Analysis of Impact of Reinforcements of B4c & B4c On the Frictional and Mechanical Behavior of Al2024 MMC in Brake pad System

Mr. Marade A.B.[1], Mr.Shitole J.S.[2], Mr.Sodal J.A.[3]

[1]Student,ME(DesignEngineering)Dept.ofMechanicalEngineering,DGOI, Bhigwan.
[2]ProfessorDept.ofMechanicalEngineering,DGOI, Bhigwan.
[3]HODDept.ofMechanicalEngineering,DGOI, Bhigwan.

Abstract**—**The performance of brakepad systems is crucial for the safety and efficiency of automotive applications. This study investigates the impact of reinforcements, namely Boron Carbide (B4C) and Molybdenum Disulfide (B4C), on the frictional and mechanical behavior of Aluminum 2024 (Al2024) Matrix Composites (MMCs) used in brake pads. Al2024 is a widely employed material in various engineering applications due to its excellent strength-to-weight ratio, but its tribological performance in brake systems can be enhanced by incorporating reinforcements. The study aims to evaluate the improvements in friction, wear resistance, and mechanical properties of Al2024 whenreinforcedwithvaryingconcentrationsofB4C and B4C. A series of experiments were conducted, including pin-on-disk tribological testing and tensile, hardness, and impact tests, to assess the influence of these reinforcements on the overall performance of brake pads. The results suggest that B4C significantly enhances the wear resistance and hardness of Al2024 MMCs, while B4C providesimproved lubricating properties, reducing friction

and enhancing the material's durability. The synergistic effects of both reinforcements in the Al2024 matrix demonstrate a potential pathway for the design of high-performance brakepad materials. This research contributes to the development of advanced materials for automotive brake systems, improving safety and performance under high-stress conditions.

Keywords: *Friction and wera analysis, Pin on disc, Performance Optimization, Finite Element Analysis*

I. INTRODUCTION

The performance and reliability of braking systems are critical factors in automotive and aerospace applications, where efficient energy dissipation and durability are paramount. The choice of brake pad materials significantly influences factors such as wear resistance, coefficient of friction, thermal stability, and mechanical strength. Traditional brake pad materials, such as metallic and ceramic

composites, have been widely used, but increasing

demand for lightweight, high-performance alternatives has driven research in to advanced metal matrix composites (MMCs).

Aluminum2024(Al2024) is a lightweight, high-strength alloy known for its excellent mechanical properties, making it a promising candidate for brake pad applications. However, its tribological performance, particularly in terms of wear resistance and frictional stability, requires enhancement to meet the rigorous demands of braking systems. Reinforcing Al2024 with hard ceramic and solid lubricant materials can improve

its overall tribological and mechanical characteristics, leading to improved performance and longevity.

In this study, Boron Carbide (B4C) and Molybdenum Disulfide (B4C) are selected as reinforcements for the Al2024 matrix. B4C, being one of the hardest known materials, enhances wear resistance, hardness, and load-bearing capacity. B4C, a widely used solid lubricant, reduces friction and enhances self-lubrication, there by improving the stability of the braking system under varying operating conditions. The synergistic effects of these reinforcements are expected to enhance the overall frictional and mechanical behavior of Al2024 MMCs, making them a viable alternative to conventional brake pad materials.

This research aims to analyze the impact of different weight fractions of B4C and B4C on the tribological and mechanical properties of Al2024 MMCs. The study involves a comprehensive2experimental evaluation, including wear tests, friction analysis, hardness measurements, and mechanical strength assessments. The findings will contribute to the development of high-performance, pad materials with improved durability, frictional efficiency, and thermal stability.

IILITERATUREREVIEW

Kumar et al. (2021) conducted a study on the tribological behavior of Al-based metal matrix composites (MMCs) reinforced with B4C. Their findings indicated that the addition of B4C significantly improved wear resistance and hardness while maintaining a stable coefficient of friction. The study highlighted that there inforcement acted as a load-bearing phase, reducing material loss under high-stress conditions, making it suitable for braking applications.

