Mechanical and Wear Properties of AL2024 T3 Reinforced Composites with TIB2 & MOS2

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Abstract: This paper presents an experimental investigation into the mechanical properties and wear behavior of aluminum alloy AL2024 T3 reinforced with titanium diboride (TiB2) and molybdenum disulfide (MoS2). The composites were fabricated using the stir casting method, and various proportions of TiB2 and MoS2 were incorporated to evaluate their effects on wear resistance and mechanical properties. The wear tests were conducted under different loading conditions. The results indicate that the incorporation of TiB2 and MoS2 significantly enhances the wear resistance and mechanical properties of AL2024 T3 composites. In this research, an attempt has been made to study the hardness, tensile strength, compressive strength, tribological beahvior, influence of wear test parameters and corrosion resistance of Al2024 T3 hybrid composites which are reinforced with hard reinforcement TiB2 and soft reinforcement MoS2 to form the composites. The Al2024 T3 hybrid composites are fabricated with the help of powder metallurgy technique. Al2024 T3 acted as a matrix material which surrounds the Titanium Diboride and Molybdenum Disulfide after consolidation in powder metallurgy technique. Titanium Diboride acted as a hard reinforcement to enhance the mechanical properties, wear resistance and corrosion resistance of the composites.

Keywords: Composite Materials, Pin On Disc, Wear Analysis, Mechanical Properties.

I. INTRODUCTION

This research aims to investigate the effects of varying TiB2 and MoS2 concentrations on the mechanical properties and wear behavior of AL2024 T3 composites. By conducting a series of wear tests and mechanical property evaluations, we seek to understand the interactions between the matrix and the reinforcements. Furthermore, microstructural analysis will provide insights into the distribution and bonding characteristics of the reinforcements within the aluminum matrix. The findings of this study will contribute to the development of advanced composite materials that meet the demanding requirements of aerospace and automotive applications. By enhancing the wear resistance of AL2024 T3 through the incorporation of TiB2 and MoS2, we aim to extend the material's service life and broaden its applicability in environments where wear and friction are critical concerns. Aluminum alloys are integral to modern engineering applications due to their lightweight, high strength, and excellent corrosion resistance. Among these, AL2024 T3 is particularly favored in aerospace and automotive sectors, where structural integrity and weight savings are crucial. Despite its favorable mechanical properties, AL2024 T3 suffers from poor wear resistance, which limits its performance in applications involving friction and abrasive conditions. Therefore, enhancing its wear characteristics while retaining mechanical integrity has become a significant area of research.

II. LITERATURE SURVEY

Javdani's (2018), review focuses on the secondary processes that enhance the properties of aluminum metal matrix composites (MMCs) post-fabrication, particularly through hot extrusion. The paper highlights how hot extrusion can improve mechanical properties such as tensile strength and ductility by refining the microstructure and promoting uniform distribution of reinforcements.

The review emphasizes the importance of processing parameters, including temperature and extrusion speed, which significantly influence the final characteristics of the composites. Javdani concludes that optimizing these parameters is crucial for maximizing the performance of aluminum MMCs, laying a foundation for future studies on processing techniques.

Aijun Zhang, Han, J., Su, B., Li, P., & Meng, J. (2017), investigates the properties of self-lubricating composites based on CoCrFeNi high entropy alloys, focusing on their microstructure, mechanical strength, and tribological performance. The authors report that the inclusion of solid lubricants improves wear resistance significantly. The research utilizes advanced characterization techniques to analyze the microstructure, revealing a complex phase structure that contributes to enhanced hardness and reduced friction. The findings suggest that high entropy alloys can serve as a promising matrix for self-lubricating composites, which may inspire further exploration of similar systems in aluminum MMCs.

Sudhagar Sukkasamy (2017), this paper examines the dry sliding wear behavior of a hybrid metal matrix composite consisting of aluminum 5059 reinforced with silicon carbide (SiC) and molybdenum disulfide (MoS2). The authors conducted wear tests under varying loads and sliding speeds to assess the tribological performance. Results indicated that the combination of SiC and MoS2 resulted in superior wear resistance compared to the unreinforced matrix. The study attributes the improved wear performance to the hard SiC particles and the lubricating effect of MoS2, demonstrating the effectiveness of hybrid reinforcement in enhancing the tribological properties of aluminum alloys.

Olubambi, P. A. (2014), in this research, the authors investigate the corrosion and wear behavior of Al–Mg–Si alloy hybrid composites reinforced with rice husk ash and silicon carbide. The study reveals that the incorporation of these reinforcements enhances both corrosion resistance and wear performance, attributed to the hardness of silicon carbide and the barrier properties of rice husk ash. The findings suggest that natural reinforcements can effectively complement traditional ceramic reinforcements, leading to sustainable and high-performance aluminum composites. This work highlights the potential of using agricultural waste in composite fabrication, paving the way for eco-friendly material development.

