven to be the best alternative. Wide-ranging uses for Aluminium Metal Matrix Composites (AMMCs) have been found in daily life. There are distinct advantages when using particle-reinforced AMMCs components over unreinforced components[1]. Common reinforcement materials include Silicon Carbide, SiC, Graphite, Niobium Carbide (NbC) and Molybdenum Disulphide (MoS_2). Nikhilesh et al. (2022) studied Al7075 (T6)-SiC-MoS_2 Hybrid Metal Matrix Composites (HMMC) and found that there is a significant improvement in the hardness[2]. The addition of solid lubricant (MoS_2) and hard ceramic reinforcing particles (Boron Carbide - B4C) to the Al7075 Aluminum matrix alloy has significantly improved the wear resistance and coefficient of friction[3]. An advanced metal matrix material composite with aluminum is frequently used in undersea, transportation, and aerospace applications[4]. The answer to this problem is hybrid metal matrix composites (HMMCs). Aluminium-based matrix composites are still being researched the most. MoS_2-reinforced aluminium composites perform better than nonreinforced matrix alloy systems in terms of reduced coefficient of thermal expansion, enhanced yield strength, stronger wear resistance, and higher elastic modulus. Vijaya et al. (2022)[5] studied specific reinforcing particles like titanium (Ti) and niobium carbide (NbC) on aluminium HMMCs.

The common mechanical characteristics stated by many researchers are carefully recognized in order to concentrate on the number of reinforcements and modifications made during formulation. Previous studies have not looked closely enough at the enhanced features of aluminium hybrid MMCs.

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The proposed research aims to create composites made of Al7475 alloy with Niobium Carbide (NbC) and Molybdenum disulphide (MoS_2) and find their mechanical characteristics, including hardness and fracture toughness. The composites are developed by liquid metallurgy technique.

2.0 Material Selection

2.1 Matrix Material: Aluminium Alloys

Al7475 is a precipitation-solidifying aluminium composite containing magnesium and silicon as its major alloying components. Al7475 alloys have great mechanical properties with ductility and are effectively weldable composites. Al7475 will be utilized as a matrix composite because of its amazing casting properties, sensible strength, and reasonableness for large-scale manufacturing. Because of their excellent properties, they discover numerous applications in various fields.

In the annealed state, the aluminium 7475 has good machining properties (Figure 1). The machining of this alloy may be done with oil-based lubricants. It is possible to heat treat aluminium and aluminium 7475 alloys. Aircraft, aircraft shell casings, and many other structures can be made with aluminium or aluminium 7475 alloy[1].

2.2 Reinforcement Materials

By linking the ceramic reinforcements and matrix using physics and chemistry properties, the concept of HMMCs was formed. From a business perspective, it is important to note that the unique features and functionalities are discovered after adding the nanoparticles. Although most research focuses on predicting improvements in mechanical features, commercial applications are still unprepared. The manufacturing and microstructure of HMMCs, which interpret the mechanical characteristics of HMMCs with reinforcements, are influenced by particle size and fractional volume. Powdered Niobium Carbide (NbC) and Molybdenum Disulfide (MoS2) are used separately with a varying weight percentages of 2, 4, 6, 8, and 10% for reinforcement of AL7575.

Figure 1: Al7475 Ingots

Figure 2: shows Niobium Carbide (NbC) powders and Figure 3 shows Scanning Electron Microscope diagram of 30 micron size Niobium Carbide particles and Figure 4 shows Molybdenum Disulfide (MoS_2) powder.

2.3 Fabrication of the Composites

The proposed work is to fabricate and determine the mechanical properties, such as the hardness and fracture toughness of Al7475+NbC and AL7475 + MoS_2 composites. The composites were developed by liquid metallurgy technique.

