Mechanical and Wear Characterization of Aluminium Alloy Metal Matrix Composite

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Abstract- This research focuses on developing lightweight, high-strength aluminum (Al) 7050-based hybrid composites reinforced with TiO_2 and hexagonal boron nitride (h-BN) using stir casting. The study investigates the effects of different weight fractions and particle sizes (20 and 40 μm) of the reinforcements on the composites' microstructure, mechanical properties, and wear behavior. Nine samples were analyzed using XRD, SEM, and EDS, confirming uniform dispersion and the presence of only Al, TiO_2, and h-BN phases. Results showed significant improvements in hardness, tensile strength, and wear resistance—especially in composites with smaller reinforcement sizes, which achieved the highest mechanical performance. Sample C9 (5% TiO_2, 6% h-BN, 40 μm) demonstrated the best wear resistance and lowest coefficient of friction, while smaller particle composites yielded higher strength and toughness. Taguchi optimization confirmed these findings, highlighting the potential of Al7050/TiO_2/h-BN composites for aerospace, automotive, and marine applications due to their enhanced strength-to-weight ratio and durability.

Key Words: Pulse Autogenous Tungsten Inert Gas (TIG), mechanical properties, tensile strength, hardness, and fatigue resistance etc

1. INTRODUCTION

Composite is a combination of two chemically dislike materials that are varied by an interface. Composites are the materials that have properties combination of metal, polymers, and ceramics. More than one material is combined to form a composite that has better properties of both materials like stiffness, toughness etc. Wood and bone are examples of natural composite materials. Most of composite materials have two phases. They are matrix and dispersed phases. Matrix material is a continuous phase in the composite material that surrounds the dispersed fiber phase [1]. Usually, the bulk properties of composite materials totally depend on the material properties of individual phases constituted with. Furthermore, the performance of the composites also depends on the constituting phases and their concentration, size, shape, distribution, orientation[2].

1.1. ALUMINUM BASED HYBRID MMCS

Hybrid MMCs are a class of composite materials in which two or more than two reinforcing materials are incorporated into the matrix. Aluminum-based hybrid metal matrix composites (MMC) combine the benefits of multi reinforcing phases into the same aluminum matrix to enhance the bulk properties. Compared with single phase composites, hybrid composites offer several benefits due to the contribution form the diversified reinforcing phases.

Mechanical Properties are the first group of properties significantly influenced by the presence of multi-phases in the matrix. Hybrid composites exhibit increased strength, stiffness, toughness at the optimized combination of the dispersed phases. By selectively producing the hybrid composites with the combination of specific reinforcements, tailored properties such as hardness, wear resistance and thermal properties can be achieved in the hybrid composites. Hybrid composites also offer the advantage of weight reduction. Without losing the strength of the structure, light weight components can be produced by using hybrid composites particularly for automotive, aerospace, marine and military applications. On the other hand, thermal stability of the hybrid composites can be increased by selecting appropriate reinforcements. The durability and reliability of hybrid composites are higher compared with the single- phase reinforced composites. Decreased cost and wide versatility are the other benefits of the hybrid composites. Even though the complexity in manufacturing hybrid composites is slightly higher compared with the single phase dispersed composites, the acquired benefits are dominated.

In the present thesis work, Al7050 alloy has been selected as the matrix material and two different reinforcing phases (TiO_2 and hBN) were selected to develop the hybrid composites by stir casting route. Different weight fractions of the reinforcement with two different sizes were selected and the composites were fabricated. The role of the combination of the reinforcing phases and the size difference within the micrometer level on the mechanical and wear performance of the produced composites have been investigated.

2. LITERATURE REVIEW

Ravindran et al. also developed hybrid composites of SiC with varying content of Graphene up to a maximum fraction of 10%. From the mechanical properties evaluation; it was observed that increased strength and also better tribological properties were recorded for the composite with 10% Graphene. Similarly, other works also reported the presence of BN in the hybrid composite to decrease the wear rate of the hybrid composites. It was also reported by Rajmohan et al. that the presence of Mica along with SiC enhances the hardness and strength of produced composites by forming a stable mechanically mixed layer.