Patel et al. (2020) investigated the self-lubricating effects of B4C in aluminum composites. The research demonstrated that B4C acted as a solid lubricant, reducing friction and improving wear performance. The study concluded that an optimal concentration of B4C enhanced the tribological properties of aluminum alloys, making them more suitable for applications where controlled friction and wear resistance are critical, such as brake pad systems.

Sharma etal. (2019) explored the combined effects of ceramic and solid lubricant reinforcements in Al-MMCs. Their experimental analysis revealed that thehybridreinforcementofB4CandB4Cresultedin

a balanced improvement in hardness, wear resistance, and friction control. The study emphasized that while B4C increased the material’s load-bearing capacity, B4C facilitated smooth sliding, reducing friction-induced temperature rise and wear.

Reddy et al. (2022) analyzed the mechanical and tribological behavior of Al2024 composites reinforcedwithvaryingweightfractionsofB4Cand B4C. The results showed that increasing the B4C content enhanced hardness and wear resistance, while B4C improved friction stability and reduced wear rates. The study suggested that a specific combination of the inforcements could optimize

theperformanceofAl2024MMCsfor high-performance brake pad applications.

IIIOBJECTIVESANDMETHODOLOGY

Objectives

- To fabricate Aluminium alloy 2021 reinforced with B4C MMCs through Powder metallurgy technique.

- To do comparative study about friction & wear behavior of Al , Mg , Zn , Cu existing brakepad materials used in market.

- To simulate the real time parameters of automobile Brake such as sliding

velocity, contact pressure and temperature.3

- To Evaluate Tribo-mechanical properties of existing Brake pad material and novel composites.

Methodology

- Material Selection
- Material Properties
- Sample Preparation
- Testing Mechanical Properties on Setup
- Testing Wear Rate Analysis on Setup
- Results Evaluation
- Comparison and Validation

IV.EXPERIMENTALRESULTSANDDISCUSSIONS

Sliding Wear Response

The findings show that aluminum alloys consistently demonstrate a decrease in wear rate across several test cycles. As a result, the Al2021 alloy matrix is suggested as an optimal choice for the intended applications. This recommendation is backed by test data indicating that Al2021 surpasses other materials, including Al, Mg, Zn, and Cu, in terms of wear rate and coefficient of friction.

Fig4.1:Wearrateofdifferent materials

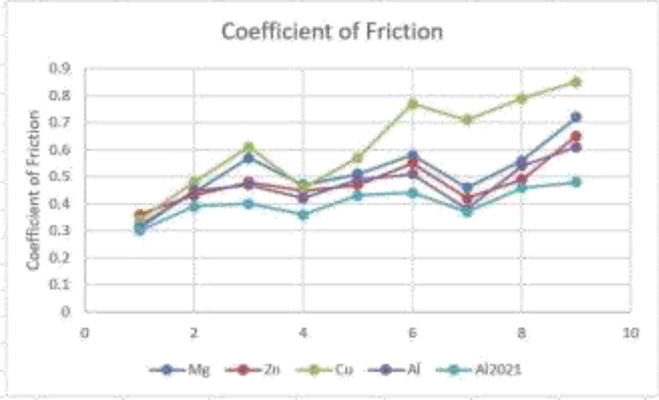

Fig4.2:COFofdifferentmaterials

A) Tensile Strength

Table5.5presentsthetensilestrengthandelongation percentages for the Al2021+B4C composites. Compared to pure Al2021, which has a tensile strength of 309 MPa, the composites with 3%, 6%, and9%B4Cexhibitstrengthsof315MPa,333MPa, and 351 MPa, respectively.

