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Study on Mechanical and Tribological Characterization of Titanium Diboride (TiB₂) Reinforced Al7075 Composites by Taguchi Technique

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ABSTRACT

Three distinct titanium diboride (TiB₂) weight percentages 3%, 6%, and 9% were incorporated into Al7075-TiB₂ composites by stir casting. Al7075-TiB₂ composites' wear and mechanical characteristics were evaluated. The microstructural investigation titanium diboride verified the stable interfacial bond between the matrix and reinforcing material as well as the uniform distribution of TiB₂ particles. Superior mechanical properties were noted when comparing the 9% TiB₂ composites to the 3 and 6% TiB₂ composites. The tensile strength was increased by 11.94% for 9% TiB₂ reinforced Al composites. Dry sliding wear was measured with pin-on-disc device. Measurements of the samples' wear loss as well as coefficient of friction (COF) showed that the cumulative wear loss for each composite varied linearly with load. As seen by the optical microscope, all specimens within the prescribed tension and sliding distance appear to have oxidative wear on the worn-out surfaces of the wear mechanism. Wear rate is most affected by weight percentage TiB₂ (48.43%), followed by load (19.08%), according to the ANOVA. The wt. % of TiB₂, at 37.68%, has the biggest effect on the COF, followed by sliding distance (20.54%). Taguchi technique validates the beneficial impact of weight percentage TiB₂ on wear loss and COF. The composite reinforced with 9% TiB₂ has the finest tribological and mechanical properties.

1 Introduction

The usage of aluminum alloys in structural applications is growing rapidly, especially in the automobile, aerospace, and soil anchoring industries. These days, metal matrix composites made of aluminum are widely employed due to their exceptional strength-to-weight ratio, excellent stiffness, and exceptional resistance to wear and corrosion. Compared to traditional metals and alloys, these composites have superior mechanical, wear and corrosion resistance properties. Generally, Al₂O₃, SiC, TiC, and B₄C are a few of the ceramics that are frequently utilized as reinforcement in composites fabrications [1]. These can be employed as particles, small whiskers, long threads, or irregular or irregular. Liquid state manufacturing techniques include stir-casting, spray-casting, compo-casting, squeeze casting, and in-situ (reactive)

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manufacture. Liquid composites are used to create Aluminium Metal Matrix Composite (AMMCs). TiB_2 differs from conventional ceramic reinforcements in that it has three key properties: low density, enhanced hardness, and enhanced thermodynamic stability [2]. Because of the numerous benefits over the ex situ approach, researchers have recently concentrated on producing aluminum- TiB_2 insitu composite employing metal matrix. Better insitu manufacturing of Al alloys is made possible by the exothermic response and increased wettability between TiB_2 with aluminum. This results in improved interfaces bonding and decreased variation in the thermo-physical characteristics of the two throughout heating. Ceramics with low wettability have higher porosity, undesirable mechanical characteristics, and uneven dispersion [3]. Several investigations into the mechanical properties and strengthening techniques of $\text{TiB}_2/\text{A356}$ composites have been conducted; the results indicate significant improvements in tensile strength [4]. When researchers [5] examined the alloy's aging response when combined with TiB_2 particles, they discovered that the quantity of TiB_2 present affected the mechanical properties of the alloy. A clear distinction was found between the particle augmentation and the tensile strength of composite in research [6]. According to Zulkamal et al. [7], the addition of TiB_2 particles enhanced resistance to wear and rectified its microstructure. The mechanical behavior of $\text{TiB}_2/\text{A356}$ composites was shown to be significantly impacted by the TiB_2 particles when researcher [8] conducted the low cycle fatigue tests on the composites. The primary determinants of composites' mechanical and wear properties include sliding distance, velocity, average load, kind of reinforcement, and amount of interfacial bonding. Of all these characteristics, the size of the particles has the most beneficial impact on the composites' performance. The sliding distance, sliding speed, load applied that is placed on the type of reinforcement, and degree of interfacial bonding is the primary determinants of the mechanical and wear properties of composites. This research examines the mechanical, tribological, and physical characteristics of Al7075 MMCs reinforced with 3, 6, and 9 weight percent titanium diboride. The sole factor that improves the performance of the composites is particle size [9].