Moorthy et al. developed hybrid composites of Al/fly ash/Graphene and wear studies have been performed by adopting Taguchi optimization method. As observed from the obtained data, load is found to be important to control the wear rate followed by the sliding speed and the content of the fly ash powder. It was also reported that an interfacial phase known as Al_4C_3 is also developed when SiC and fly ash powders were used in the stir casting process because of the process of chemical reactions at the interface of the matrix and the incorporated reinforcements. It was also reported that other phases such as $MgAl_2O_4$ also formed when fly ash is added in addition to SiC into Al matrix to develop hybrid composites.

Another combination of reinforcements used to develop hybrid composites is using agro-waste products. These products are relatively cheap and widely available to produce hybrid composites and hence, several studies were also carried out in developing different combination of hybrid composites. Ash produced from rice husk, bamboo leafs, palm kernel shell, corn cob and maize stalk are a few examples used to develop Al based hybrid composites in the literature.

Prasad et al. produced Al hybrid composites by selecting rice husk ash and SiC as the reinforcing phases. From the mechanical properties evaluation, increased yield strength and tensile strength have been reported at the cost of losing ductility and fracture toughness. This is similar to what reported by Alaneme and Adewale in developing hybrid composites of Al6063-SiC-rice husk ash. Improved strength and stiffness were observed with the increased content of rice husk ash. On the other hand, ductility was clearly observed as decreased with the increased amount of rice husk ash.

From the works of Alaneme and Adewuyi , it was observed that the addition of Bamboo leaf ash into Al-Mg-Si alloy in addition to Al_2O_3 has a significanteffect on the mechanical performance of the developed composites. On contrary to several reports in using agro-waste as the reinforcing phase, use of bamboo leaf ash as the reinforcing phase could not resulted in improvement in the mechanical performance. Interestingly, the ductility was increased with the 10% of the bamboo leaf ash at the cost of losing some strength. Other composites produced by using agro- waste as one of the reinforcing phases have also exhibited better ductility without losing the strength of the composites.

Liyun Wu reported development of Al7050 composite by incorporating Graphene (0.5% by weight) selective laser sintering process. From the wear studies, itwas observed that the addition of Graphene is advantageous to improve the tribological properties of the composites. Similarly, Venkatesan et al. also used different manufacturing methods including stir casting and squeeze casting to developAl7050-Graphene composites. The Graphene size of 50-100 nm has been used with different fraction of 0.3, 0.5 and 0.7% successfully in all the processing routes. Furthermore, the optimization studies were carried out to evaluate the best fraction of the reinforcement by ANOVA method and found that 0.3% with squeeze casting is better in achieving improved mechanical properties among all the combinations. The composites were also observed with sound quality without significant pores or defects. Form the wear properties evaluation for different sliding distances, lower coefficient of friction and wear rate values were recorded and the 0.3% composites has shown relatively better performance among all the combinations.

SiC is the next reinforcement widely used to develop Al7050 composites by stir casting route as observed in the literature. Sathish and Karthick studied the tribological performance of Al7050 composites reinforced with SiC particles. Different weight fractions (0, 4 and 6%) were considered to develop the composites. From the study, the authors demonstrated the promising role of 6% reinforcement on the material properties among all of the combinations. From the microstructural studies, the reinforcements were observed as uniformly dispersed in the matrix. However, some porosity was observed due to the poor stir casting condition in some samples. Three process parameters (1, 2 and 3%) and three sliding distances (1000, 1400 and 1800 m) were selected to conduct the wear experiments and the optimization set of parameters were obtained by carrying Taguchi analysis. From the obtained results, it was noticed that the sliding velocity is the most prominent factor that affect the wear performance.

3. OBJECTIVES AND METHODOLOGY

The objectives of the present thesis work are defined below.

- To develop hybrid composites of Al7050 by dispersing different weight fractions of TiO_2 and h-

BN as reinforcements with two different sizes (20 and 40 µm) by stir casting route.

- To investigate the role of added reinforcements on the microhardness, impact strength and tensile properties of the composites
- To study the effect of these reinforcements in different weight fractions on the wear behavior of the Al7050/TiO2/hBN hybrid composites.