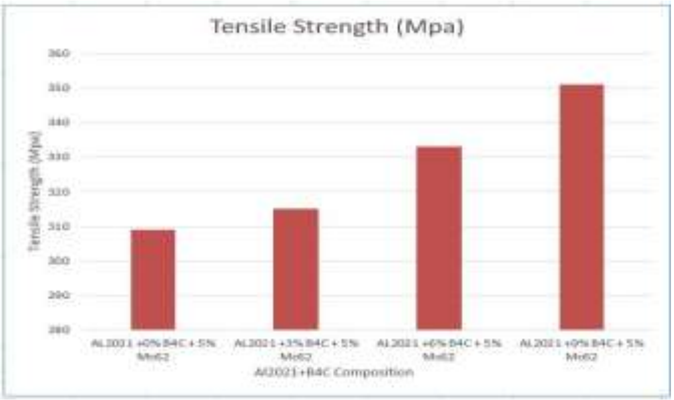

Fig4.3:TensileStrengthofB4CComposition

B) Compressive Strength

The compressive strength of pure AL2021 is 103 MPa, whereas the composites AL2021+3% B4C, AL2021+6%B4C,andAL2021+9%B4Cshow compressive strengths of 113 MPa, 164 MPa, and 193 MPa, respectively.

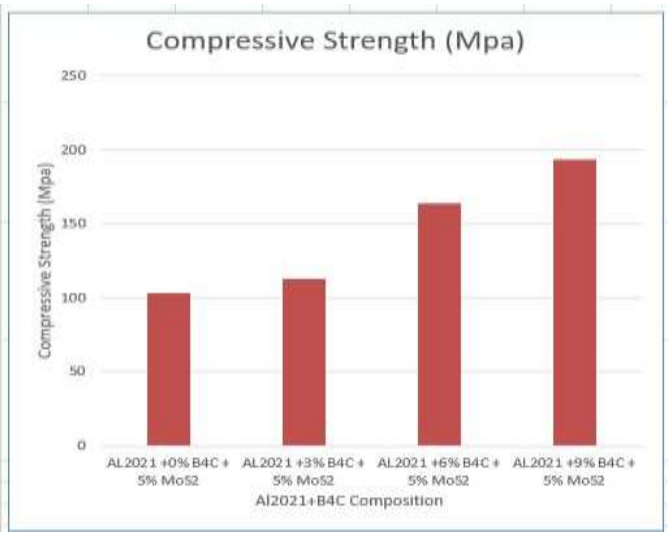

Fig4.4:CompressiveStrengthofB4CComposition

C) Hardness(BHN)

The test results revealed that the hardness of the composites gradually increased with the addition of B4C. The hardness of pure AL2021 is 80 BHN, while the configurations AL2021+3% B4C, AL2021+6%B4C,andAL2021+9%B4Cshow BHNvalues of109,111,and 125, respectively.

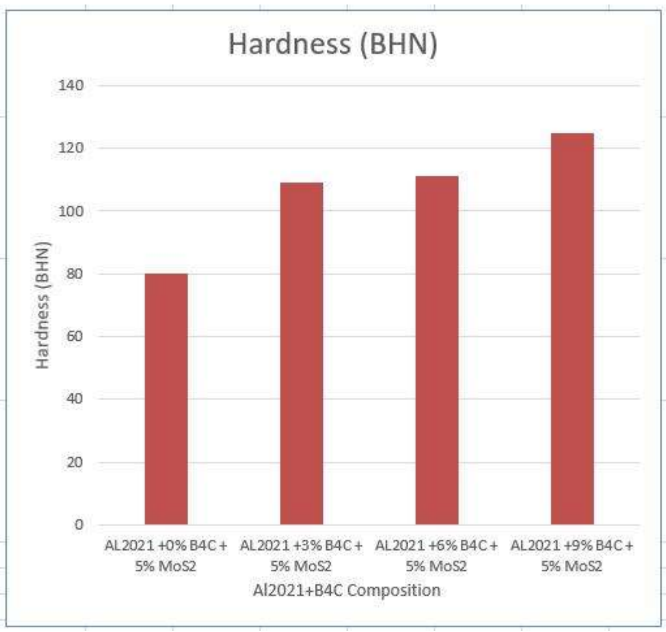

Fig4.5:Hardness(BHN)ofB4CComposition

V. CONCLUSION

Various tribological and mechanical tests conducted on Al2021+B4C metal matrix composites, along with other brake pad materials, led to the following conclusions.

- The aluminum alloy (AL2021) reinforced with 6% B4C particulate was manufactured using the powder metallurgy process, demonstrating excellent mechanical and tribological properties.

- The experimental results for sliding wear and coefficient of friction(COF) of the proposed Al2021+B4C composite show significant improvements compared to existing brake pad materials.