III. OBJECTIVES

The objective of this dissertation is to conduct experiments on a composite component and validate the results.

- To fabricate Al2024 T3 based Hybrid metal matrix composites through Powder metallurgy technique.
- To identify the Tribological properties, Hardness, Compressive strength, Tensile strength of the all fabricated Al2024 T3 based Metal Matrix and Hybrid Metal Matrix composites.
- To identify the better composition of weight percentage of Titanium Diboride and weight percentage of Molybdenum Disulfide with Al2024 T3 matrix, the mechanical properties of all fabricated composites are compared with each other.

IV. EXPERIMENTAL RESULTS AND DISCUSSIONS

Sliding Wear Response

Al2024 T3 alloys show superior results for wear rate and coefficients of friction.

Table 4.1: Different combinations of Al2024 T3 with reinforcing materials

Samples	Compositions of Pins
A	Al2024 T3 +0% TiB2+0% MoS2
B	Al2024 T3 +3% TiB2+6% MoS2
C	Al2024 T3 +6% TiB2+6% MoS2
D	Al2024 T3 +9% TiB2+6% MoS2

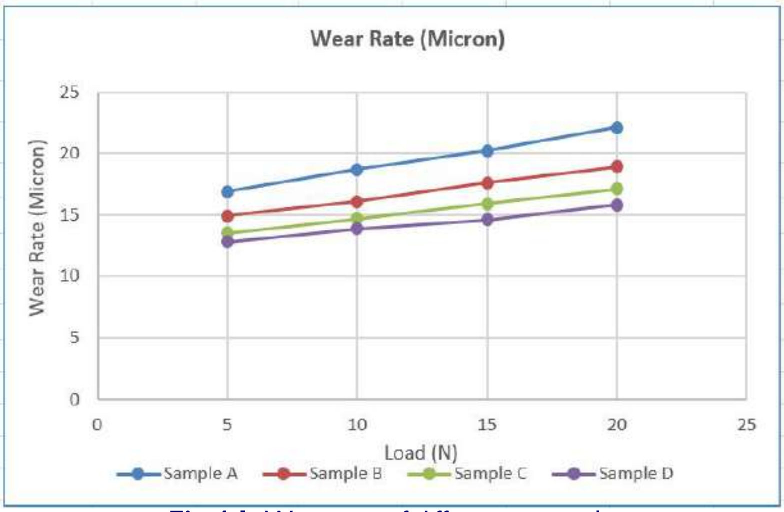

Fig 4.1: Wear rate of different materials

Table 4.2: Sliding wear rate and COF results of various Hybrid Metal Matrix material

S.No	Load (N)	Wear (Micron)				Coefficient of friction (COF)			
		SMP-A	SMP-B	SMP-C	SMP-D	SMP-A	SMP-B	SMP-C	SMP-D
1	5	15.3	13.9	12.5	11.7	0.164	0.159	0.131	0.129
2	10	16.6	14.7	13.8	12.6	0.175	0.167	0.142	0.133
3	15	17.3	16.5	14.9	13.3	0.188	0.173	0.158	0.145
4	20	20.8	16.7	15.4	14.5	0.194	0.184	0.164	0.153

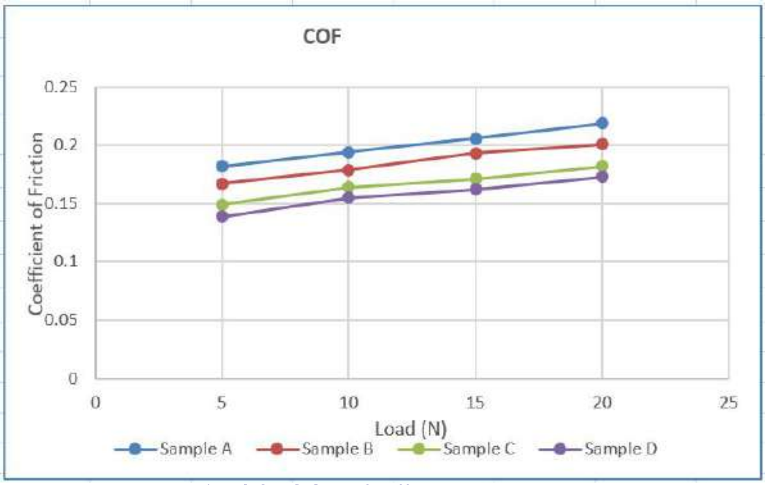

Fig 4.2: COF of different materials

A) Tensile Strength

The tensile strength of the Al2024 T3+ TiB2 + MoS2 composites are shown in table, respectively. In contrast to pure Al2024 T3, which claims a strength of 178 MPa, AL2024 T3+3%TiB2+6%MoS2, AL2024 T3+6%TiB2+6%MoS2 and AL2024 T3+9%TiB2+6 %MoS2 report strengths of 232, 247, and 279 MPa, respectively.