3.1. METHODOLOGY

The methodology adopted to complete the defined workplan as shown in Fig 3.1 isexplained below.

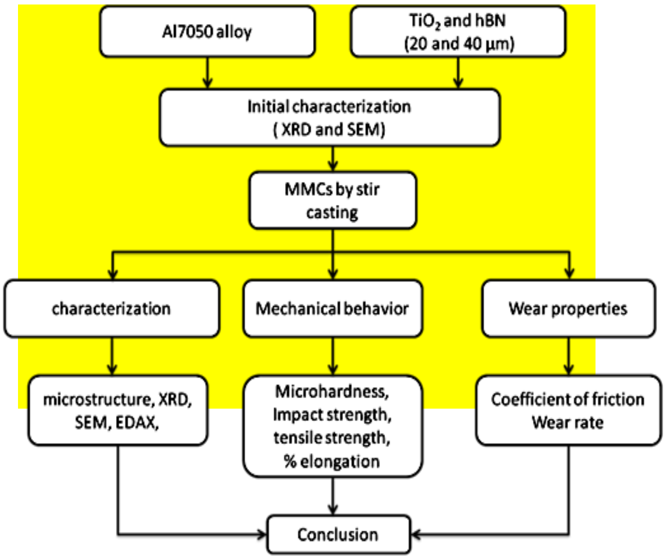

Fig 3.1 Flow chart of the work plan

4. EXPERIMENTAL DETAILS

The study materials, experimental procedures, equipment specifics, data collecting, and analysis are all covered in detail in this chapter. Every consumable and raw material used in this research project was purchased from a commercial supplier. Standard operating protocols were used for sample testing, data collection, and analysis.

4.1. DEVELOPMENT OF Al7050 HYBRID COMPOSITES

We bought billets of Al 7050 aluminium alloy from Mallinath Metals in Mumbai, India. The primary alloying ingredient in this alloy is zinc, and heat treatment can change its characteristics.

To ensure effective mixing of the molten material, a stainless steel stirrer running at 230-240 V, 50-60 Hz, and 850 watts is utilised. The molten alloy was then mixed with the warmed reinforcement particles (TiO2 and h-BN). To achieve a uniform dispersion of the reinforcing particles in the molten metal, the reinforcement particles were added one at a time and the molten mix was stirred for an additional two minutes at a speed of 250–300 rpm. The stirred molten mixture was then poured into a 100 mm x 100 mm x 10 mm steel die. The temperature reached 780 °C as the molten mixture was being poured into the die, allowing it to flow freely within the mould. Fig 4.1 presents the stir castingfurnace used to produce the hybrid composites.

Fig 4.1 Stir casting equipment

In order to understand the role of the weight fractions of the reinforcements and the size of the reinforcing particles on the composites, mechanical and wear behavior, two different sized particles of 1:2 size ratio (20 and 40 µm) were selected. By selecting different weight fractions, Al7050 hybrid composites were fabricated by adding 1, 3 and 5% by wt., TiO2 and 2, 4 and 6 % by wt., h-BN by stir casting route. The composition of the hybrid composites (% of both the reinforcements)has been selected based on the available literature (Imran et al., 2013). The weight fractions of the reinforcements added to the base alloy to develop the hybrid composites are presented in Table 4.1. Two different sizes i.e. 20 µm (S) and 40 µm (C) of reinforcements were used to produce the composites.

Table 4.1 Composites with different reinforcement sizes and their composition

Sample	Reinforcement particle size (μm)	Al 7050 (wt.%)	TiO2 (wt.%)	h-BN (wt.%)
C1	40	97	1	2
S1	20			
C2	40	95	3	2
S2	20			
C3	40	93	5	2
S3	20			
C4	40	95	1	4
S4	20			
C5	40	93	3	4
S5	20			
C6	40	91	5	4
S6	20			
C7	40	93	1	6
S7	20			
C8	40	91	3	6
S8	20			
C9	40	89	5	6
S9	20			

4.2. SAMPLE PREPARATION

For the material to be tested and characterised in accordance with the standard process, the specimen sizes should be appropriately chosen in accordance with the ASTM standard sizes. Additionally, the specimen should ideally be the right size to handle comfortably and conveniently during testing. All the specimens for the current work were prepared by wire electric discharge machining (EDM). A total of 3 samples (n=3) were used for every test to investigate the material properties. Fig 4.2 shows the wire EDM equipment.