In contrast to the literature currently in publication, many studies have examined different grades of aluminum, but relatively few have examined the impact of TiB_2 % by weight on Al7075 alloy. The method of responding to surfaces with statistical tools was applied in order to identify the key factors affecting COF and wear loss. Overall, the findings indicated that Al7075- TiB_2 composite might be considered an exceptional material for applications requiring extremely robust and long-lasting components, particularly in aircraft and automotive engineering industries. The novelty of the study is to investigate the effect of TiB_2 on mechanical and wear behavior in Al7075 composites. Further, wear parameters were optimized using statistical tool to analyse the wornout surface and wear mechanism.

2 Materials and Experimental Method

The study's main objective is to investigate the wear loss and mechanical properties of stir-cast composites made of an aluminum matrix. In the present study, hybrid composites comprising a metal matrix with an Al-7075 alloy enhanced with TiB_2 were fabricated by stir casting. The alloy Al-7075 is widely utilized in marine applications and aircraft building. Table 1 displays the weight percentage of the chemical structure of Al7075. As reinforcements, 100 mesh on average TiB_2 particles were used. Metal matrix composites were made by stir casting. Stirring the basic alloy, heated reinforcement particles were combined with it. To extract the inert gases from the molten metal, a degassing tablet was utilized. Five minutes of vigorous whirling at 100 rpm was done to get the molten slurry into a heated mold. After the cast samples solidified, the cast parts were removed. Samples were pre-machined and CNC-turned in accordance with "ASTM" specifications. Test samples are depicted in Fig. 1.

Table 1 - Chemical composition of Al7075 alloy (wt. %).

Content with Wt. %	"Mg"	"Cu"	"Si"	"Mn"	"Fe"	"Ni"	"Sn"	"Pb"	"Ti"	"Cr"	"Zn"	Al: Rem
	2.303	1.482	0.057	0.051	0.252	0.053	0.011	0.021	0.053	0.285	5.420	

To provide a smooth surface finish during metallographic examinations, the composite specimens were polished using diamond grit sheets of varying diameters. After polishing, the samples were etched using a common etching chemical called Keller's reagent and left to air dry. To examine the homogeneous dispersion of the tiny particles within a matrix, a Nikon E-200 microscope was utilized. On a universal testing machine (UTM), the manufactured MMCs were put through a tension test with a 400 KN load and ASTM E8 standards (gauge diameter: 10 mm and gauge length: 50 mm). Wear

specimens for testing, measuring 30 mm in length and 6 mm in circumference, were used to assess the wear characteristics of the generated composites based on the weight loss technique concept.

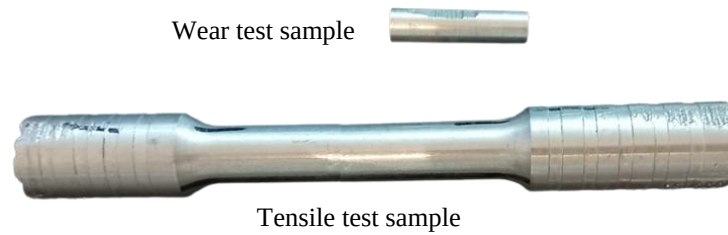


Fig. 1 - Pre-machined cast samples.

The wear test, which employed the PIN-ON-DISC technique and varied variables like a load of 10–30 N, a sliding distance of 500–1500 m, and an average speed of 2 m/s, was conducted on an EN32 steel disc. Using the standards established by ASTM G-99 criteria, the impact of wear process parameters on MMC wear characteristics was evaluated. Following each analysis, samples were cleaned, and the cumulative weights of all the specimens were calculated to within ± 0.001 g. Ultimately, the difference between the composite samples' initial and final weights was used to calculate the wear reduction.

3 Result and discussions

3.1 Microstructure Examination

Using microstructural analysis, the distribution of reinforced particulates inside the material matrix was examined. The microstructural properties of Al7075/TiB₂ composites controlled their mechanical and tribological performance. Fig. 2 shows the optical microstructure images of the composites as-cast and enhanced with 9% TiB₂.