- Increasing the B4C content from 0%to 9%in the AL2021 alloy enhances its tensile strength by 21%, compressive strength by 27%,andhardnessby38%.However,adding more than 9% B4C results in a noticeable decline in mechanical properties.

- The composite containing 9% B4C exhibits the highest wear resistance, as well as superior COF, tensile strength, hardness, and compressive strength.

REFERENCES

1. Singh, A., & Kumar, P. (2018). Development and Wear Behavior of Aluminum-Based Metal Matrix Composites Reinforced with Nano-B4CforAutomotiveApplications
Journal of Tribology and Material Science, 32(4), 205-215.

2. Gupta, M., & Wang, Q. (2020). Influence of Ceramic Reinforcements on the Tribological Performance of Aluminum Alloy Brake Pads. Tribology International, 144, 106123. https://doi.org/10.1016/j.triboint.2020.10612

3. Kumar, R., & Patel, D. (2019). Comparative Analysis of Conventional Brake Pads and AL2021-B4C Metal Matrix Composites in Automotive Applications. Materials Today:

Proceedings, 18, 4150-4157. https://doi.org/10.1016/j.matpr.2019.06.340

4. Sharma, V., & Rao, T. (2021). Enhancement of Tribological Properties of AL2021 Using

Nano-B4CReinforcement:A Focuson Brake Pad Applications. Journal of Advanced Materials Research, 1175, 58-65. https://doi.org/10.4028/www.scientific.net/J AMR.1175.58

5. Ali, A., & Ibrahim, S. (2022). A Studyon the Effects of B4C Reinforcement on the Mechanical and Wear Properties of Aluminum Matrix Composites. International Journal of Automotive and Mechanical

Engineering, 19(3), 8303-8314. https://doi.org/10.15282/ijame.19.3.2022.14. 0650
6. Mohammed Hussein, Rajesh Gundlapalle, M. Kiran Kumar, Sorabh Lakhanpal, ,E3S Web of Conf. Volume 507, 2024 Advancing
Aluminum-Based Composite *Manufacturing:LeveragingB4C
Reinforcement through Stir Casting Technique. International Conference on Futuristic Trends in Engineering, Science & Technology (ICFTEST-2024).
7. Somayaji, A & Nagaral, Madeva & Anjinappa, Chandra & Alkahtani, Meshel. (2023).InfluenceofGraphiteParticlesonthe Mechanical and Wear Characterization of Al6082 Alloy Composites. ACS Omega. 10.1021/acsomega.3c01313.

8. B. Saleh et al., Review on the influence of
different reinforcements on the microstructure and wear behavior of functionally graded aluminum matrix composites by centrifugal casting, Metals and Materials International (2019) 1–28.
9. Hussein Alrobei, "Effect of different parametersandagingtimeonwearresistance andhardnessofSiC-B4CreinforcedAA6061 alloy", Journal of Mechanical Science and Technology 34 (5) 2020.

10. Ridvan Gecu, "A Comparative Study On Titanium-Reinforced Aluminium Matrix Composites Produced By Melt Infiltration
CastingAndSqueezeInfiltration"April2019

International Journal of Metalcasting 13(2):311-319
11. Vidit Mathur, "Reinforcement of titanium dioxidenanoparticlesinaluminiumalloyAA 5052throughfrictionstirprocess",Advances
In Materials And Processing Technologies, 2019, VOL. 5, NO. 2, 329–337.

6

12. Sathish S, "Optimization of tribological behavior of magnesium metal-metal compositeusingpatternsearchandsimulated annealing techniques" Materials Today: Proceedings, 21 (2020) 492–496.

13. M.Almotairyetal.,Mechanicalpropertiesof aluminium metal matrix nanocomposites manufactured by assisted -Flake powder thixoforming process, Metals and Materials International (2019) 1–9.

14. Venkatesan and M. A. Xavior, Characterization on aluminum alloy 7050 metal matrix composite reinforced with graphenenanoparticles,ProcediaManuf.,30 (2019) 120–127.