Fig 4.2 Computer numerical controlled wire electric discharge machining and themachining chamber.

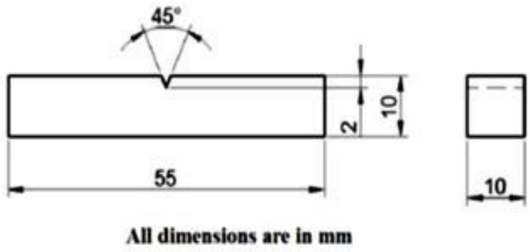

Fig 4.3 Dimensions of impact strength test sample

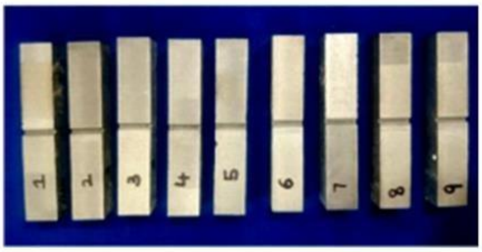

Fig 4.4 Impact test specimens

A specimen size for easy and comfortable polishing is 10 to 25 cm across the polished surface, either round or square, and approximately with 10 to 20 mm length. Hence, in the present work, samples of size 20 mmx20 mm x10 mm were cut from theproduced composites and from the base alloy.

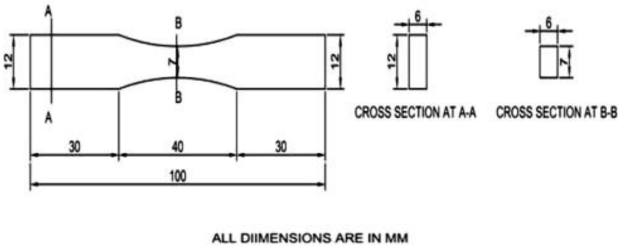

Fig 4.5 ASTM E8M04 tensile standard

Fig 4.6 Tensile test specimens.

Specimens for impact strength were prepared as per the standard dimensions for the Izod impact test. Fig 4.3 shows the impact sample standard dimensions and Fig 4.4 shows the impact test samples. Tensile specimens were prepared as per ASTM E8M04 standard. The dimensions of the tensile test specimen are presented in Fig 4.5 and Tensile test samples are shown in Fig. 4.6. The specimens were subjected to fine polishing to remove the oxide layers at the surface and also to bring to accurate cross- sectional area.

For wear studies, square pins of 10 mm x 10 mm cross section and a height of 30 mm were machined from the produced composites and used as the test specimens as shown in Fig 4.7. Wear tests were carried out by pin on disc method in which, EN31hardened steel disc was used that consists of 100 mm diameter, 8 mm thickness and a hardness of 60 HRC with a surface roughness (Ra) of 1.6 µm.

Fig 4.7 Wear specimens.

4.3. SUMMARY

Density of the composite materials was measured from the theoretical and experimental routes. Microhardness measurements were done by conducting Vicker's indentation method. Izod impact test was carried out as per the standard procedure to investigate the impact strength of the samples. Uni-axial tensile tests were conducted for all the composite materials and compared. Wear tests were carried out by using a pin on disc equipment to assess the wear characteristic of the composite in dryconditions. All the tests were carried on calibrated equipment's and measurements wherever recorded by using precision devices.

5. RESULTS AND DISCUSSION

This chapter presents the results of the research work and detailed discussion of the obtained results. The significance of the added TiO_2 and h-BN reinforcements with different weight fractions at different particle sizes (~ 20 and ~ 40 µm) in Al7050 alloy hybrid composites on mechanical and wear behavior of the developed composites is discussed.

5.1. DENSITY OF THE COMPOSITES

The density values of the composites measured form the theoretical procedure by adopting rule of mixture and also experimental method by adopting Archimedes principle are compared in Fig 5.1. The calculated porosity values are presented in Table 5.1. It is clearly observed that there is a marginal difference between the density values of the composites obtained from the theoretical and experimental procedures.

