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Evaluation of Mechanical Properties of Aluminium Alloy (Al-2024) Reinforced with Molybdenum Disulphide (MOS_2) Metal Matrix Composites

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Abstract

The results of an experimental investigation on the mechanical properties of molybdenum disulphide (MOS_2, also called molydisulphide) powders reinforced in aluminium alloy (Al-2024) composite samples are reported in this paper. MOS_2 powders of approximately 40µm particle size were reinforced in an aluminium alloy matrix to produce composite samples of ratios, 1, 2, 3, 4 & 5 weight % through stir casting technique. The fabricated composite specimens were subjected to a series of tests to evaluate the mechanical properties such as hardness and tensile strength. The same are compared with the base alloy. SEM and XRD analysis was carried out to analyze the microstructure and the dispersion of the reinforced particles in the alloy matrix. It was fairly observed from the results that, the hardness and tensile strength increased with the increase in wt. % of reinforcement particles in the matrix up to 4% addition of reinforcement and the hardness and tensile strength decreased for 5% addition of reinforcement in the matrix. The SEM and XRD results revealed the homogeneous dispersion of MOS_2 particles in the matrix.

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Keywords: Al-2024; Molybdenum Disulphide (MOS_2); stir casting; SEM & XRD.

1. Introduction

The demands made on materials for better overall performance are so great and diverse that no one material can satisfy them. This led to a resurgence of the ancient concept of combining different materials in an integral composite material system that results in a performance unattainable by the individual constituent, and offers great advantages. Composites are materials in which two phases are combined, usually with strong interfaces between them

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. They usually consist of a continuous phase called the matrix and discontinuous phase in the form of fibers, whiskers or particles called the reinforcement. A. Chennakesava Reddy et al (2010). The commonly used metallic matrices include Al, Mg, Ti, Cu and their alloys. These alloys are preferred matrix materials for the production of MMCs. The reinforcements being used are fibers, whiskers and particulates T. Miyajima et al (2003). The advantages of particulate-reinforced composites over others are their formability with cost advantage Mortensen et al (2001). Further, they are inherent with heat and wear resistant properties. Y.M. Pan et al (1990) and S.V. Prasad et al (1987).

Aluminum matrix composites (AMCs) are emerging as advance engineering materials due to their strength, ductility and toughness. The aluminum matrix is getting strengthened when it is reinforced with the hard ceramic particles like SiC, Al_2O_3, and B_4C etc. Aluminium alloys are still the subjects of intense studies, as their low density gives additional advantages in several applications. These alloys have started to replace cast iron and bronze to manufacture wear resistance parts. MMCs reinforced with particles tend to offer enhancement of properties processed by conventional routes. The alloys primarily utilized today in transport aircraft are 2024-T4 and the alloys having still higher strength (2014-T6, 7075-T6, 7079-T6 and 7178-T6). Aluminium alloy 2024 has good machining characteristics, higher strength and fatigue resistance than both 2014 and 2017. It is widely used in aircraft structures, especially wing and fuselage structures under tension. It is also used in high temperature applications such as in automobile engines and in other rotating and reciprocating parts such as piston, drive shafts, brake- rotors and in other structural parts which require light weight and high strength materials Feng YC et al (2008).

MoS_2 is an attractive layered structure that has gained a considerable amount of interest in the scientific community, especially in recent years. MoS_2 is a relatively cheap material as it occurs in nature as its mineral, molybdenite Rabin Bissessur et al (2005).

2. Materials and Methods:

2.1. Materials:

Aluminium alloy Al-2024 used for the matrix is purchased from perfect metal works, Bangalore, Karnataka, India, particles of MoS_2 were purchased from Sigma Aldrich, Bangalore, Karnataka, India and Magnesium powder was commercially available. The chemical composition of the matrix aluminium alloy is given in the table 1.

Table 1: Composition of matrix metal

Con	Cu	Mg	Si	Fe	Mn	Zn	Ti	Cr	Al
%	4.29	1.29	0.07	0.20	0.54	0.03	0.06	0.01	Rem

2.2. Experimental Work:

Appropriately estimated amount of Alminium alloy was fed into the electric furnace and was melted at 700^0C at Linsons Alloys Pvt. Ltd. Hyderabad. At this high temperature magnesium ribbons are added into the molten aluminum alloy. The magnesium ribbons are added to increase the wettability of aluminum so that the reinforcement added to the metal is evenly dispersed. An appropriate amount (1% of the wt. of base metal) of Molybdenum Disulphide (MoS_2) powder was then added slowly to the molten metal. The MoS_2 powder added to the molten metal was pre-heated upto 500^0C to remove the moisture (if any) in it. Simultaneously, the molten metal was stirred thoroughly at a constant speed of 300 rpm with a stirrer. The high temperature molten metal was poured into the pre-heated (300^0C) cast iron moulds to get the required specimens. The same procedure was followed to get the AMC's of different wt. % - 2%, 3%, 4% & 5%. The experimental setup is shown in Fig.1.