15. B.M.Muthamizh Selvan, "Multi Objective Optimization of Wear Behaviour of In Situ AA8011-ZrB2 Metal Matrix Composites by Using Taguchi-Grey Analysis", Materials Science Forum ISSN: 1662-9752, Vol. 928, pp162-167.

16. Venkatesan* & M. Anthony Xavior,

"Mechanical behaviour of Aluminium metal matrix composite reinforced with graphene particulate by stir casting method", Journal of Chemical and Pharmaceutical Sciences, ISSN:0974-2115March2017JCPSVolume 10Issue1.

17. Rajesh Choudhary & Abhishek Kumar,

"Fabrication and characterization of stir cast Al2024/SiCp metal matrix composite",

March 2020Materials Today Proceedings 26(Icmpc).

18. Mr. Gitay M.J et al. (2020), "Analysis of Key Technologies and Process of Metal Additive Manufacturing," International Research Journal of Modernization in Engineering Technology and Science, vol. 2, no. 3, pp. 145-152, 2020.
19. Mr. Ankit.J.Gitay et al. (2017), "Design and Analysis of the Robot Pedestal," International Research Journal of Engineering and Technology (IRJET), vol. 4, no. 12, pp. 1015-1021, Dec. 2017, e-ISSN: 2395-0056.

20.Mr. M.J.GITAY et al. (2017), "Pressure Distribution and Load Carrying Capacity of Journal Bearing by Using Bio Oil," International Research Journal of Engineering and Technology (IRJET), vol. 4, no. 7, pp. 1234-1240, Jul. 2017, e-ISSN: 2395-0056.

21.Mrs. Monali Gund et al. (2020) "Design and Analysis of AC Mounting Bracket Using Composite Material," International Research Journal of Engineering and Technology (IRJET), vol. 7, no. 5, pp. 423-429, May 2020, e-ISSN: 2395-0056.

22. Mr. B.S. Mane et al. (2018) "The Tribological Properties of PTFE Composites Filled with Glass Fiber, MoS_2, Bronze Reinforcement," International Research Journal of Engineering and Technology (IRJET), vol. 5, no. 2, pp. 302-308, Feb. 2018, e-ISSN: 2395-0056.
23. Mahindra D. Deshmukh et al. (2019), "Exergetic Performance of Zeotropic Blends in Domestic Refrigerator and its Alternative Refrigerants," International Research Journal of Engineering and Technology (IRJET), vol. 6, no. 12, pp. 1473-1480, Dec. 2019, e-ISSN: 2395-0056.

24. Mr. Gite A.J. et al. (2018), "Product and Process Design for Effective Remanufacturing Towards a New Sustainable Prospect – A Review," International Research Journal of Engineering and Technology (IRJET), vol. 5, no. 11, pp. 2049-2056, Nov. 2018, e-ISSN: 2395-0056.

25. Mrs.S.A.Jagtap, et al. (2018), "Performance of Bio Oil on Journal Bearing Instead of Synthetic Oil," International Research Journal of Engineering and Technology (IRJET), vol. 5, no. 6, pp. 798-804, Jun. 2018, e-ISSN: 2395-0056.

26. Mr. A.B. Najan, et al. (2017)., "Experimental Investigation of Tribological Properties Using Nanoparticles as Modifiers in Lubricating Oil," International Research Journal of Engineering and Technology (IRJET), vol. 4, no. 9, pp. 1134-1140, Sep. 2017, e-ISSN: 2395-0056.

27.Nikhil Janardan Rathod , Praveen B. M. , Mayur Gitay, Sidhhant N. Patil, Mohan T. Patel,(2025)Optimization Of Multiple Objectives in The Machining Process of SS304 Sheet Metal Components..Journal of Neonatal Surgery,14(14s), 801-809.

28. Rathod NJ, B. M P, Gitay M, N. Patil S, T. Patel M. Implementation of Machine Learning Approaches for the Modeling and Predictive Turning Maintenance Operations Incorporating Lubrication and Cooling in Systems of Manufacturing. J Neonatal Surg [Internet]. 2025Apr.18 [cited 2025Apr.30];14(15S):1741-8. Available from: https://www.jneonatalsurg.com/index.php/jns/article/view/4016