Mechanical and Tribological Characterization of Al alloy-based Bio Composite

R. Sibin Raj[1], R. Shadakshari[2], Asha[3], P.B. Bharath Kumar[3], N. Madan Tej[3] & Soumya[3]

[1]Assistant Professor, Aeronautical Engineering
Acharya Institute of Technology, Bengaluru, Karnataka, India
[2]Associate Professor, Mechanical Engineering
Acharya Institute of Technology, Bengaluru, Karnataka, India
[3]Aeronautical Engineering
Acharya Institute of Technology, Bengaluru, Karnataka, India
***DOI**: https://doi.org/10.34293/acsjse.v4i1.101*

Received Date: 23.12.2023 **Accepted Date:** 20.02.2024 **Published Date:** 01.04.2024

Abstract - *Al6061 alloy is most commonly used in automotive industry, marine industry and aerospace industry applications to reduce weight and improve strength of the composite. Al6061 alloy used as matrix material. The powder of bone is used asreinforcement to produce the Al6061 alloy-based bio composite. As bone takes long period of time to decompose that will affect the environment and the people living near the disposal area of bone. Bone has good compression strength and it is light in weight, which helps to improve the strength of the Al6061 alloy composite. The Al6061 alloy-based bio composite is produced through powder metallurgy method and the samples were successfully obtained for testing and analysis. Theprepared samples are analysed for hardness test, compression test and wear test.*
***Keywords**: Al 6061, Bone Powder, Environmental Pollution, Powder Metallurgy, Bio Composite*

I INTRODUCTION

Metal Matrix Composites (MMC) are basically compounds mixed with strengthening components like fibers, whiskers, or particles. They come in different types such as Aluminum-based, Magnesium-based, Copper-based, and Titanium-based composites [3]. People are increasingly looking for lightweight composite materials to improve the performance of car and plane parts. Among these, aluminum alloy metal matrix composites are often used because they're cost-effective, lightweight, resistant to rust, tough, and conduct electricity well. One of the most interesting types is AA6061 composites, which are used in various industries like automotive, defense, aerospace, and marine because they offer better mechanical properties, can be shaped easily, and are made more efficiently [1]. Choosing the right mix of strengthening elements is crucial for how well a material performs. To lower costs, things like fly ash, breadfruit seed hull ash, sugarcane bagasse, and other natural materials are used in making these composites. The reinforcing materials used in Aluminum Matrix Composites (AMCs) fall into three main categories: industrial materials, waste synthetic ceramic bits, and leftovers from farming or nature. The specific characteristics of the chosen strengthening material and the alloy used for the matrix determine how well the final composite will work [4]. Changes in the mechanical behavior happen because of differences in the percentage of strengthening material and the mix of the matrix material. Aluminum Metal Matrix Composites (AMMCs) are used in many engineering fields and

have both structural and functional applications. Bones are strong and light. When they're thrown away, they harm the environment and people nearby. They can handle high heat, so industries like using them. Researchers have found lots of uses for waste bones, like purifying water and making medicines and the physical properties of the Bone methodology is represented in Table 1. But before using bone powder for anything, we need to check if it works with other stuff, what we're using it for, and how to handle and throw it away safely. Following the rules for getting rid of bone powder is important to keep the environment clean [2].

Table 1 Physical Properties of Bonemethodology

Physical Properties	Value
Density	0.92-1.35\cm^3
Melting Point	1670 c (3038 F)
Thermal expansion	10^6/K
Modulus of elasticity	23-26GPa
Thermal conductivity	0.64-0.04

The Al6061 alloy-based bio composite is fabricated and three samples were successfully obtained and the details of the composition are presented in Table 2. The sample preparation process involves the powder mixing with suitable ratio of Al6061 alloy and the bone powder, once the powder mixing is done then the mixed powder is poured into the die and tightly fixed with the C- clamps, then powder compaction takes place with the certain load. Once the sample is removed from the die, the sample has given for heat treatment with suitable temperature and required period of time.