Fig.1 Molten metal in the furnace

2.3. Testing:

The fabricated specimens were proposed to test for mechanical properties like hardness and tensile strength. The SEM analysis and XRD analyses were proposed to be done to know the dispersion of the reinforcement in the metal matrix.

2.3.1. Hardness Test:

Bulk hardness measurements were carried out on the base metal and composite samples by using standard Rockwell hardness test machine. Rockwell hardness measurements were carried out in order to investigate the influence of particulate weight fraction on the matrix hardness. Load applied was 100 kg and indenter used was 1/16'.

2.3.2. Tensile testing:

The specimens were machined to get dog boned structure as per ASTM E-8 standards. Test was carried out on a computerized UTM (TUE-C-600 Model Machine). The tensile test specimens are shown in Fig.2.

Fig.2 Tensile Test Specimens

3. RESULTS & DISCUSSIONS:

3.1. Hardness:

The tests revealed that, the hardness of the composite specimen had increased gradually with increase in the wt. % of MoS_2 powder incorporated in the metal matrix up to 4% wt. and the hardness decreased on further reinforcement i.e. 5% wt. The results are tabulated in table 2. . The trend of increase in hardness is shown in Fig.3.

Table 2: Hardness Test Result

S.No	Combination	Hardness No (HRB)
1	0% MoS_2	64.3
2	1% MoS_2	66.2
3	2% MoS_2	77.0
4	3% MoS_2	85.3
5	4% MoS_2	88.7
6	5% MoS_2	81.1

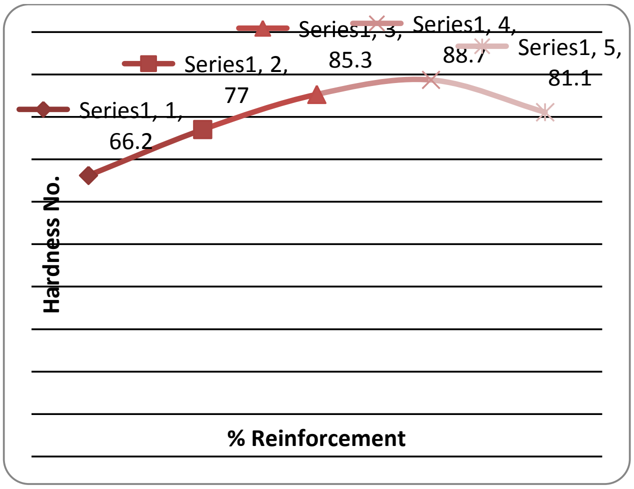

Fig.3. Graph showing the trend of Hardness

3.2. Tensile Strength:

The tensile test results are given in the table 3. The tests revealed that, the ultimate tensile strength gradually increased by the increase in wt. % of the reinforcement added to the metal matrix. The maximum Tensile strength was observed at 4% MoS_2.The trend of increase in ultimate tensile strength is plotted in a graph shown in Fig.4. When the reinforcements are added, the particulate reinforcements form nuclei which results in greater number of grain formation. Thus the movement is restricted further, which results in greater strength P.K.Rohatgi et al (2004). Thus the observation in the overall increase of the tensile strength is aptly justified and explainable. The SEM micrographs of the fracture surfaces of the tensile test specimen are shown in Fig.5 & 6. It can be predicted from the micrographs that the fracture is a ductile fracture.

Table 3: Tensile Test Result

S.No	Composition	Tensile Strength N/mm^2	Yield Strength N/mm^2	% Elongation
1.	Al 2024	222.4	167.37	2.9
2.	Al+1% MoS_2	191.38	148.73	3.53
3.	Al+2% MoS_2	211.15	171.23	3.15
4.	Al+3% MoS_2	220.5	132.3	2.92
5.	Al+4% MoS_2	**261.03**	**213.08**	**2.88**
6.	Al+5% MoS_2	208.59	162.65	3.07