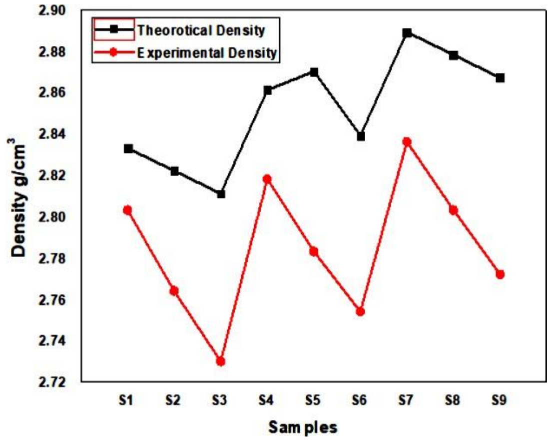

Fig 5.1 Comparison of density values of the developed composites

It can be observed that with the addition of reinforcements, the density of the composites has been gradually increased. This can be understood by considering the role of the density of the reinforced particles in the composite which is relatively higher compared with the density of the matrix.

Table 5.1 Comparison of the density values and porosity values of the composites

Sample No	ρth(g/cc)	ρexp(g/cc)	Porosity%
1	2.833	2.803	1.07
2	2.861	2.818	2.06
3	2.889	2.836	2.88
4	2.882	2.764	1.51
5	2.85	2.783	2.35
6	2.878	2.803	2.99
7	2.811	2.73	1.83
8	2.839	2.754	2.61
9	2.867	2.772	3.30

The increase in the distribution of particles in the liquid metal may cause a minor surge in porosity owing to interspaces among matrix and reinforcement material. The effect of increase in addition of reinforcement particles exhibits pore nucleation at the surface of reinforcement particles which further increases porosity of composites. The porosity percentage of the synthesized hybrid composites is observed to be less than 4% which is an acceptable limit of aluminium metal matrix composites.

5.2. MICROHARDNESS MEASUREMENT

The hardness data of the samples is compared in Fig 5.2. The base alloy hardness was measured as 75 ± 3.1 HV. Compared with the base alloy, increased hardness was noticed for the hybrid composites (Table 5.2). Composites having 40 µm sized reinforcement recorded increasing trend in the hardness values with the increased reinforcement fraction. When the reinforcement was decreased to 20 µm size, further increased hardness was noticed in the composites. Compared with the large particle reinforcements, the increment in the hardness was higher in the case of smaller particles size for both the reinforcements (TiO_2 and h-BN) and adding h-BN was observed with higher level of effect on increasing the hardness.

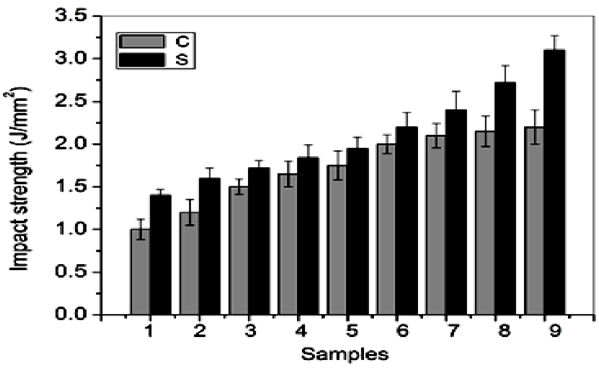

Fig 5.2 Comparison of the microhardness of the composites

Table 5.2 Microhardness mean values with standard deviation of samples with 40µm size reinforcement and 20 µm size reinforcement.

Sample 40 µm	Microhardness(HV 0.1)	Sample 20 µm	Microhardness (HV 0.1)
C1	79.2 ± 1.4	S1	86.02 ± 1.2
C2	81 ± 2.1	S2	89.91 ± 1.6
C3	83.34 ± 2.5	S3	90.06 ± 2.2
C4	85.92 ± 3.8	S4	92.45 ± 1.9
C5	86.48 ± 5.5	S5	94.86 ± 2.4
C6	88.67 ± 7.9	S6	96.34 ± 2.1
C7	89.56 ± 6.7	S7	100.66 ± 2.5
C8	92.15 ± 8.2	S8	104.54 ± 3.5
C9	95.08 ± 7.1	S9	110.7 ± 4.1

In addition, there were more variances in the hardness values between the composites with 40 µm reinforcements and those with 20 µm reinforcements. For example, the C3 sample's hardness values were lower than those of the S3 sample. The percentage of reinforcements in both samples is the same, at 5% TiO2 and 2% h-BN. All of the combinations have shown a similar pattern.