Table 2 Composition Details of Al6061 Powder and Bone Powder Powder Mixing and Compaction

No of Samples	Quantity (gm)		Percentage (%)	
	Al6061	Bone Powder	Al6061	Bone Powder
1	50	0	100	0
2	46	4	92	8
3	42	8	84	16

The Pure Al6061 powder was mixed with the known percentage of ingredients to form the Al6061 alloy-based bio composite was carried out in a high energy planetary ball mill. The mixed powder is poured in to a jar containing 25 steel balls of 10mm diameter each and then it is made to rotate in planetary ball mill for about 3 hours at 250rpm to ensure homogeneous mixing and the setup of the planetary ball mill is shown in Figure 1. The Al6061 powder was mixed with Bone powder in the weight percentage of 8% and 16% using planetary ball mill continuously for duration of 3hr at 250rpm in order to get homogenous mixing. The mixture of each proportion was compacted in a die part and assembled, using hydraulic press of 1000KN capacity and the hydraulic press setup is shown in Figure 2. The mixture was then pressed at a load of 30tons in order to get a final size of 20mm diameter and 70mm length billet Compacted specimens has placed in a vacuum tube furnace at temperature of 580c for 2hrs in nitrogen atmosphere followed by air cooling.

The removal of the billet from the die was proceeded by separating the die by dissembling it once the die has separated carefully, the bottom part of the die where the billet is attached, is tightly clamped in the wise. With the help of the plunger and hammer, h itting the billet parallel to the plunger and the billet slowly.

Figure 1 Planetary Ball Mill

Figure 2 Hydraulic Press

A. Mechanical Characteristics

Machining like turning and facing has been carried out in this process using lathe machine. After the heat treatment process is done, the samples are taken for further mechanical process, which involves reducing the diameter of the samples from its initial diameter of 20mm to 18mm diameter by mechanical process called turning operation. And to reduce the length from its initial length of 70mm to 50mm, we performed the facing operation.

***Hardness Strength*:** Hardness is the resistance to localized plastic deformation, such as an indentation (over an area) or a scratch(linear), induced mechanically either by pressing or abrasion [8]. Rockwell hardness using ball indenter has been carriedout in the Material testing lab at Acharya Institute of Technology. Placing the sample and applied the load over the 100kgs and the results are tabulated.

***Compression Strength*:** In mechanics, compression strength is the capacity of a material or structure to withstand loads tending to reduce size. In other words, compression strength resists compression. Compression strength is often measured on a Universal Testing Machine (UTM). Measurements of compressive strength are affected by the specific test method and conditions of measurement [7]. The compression strength test is carried out in the Geological and metallurgical laboratory (GML) with the guidelines by the lab instructor of the Geological and Metallurgical Laboratory (GML).

B. Tribological Characteristics

Tribology is all about how surfaces rub against each other when they move. It looks at things like friction, lubrication, and wear and tear when there's pressure on them. Making sure these parts of machines work well is super important for their smooth running and long

life. By managing friction, we can save energy, make machines work better, and make them last longer [5].

***Wear Resistance*:** Wear of material from a surface can lead to severe damage and failure of the component and/or the machine. The most common approach to reduce friction and minimize wear and catastrophic failure of machine components or the machine itself is by a proper selection of materials [6]. Wear resistance test has been carried out in Mechanical lab of Acharya Institute of Technology with the guidelines of the instructors of the lab and the results have been noted.

II RESULTS AND ANALYSIS

Hardness Test

Table 3 Hardness Test Results

Samples	Rockwell Hardness No			Average
	T1	T2	T3	
1	20	13	25	19.3
2	50	45	48	47.6
3	55	67	74	65.3