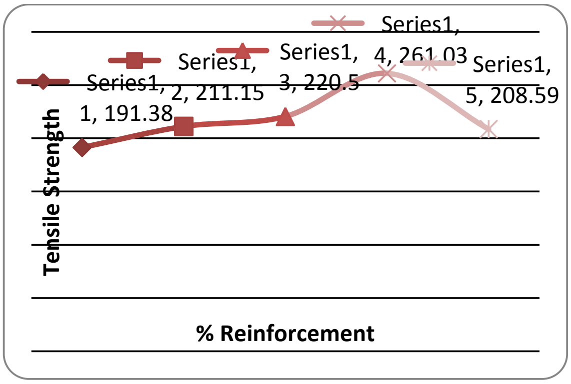

Fig.4. Graph showing the trend of Tensile Strength

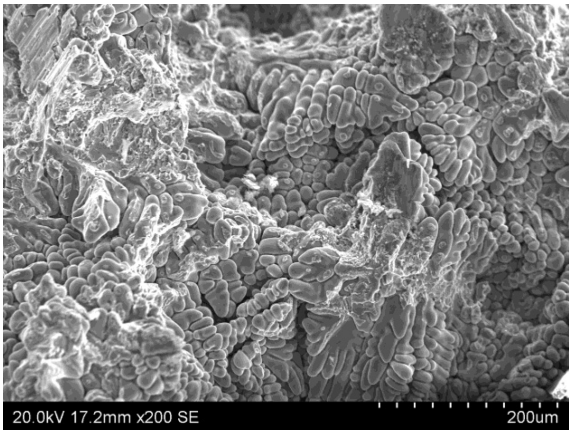

Fig.5. SEM micrograph of 4% MoS_2 fracture surface of tensile test specimen

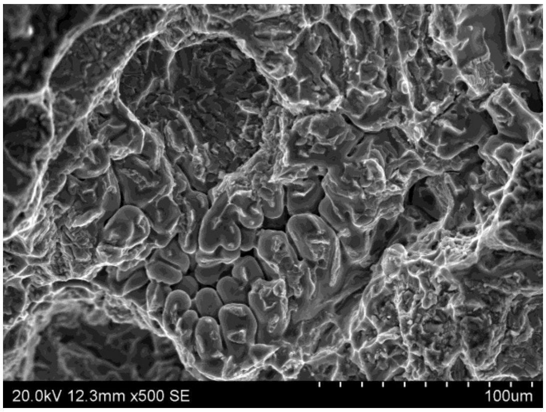

Fig.6. SEM micrograph of 2% MoS_2 fracture surface of tensile test specimen

3.3. Optical & SEM Analysis:

The morphology, density, type of reinforcing particles and its distribution have a major influence on the properties of particulate composites. Prashant Sharma et al (2012).The specimens were prepared for microstructure analysis by thoroughly polishing and etching. Then the specimens were observed under an optical microscope for studying the microstructure. The optical micrograph is shown in fig.7, which shows the even dispersion of the reinforcement in the matrix. The SEM images of the prepared samples were taken & shown in fig. 8 to 10. The SEM EDAX is shown in the fig.11. The XRD analysis confirmed the presence of MoS_2 within the matrix. The XRD pattern is shown in the fig.12.