Table 1: Al7475 Matrix Alloy Elements

Elements	Si	Fe	Cu	Mn	Mg	Cr	Zn	Al
AL7575	0.12	0.15	2.6	0.10	2.6	0.04	6.5	Remaining Amount

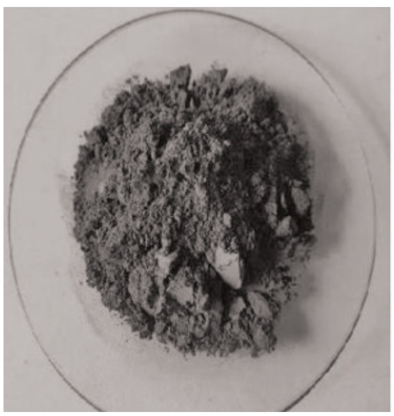

Figure 2: Niobium Carbide (NbC) powder

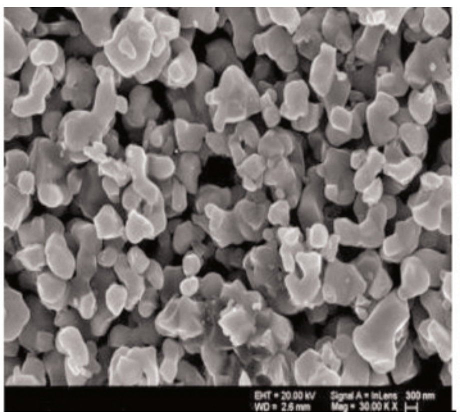

Figure 3: Scanning Electron Microscope image of NbC powder

Figure 4: Molybdenum disulfide (MoS_2) powder

Figure 5: Casted specimens

3.0. Results and Discussions

3.1 Hardness Test of Composites with NbC and MoS_2

The hardness test is conducted by using the Brinell hardness tester as per the ASTM E10[6].

3.2 Fracture Toughness

The Charpy Impact test is used to determine the toughness of the composite material. Tests are carried out to determine the quantity of energy that is being absorbed by the material before failure by using ASTM standard (ASTM E23). Test samples are prepared as per the standard with a dimension of 10mm * 10mm * 55m with 'U' notch with the depth of 2mm at the middle section of the sample. The results are obtained in Table 4 and Table 5.

Table 2: Brinell hardness number for various compositions of AL7075-NbC composites

	Composition	Brinell Hardness (BHN)
1	AL7475 Alloy	61.7
2	AL7475 + 2% NbC	73.4
3	AL7475 +4% NbC	82.3
4	AL7475 +6% NbC	88.7
5	AL7475 +8% NbC	99.3
6	AL7475 +10% NbC	94.5

Table 3: Brinell hardness number for various compositions of AL7075/ MoS_2 composites

	Composition	Brinell Hardness(BHN)
1	AL7475Alloy	61.7
2	AL7475+2% MoS_2	65.65
3	AL7475+4% MoS_2	71.25
4	AL7475+6% MoS_2	74.25
5	AL7475+8% MoS_2	76.25
6	AL7475+10% MoS_2	72.22

Table 4: Fracture Toughness for AL7475 and AL7475/NbC composites

	% of Reinforcement	Fracture toughness (J/cm^2)
1	AL7475	16
2	AL7475+2%NbC	11.8
3	AL7475+4%NbC	9.2
4	AL7475+6%NbC	8.4
5	AL7475+8%NbC	6.4
6	AL7475+10%NbC	7.2

Table 5: Fracture Toughness for AL7475 and AL7475/ MoS_2 composites

	% of Reinforcement	Fracture toughness (J/cm^2)
1	AL7475	16
2	AL7475+2%MoS_2	14.4
3	AL7475+4%MoS_2	13
4	AL7475+6%MoS_2	12.5
5	AL7475+8%MoS_2	11.8
6	AL7475+10%MoS_2	10.9

4.0 Conclusion

AL7475-NbC and Al7475-MoS_2 composites were produced by reinforcing particles utilizing liquid metallurgical processes. The obtained casting was uniform with very few blow holes. Visual examination was used to identify casting flaws, and it also found strong bonds between the matrix and the reinforcement particles, which improved the capacity of the matrix to transfer load to the reinforcement material. The Brinell hardness of AL7475 + NbC and Al-MoS_2 is increased with an increase in the percentage of NbC and MoS_2. The maximum value is reached upto 8%. Further, increase to 10% results in a decrease in hardness. It is due to improper bonding between the matrix and reinforcements. It was found that the fracture toughness of AL7475 – NbC and Al7475-MoS_2 is decreased with an increase in the percentage of NbC and MoS_2. The minimum value is reached up to 8%. Further, increase to 10% results in increase of fracture toughness. It may be attributed to the voids created between the matrix and reinforcements.

5.0 References

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