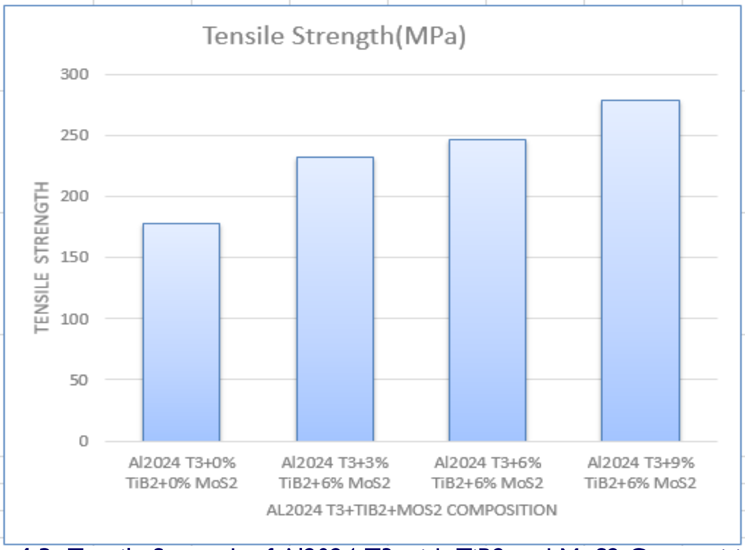

Fig 4.3: Tensile Strength of Al2024 T3 with TiB2 and MoS2 Composition

B) Compressive Strength

The compressive strength of AL2024 T3 is 241 MPa, while that of AL2024 T3+3% TiB2+6%MoS2, AL2024 T3+6% TiB2 + 6 %MoS2, and AL2024 T3+9%TiB2 + 6%MoS2 configurations report compressive strengths of 283, 327 and 355 MPa, respectively

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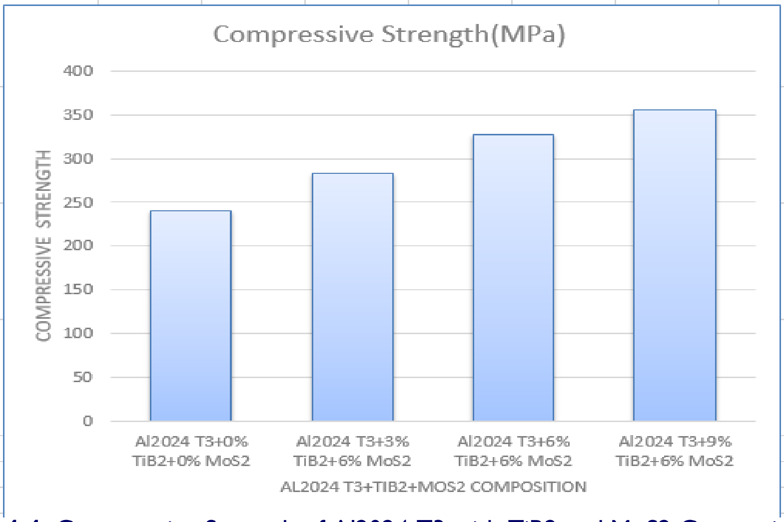

Fig 4.4: Compressive Strength of Al2024 T3 with TiB2 and MoS2 Composition

C) Hardness (BHN)

AL2024 T3 displays a hardness of 85 BHN. AL2024 T3+3% TiB2 + 6 %MoS2, AL2024 T3+6% TiB2 + 6 %MoS2, and AL2024 T3+9%TiB2 + 6 %MoS2 configurations, respectively, report BHN values of 90, 95, and 108.