5.3. IMPACT STRENGTH MEASUREMENTS

The impact strength of the produced composites is clearly influenced by the size of the reinforcing particles. Remarkably, composites with reinforcements of varying sizes have demonstrated varying impact strengths with the same weight fraction of reinforcements (Fig. 5.3). According to the results, the impact strength of the composites was found to be greatly increased by increasing the amount of reinforcing phase (40 µm size) (Table 5.3). Additionally, the impact strength values of the composites with 20 µm reinforcements were higher than those of the composites with 40 µm reinforcements. When compared to composites with weight percentages of TiO2 (1%, 3%, and 5%), those containing 6% h-BN have demonstrated greater impact strength values. .

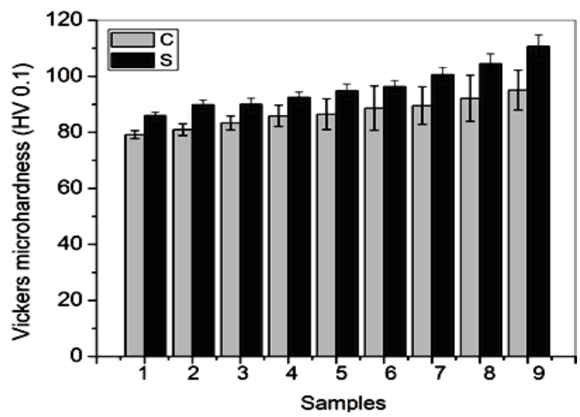

Fig 5.3 Comparison of the impact strength of the composites

Table 5.3 Impact strength mean values with standard deviation of samples with40 µm size and 20 µm size reinforcement

Sample40 µm	Impact strength (J/mm^2)	Sample20 µm	Impact strength (J/mm^2)
C1	1 ± 0.12	S1	1.4 ± 0.07
C2	1.2 ± 0.15	S2	1.6 ± 0.12
C3	1.5 ± 0.09	S3	1.72 ± 0.09
C4	1.65 ± 0.15	S4	1.84 ± 0.15
C5	1.75 ± 0.17	S5	1.95 ± 0.13
C6	2 ± 0.11	S6	2.2 ± 0.17
C7	2.1 ± 0.14	S7	2.4 ± 0.22
C8	2.15 ± 0.18	S8	2.72 ± 0.2
C9	2.2 ± 0.2	S9	3.1 ± 0.17

Ability to withstand against a sudden load is essentially a required property in the load bearing applications of automobile and other transportation applications. Presence of reinforcing particles helps to absorb more energy when the structure is subjected to a sudden load.

5.4. TENSILE PROPERTIES

From tensile samples before and after the tensile test. It is observed that the fracture was happened in the gauge length of the test specimens for all thecomposites. From the obtained data, the stress strain curves were developed and shown in Fig 5.5. From the curves, ultimate tensile strength and % of elongation values were obtained and compared.

The composites' stress-strain curves are shown in Fig. 5.5. The data clearly shows that the composites' strength has grown dramatically with the addition of reinforcements. For both particle sizes, sample S9 yields the highest ultimate strength. By preventing dislocation movement and exhibiting resistance, the hard ceramic reinforcement TiO_2 is used to increase the ultimate strength of Al 7050/TiO_2/h-BN composites through orowan strengthening.