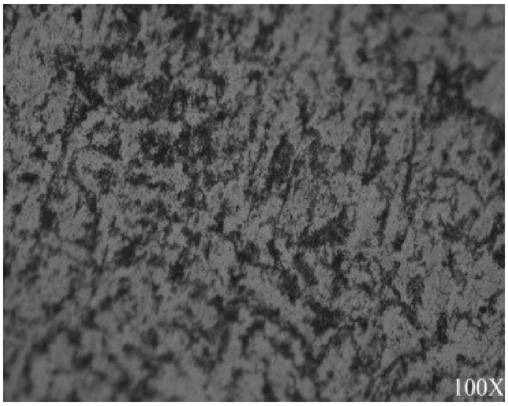

Fig.7. Optical micrograph of Al-5% MoS_2 specimen

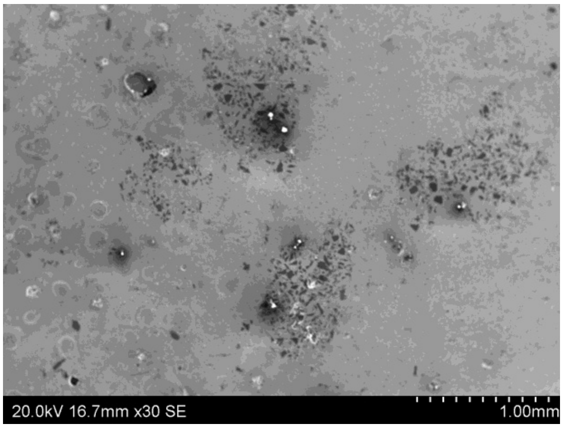

Fig.8. SEM micrograph of Al 2024 alloy

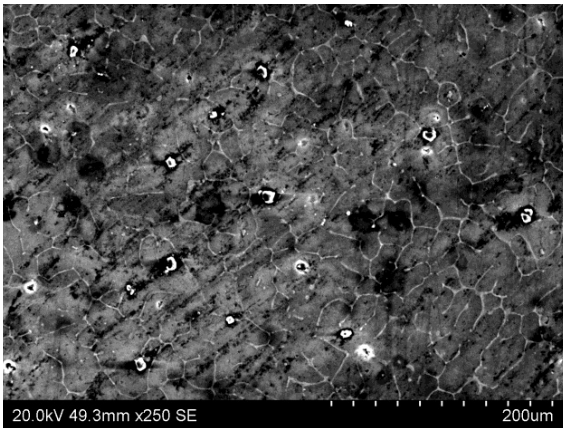

Fig.9. SEM micrograph of 2% MoS_2-Al 2024 alloy composite

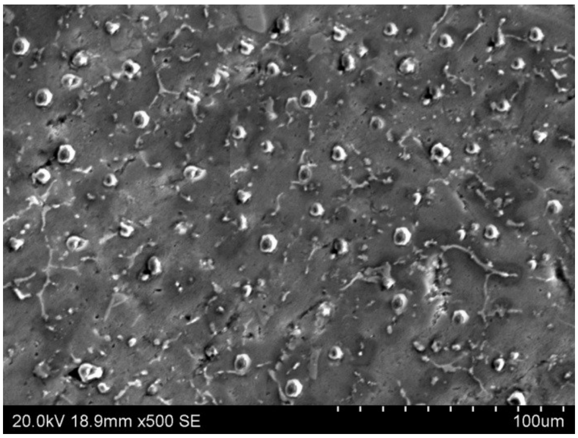

Fig.10. SEM micrograph of 2% MoS_2-Al 2024 alloy composite

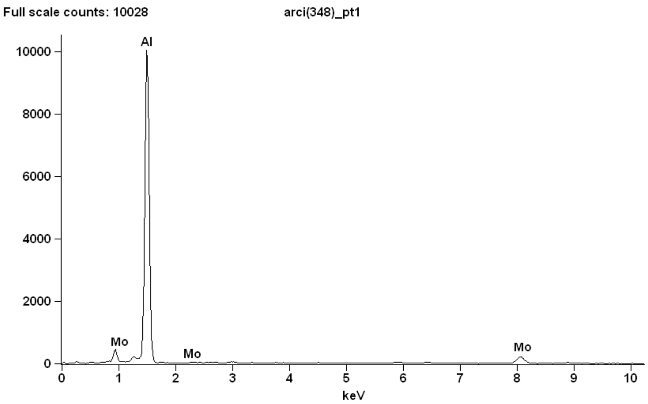

Fig.11. EDAX pattern of typical Al 2024-MoS_2 composite specimen

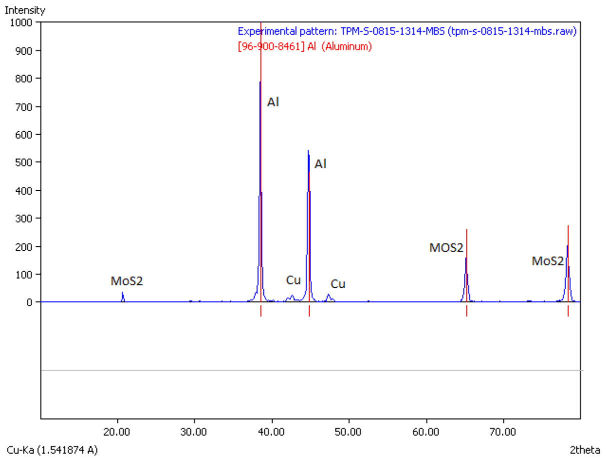

Fig.12. XRD pattern of typical Al 2024-MoS_2 composite specimen

4. CONCLUSIONS:

The 2024 Al- MoS_2 composites of combinations 1%, 2%, 3%, 4% & 5% were produced through stir casting method. The mechanical properties of the samples were evaluated and compared with base metal properties. The following conclusions are made from the study.

1. Al- MoS_2 composites were successfully fabricated by stir casting method.
2. The tensile Strength of 2024 Al with 4% MoS_2 showed highest value.
3. The Hardness was found to be the maximum for 4% MoS_2 composite.
4. Optical micrographs revealed that the MoS_2 particles were well distributed in the aluminium matrix.
5. XRD analysis revealed the presence of MoS_2 particles in the composite with homogeneous dispersion.

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