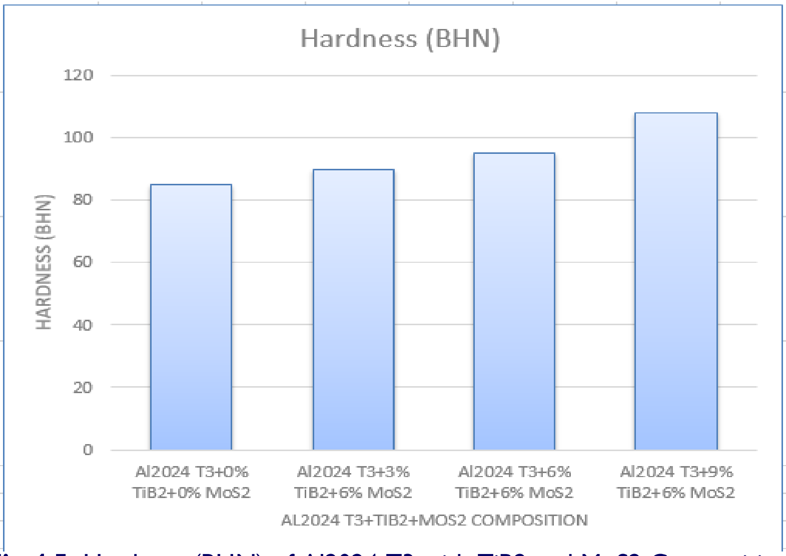

Fig 4.5: Hardness (BHN) of Al2024 T3 with TiB2 and MoS2 Composition

V. FINITE ELEMENT ANALYSIS

Finite Element Method is a numerical procedure for solving continuum mechanics of problem with accuracy acceptable to engineers.

5.1 Structural Analysis

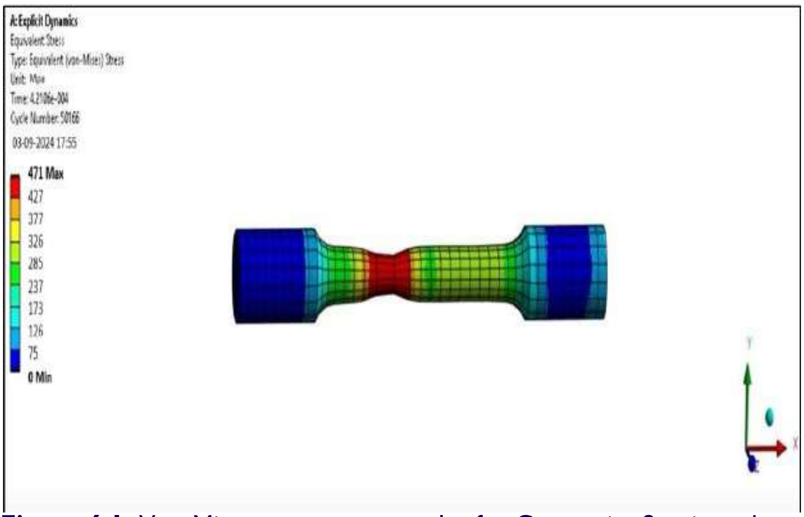

Figure 6.1: Von-Mises stress contour plot for Composite Specimen bar

The maximum equivalent stress observed in the Composite Specimen bar is 471 MPa.

5.2 Summary

It is observed from the results that, Maximum stresses are developed in the Composite Specimen bar and exactly matches with the field failure. A comparison of equivalent stress values for Composite Specimen bar design and subsequent modified designs of the Composite Specimen bar are calculated. Following table shows comparison between different designs of Composite Specimen bar through FEA.

Table 5.1: FEA Results

Description	Finite Element Analysis	
	Von-Mises Stres (Mpa)	Tensile Stress (Mpa)
Composite Specimen Bar	471	272

A stresses in the proposed Composite Specimen bar is minimum. The proposed Composite Specimen bar design is feasible and carried forward for manufacturing and compared the experimental results with finite element study.

VI. CONCLUSION

- The addition of TiB2 and MoS2 to Al2024 improves the hardness, compression and tensile strength of the hybrid metal matrix with decreased extension. Due to the higher mass density of TiB2 and MoS2, the mass density of strengthened MMCs and HMMCs is heavier than the base alloy. Hardness increases with the addition of up to 9% of TiB2 weight and above 9% of weight decreases the hardness of the hybrid composite.
- The compressive and tensile strength of the hybrid composite increased dramatically by weight percentage of TiB2 from 3% to 9% and MoS2 with 6.In the other side, the compressive and tensile strength of the hybrid composite is steadily improved with the use of increased %wt of Titanium Diboride as reinforcement along with aluminium alloy 2024 T3.
- Composites containing 0, 3, 6 and 9 weight percent of TiB2 show severe wear and COF, while with 9% TiB2, there is some mild wear and COF values.
- If we compare the von-Mises stress values for applied load, the design of specimen bar is more feasible and safe. The percentage variation between FEA and Experimental method for specimen bar is 1%. It is observed from above table that, there is less than 10% variation observed between FEA and Experimental methods. This variation is acceptable. Therefore, it is concluded that, the composite specimen bar is safe for the current application.

Description	Finite Element Analysis		Experimental		% Error
	Von-Mises Stress (Mpa)	Tensile Stress (Mpa)	Von-Mises Stress (Mpa)	Tensile Stress (Mpa)	
Composite Specimen Bar	471	272	483	279	2.50%

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