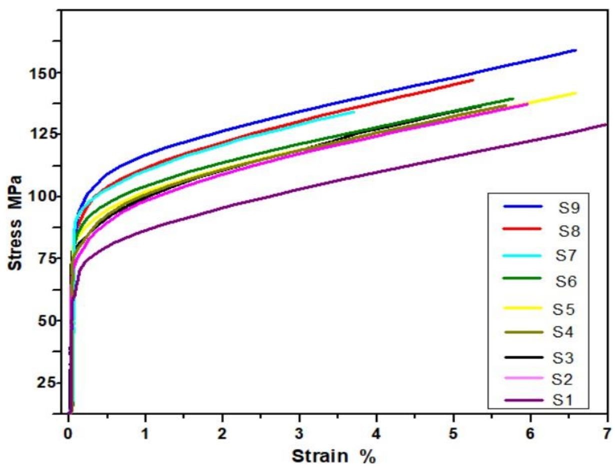

Fig 5.5 Stress-strain curves of the composites

5.5. WEAR STUDIES

From the wear studies carried out by using three samples for each type (n=3), theresults are compared in this section. The wear rate and the coefficient of friction of the samples are compared in Fig 5.6.

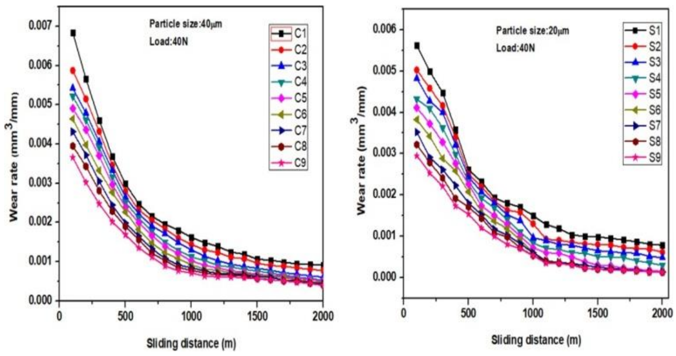

Fig 5.6 Comparison of wear rate verses sliding distance for the composites obtainedat 40 N load having two particle sizes 40 μm and 20 μm.

The composites with smaller reinforcing particles showed a tendency of reduced wear rate with increasing sliding distance under the same set of loading circumstances. For example, sample C1 (Al7050T1B2 with 40 μm reinforcement size) was reported to have a wear rate of 0.000919 mm3/m at 2000 m of sliding distance, while sample S1 (Al7050T1B2 with 40 μm reinforcement size) had a wear rate of 0.000785 mm3/m.

5.6. VALIDATING THE WEAR CHARACTERISTICS OF THECOMPOSITES BY OPTIMIZATION STUDIES

5.6.1. Regression analysis

Regression analysis was utilized in numerous investigations to determine the relationship between experimental results and control parameters as stated by Sarikaya et al.. The relationship between the change in % of composition (Al 7050 & TiO_2) of the samples 7, 8 & 9, impact of applied load and sliding distance on wear rate and coefficient of friction for 20 μm and 40 μm particle sizes were established using a first-degree mathematical model created using multi-variable linear regression analysis. As a result, control factors such as load (N), sliding distance (m) and change in % of composition (Al 7050 & TiO_2) of the samples 7, 8 & 9 were calculated.

Table 5.4 Experimental results validation

Particle Size	Level	Experiment	Regression	
			Predicted	Error(%)
20 μm (Wear Rate)	L2-SD2-S9 (Random)	0.000160	0.000150	6.67
	L1-SD1-S7 (Optimum)	0.000540	0.000528	2.27
40 μm (Coefficient of Friction)	L2-SD2-S7 (Random)	0.5868	0.583299	0.60
	L1-SD1-S7 (Optimum)	0.6309	0.629869	0.16

This study focuses on minimizing the damage resulting from wear rate and coefficient of friction with Taguchi Design. ANOVA was utilized to determine the best process parameter levels for reducing wear rate. Furthermore, utilizing the regression analysis approach, the trials with each parameter resulted in the creation of first-order mathematical models. The load has the maximum influence on the wear rate and coefficient of friction of the composite specimen, followed by sliding distance and finally the impact of change in samples (change in wt % proportion of Al7050-TiO2- hBN reinforcement) has the least influence. ANOVA findings also show that load is the most influencing factor on wear rate and coefficient of friction. Studies indicated that a combination of minimum load, minimum sliding distance, higher wt % of Al7050 and lower wt % of TiO2 should be utilized to minimize wear rate and coefficient of friction. The optimal parameters have been determined for all the tests at a lower load (20N) and with a lower sliding distance (1000 m). Regression models have shown that the experimental results are extremely reliable with statistical outcomes. Following validation trials, the evaluated value was calculated in 95 percent confidence intervals.