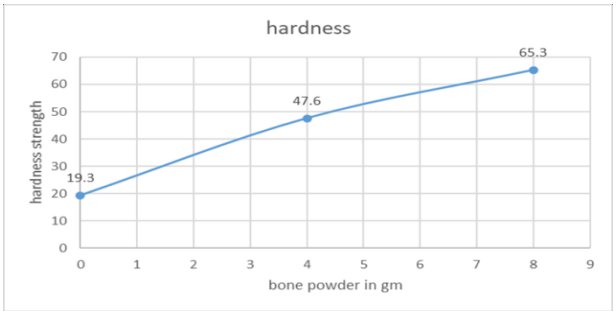

Figure 3 Graphical Representation of Hardness Strength

Compression Test

Table 4 Compression Test Results

Samples (Mpa)	Compression Strength
1	37.2
2	37.9
3	47.7

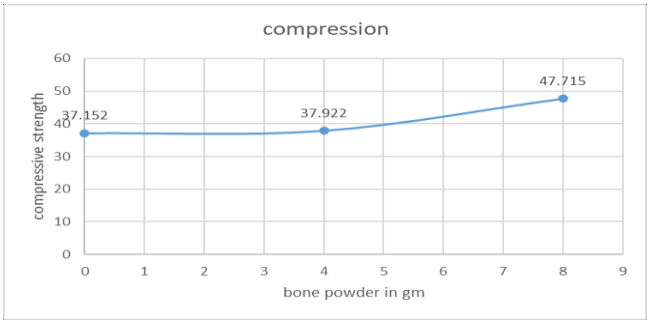

Figure 4 Graphical Representation of Compression Strength

Wear Test

Table 5 Wear Test Results

Samples	Wear (micrometers)	Frictional Force (N)
1	297	166.6
2	291	171.2
3	256	198.2

Figure 5 Graphical Representation of Wear

III STRENGTH CONCLUSION

The addition of bone powder as a reinforcement in Al6061 powder enhances their mechanical properties and tribological performance. The study revealed improved hardness and wear resistance in the composite materials compared to pure aluminium alloys. These enhancements are attributed to the unique structure and composition of bone powder, which effectively supports load distribution and reduces wear rate under various testing conditions. This research opens avenues fo r utilizing sustainable and biologically sourced materials in metal matrix composites, presenting a promising option for applications requiring lightweight yet durable materials in industries such as automotive and aerospace.

IV REFERENCES

[1] Hashim, J., Looney, L., & Hashmi, M. S. J. (1999). Metal matrix composites Production by Stir casting. *Journal of Materials Processing Technology, 92-93*, 1-7.

[2] Christy, J. V., Arunachalam, R., Mourad, A., Krishnan, P. K., Piya, S., & Maharbi, M. A. (2020). Processing, properties, and microstructure of recycled aluminium alloy composites produced through an optimized stir and squeeze casting processes. *Journal of Manufacturing Processes*, *59*, 287-301.

[3] Gupta, P. K., & Srivastava, R. K. (2018). Fabrication of ceramic reinforcement aluminium and its alloys metal matrix composite materials: A review. *Materials Today: Proceedings, 5*(9).

[4] Raja. S., Ravichandran, M., Stalin, B., & Anandakrishnan, V. (2020). A review on tribological, mechanical, corrosion and wear characteristics of stir cast AA6061 composites. *Materials Today Proceedings, 22*.

[5] Bodunrin, M. O., Alaneme, K. K., & Chown, L. H. (2015). Aluminium matrix hybrid composites: A review of reinforcement philosophies; Mechanical, corrosion and tribological characteristics. *Journal of Materials Research and Technology, 4*(4).

[6] Chauhan, A., Vates, U. K., Kanu, N. J., Gupta, E., Singh, G. K., Sharma, B. P., & Gorrepati, S. R. (2021). Fabrication and characterization of novel nitinol particulate reinforced aluminium alloy metal matrix composites (NiTip/AA6061 MMCs). *Materials Today: Proceedings, 38*.

[7] Kalaiselvan, K., Murugan, N., & Siva Parameswaran. (2011). Production and characterization of AA6061–B_4C stir cast composite. *Materials & Design, 32*(7).

[8] Dinaharan, I., Murugan, N., & Siva Parameswaran. (2011). Influence of in situ formed ZrB_2 particles on microstructure and mechanical properties of AA6061 metal matrix composites. *Materials Science and Engineering: A, 528*.