6. CONCLUSIONS AND FUTURE SCOPE

This chapter presents the conclusions which are drawn from the current thesis work and also propose potential research scope for the future to explore the developed hybrid composite for wide range of applications.

6.1. CONCLUSIONS

The current research work uses a stir casting method to create hybrid composites of Al7050/TiO2/h-BN with varying weight fractions of TiO2 and h-BN particles. It has been studied how the kind of reinforcing particles and their proportions affect wear resistance and mechanical performance. Additionally, by choosing two distinct reinforcing particle sizes (20 and 40 μm), the role of the size of the reinforcing particles with varied quantities in the created hybrid composites has been investigated. Wear behaviour and mechanical characteristics were examined. The experimental findings led to the following deductions.

- The composites' tensile strength was raised via reduced grain size, matrix material recrystallisation, and an orowan strengthening mechanism.
- The density of the composites was measured as increased from 2.833 g/cc to 2.867 g/cc (theoretically) and observed as decreased from 2.803 g/cc to 2.772 g/cc (Experimentally) due to the presence of porosity resulted during the composite preparation.
- The 40μm-sized sample S9 (7050T5B6) has a greater hardness of 95.08 VHN and is 26.8% better than the matrix material. Hard TiO2 particles and a higher dislocation density are the causes of the Al7050/TiO2/h-BN composites' improved hardness.
- Al 7050/TiO2/h-BN composites have a 65% higher ultimate tensile strength than the original Al 7050 alloy, and sample S9 (7050T5B6), which is 40μm in size, achieved a maximum tensile strength of 156.88 MPa.
- Because of its anti-wear qualities and high thermal conductance of h-BN particles, sample 9 shows a lower wear rate and coefficient of friction than other samples. This is because the wear rate of all the composites decreased as the sliding distance increased due to the depletion of abrasive reaction between mating surfaces. Delamination and abrasion are the main wear mechanisms in hybrid composites, according to worn morphology.
- The size of the dispersed particles played a significant influence in Al7050 hybrid composites dispersed with various fractions of TiO2 and h-BN particles with sizes of 40 and 20 μm.
- The composites showed increased impact strength and hardness, and the effect was found to be considerable when the reinforcing phases were smaller in size.
- The tensile tests showed that the higher amount of TiO2 and h-BN particles resulted in increased strength and lower ductility behaviour. The composite with 20 μm reinforcement, 5% TiO2, and 6% h-BN particles showed a higher strength of 183.77-8.1.
- According to wear studies, higher reinforcement content resulted in reduced coefficient of friction values and a decreased wear rate. The wear rate and coefficient of friction values were also shown to decrease with decreasing particle size.
- Optimisation tests showed that the load has the biggest impact on the composite specimen's wear rate and coefficient of friction, followed by sliding distance and sample composition (change in weight percentage of TiO2 reinforcement). The experimental results were shown to be very reliable with statistical results based on the regression models.

Therefore, based on the findings, it is possible to successfully create high-performing hybrid composites of Al7050-TiO2-h-BN with enhanced wear properties. Enhancing the characteristics of these hybrid composites is significantly influenced by the size of the reinforcing particles. For the development of low-weight, high-strength structures and components for automotive, aeronautical, and marine applications, smaller reinforcement sizes are preferred in order to obtain superior characteristics in hybrid composites.

6.2. SCOPE FOR THE FURTHER WORK

To increase the utility of these hybrid composites in engineering applications, more research can be done in the following areas.

Usually, machining of composite materials is challenging due to the presence of multi phases of different mechanical properties. Machining of hybrid composites is further more complex. Hence, studying the machining characteristics of these hybrid composites can be carried out as future researchwork.

Electro chemical events are also highly influenced by the chemical composition of the materials. Hence, the corrosion performance of these hybrid composites can be assessed to understand their performance in marine applications.

The response of the structures made of these hybrid composites towards the vibration absorption is not known yet. Studies on evaluating the damping characteristics of these composites can be one of the future objectives.

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