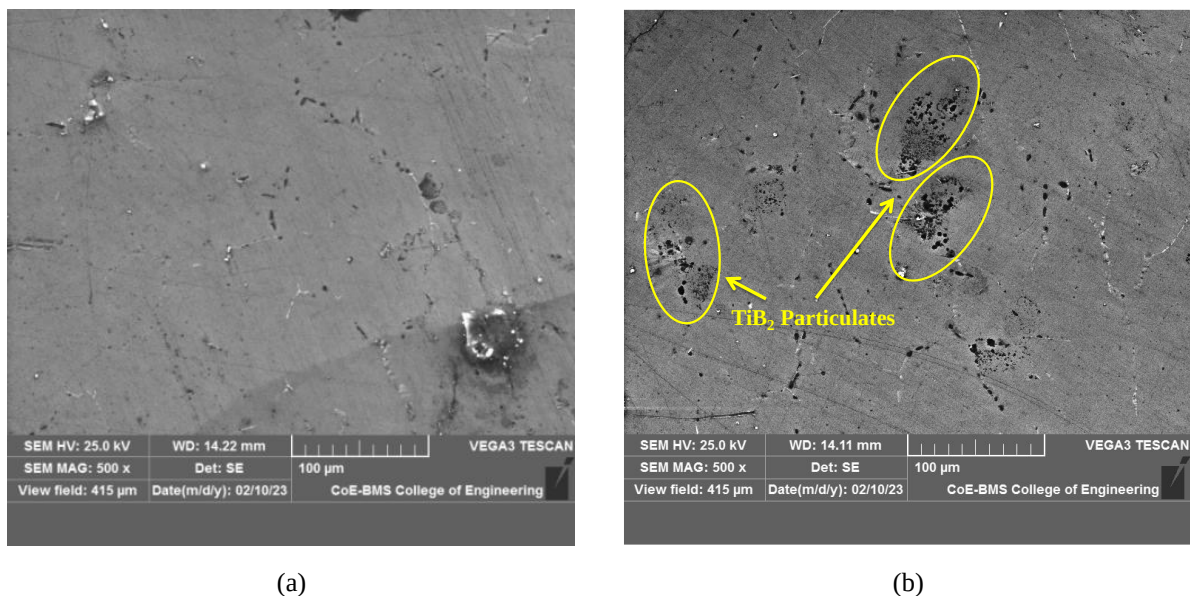


Fig. 2 - Optical microstructure images of (a) as-cast and (b) composite with 9% TiB₂.

The microstructural image displays a uniform distribution of tiny TiB₂ particles with holes in them. Stircasting method was used to fabricate the samples. Porosity could therefore not be totally removed. Furthermore, the 9% TiB₂ reinforced composite's cluster structure was clearly shown in microstructural photos. One of the main causes of the clusters' improved mechanical and tribological qualities was their increased TiB₂ concentration. The homogeneous distribution of 9% titanium diboride particulates in the base materials and the robust interfacial contact between the reinforcing material and the matrix were the primary causes of the enhanced mechanical and tribological properties of the 9% TiB₂ composite. The quantity of

hard particles causes the grain structure to change by increasing the amount of nucleation sites and providing additional obstacles to the grain fissures [10, 11].

3.2 Density and Porosity

To determine the degree of porosity, which influences the casting technique's dependability, the samples' density was examined. Equation (1) shows how reinforcements affect the density of the hybrid composite material. Archimedes' concept (the water displacement method) was used to compute the density of the composite samples.

$$\rho_{\text{exp}} = \frac{m}{V} \dots \dots (\text{kg/mm}^3) \quad (1)$$

Where, m = mass (kg) and V = volume of the test samples (mm³).

Equation (2) can be used to differentiate the theoretical (ρ_{th}) and experimental (ρ_{exp}) density values in order to calculate porosity. Because air is trapped during casting, a porosity level typically occurs in the created composites. Although porosity cannot be completely eliminated, it can be decreased by managing the casting process, which will impact the composite material's mechanical and other qualities.

$$\text{Porosity (\%)} = \left(\frac{\rho_{\text{th}} - \rho_{\text{exp}}}{\rho_{\text{th}}} \right) * 100 \quad (2)$$

The porosity and density of the Al7075 and TiB₂ composites are shown in Fig. 3. The density values of the composites are nearly parallel to one another and show a similar pattern. When reinforcements were added, densities increased. The enhanced density of TiB₂ particles may be the cause of this increase in density values [12]. The lower porosity percentage of each composite shows stronger interfacial bond among the reinforcement and matrix material. The porosity of the composite is primarily determined by two factors: improved stirring and consistent solidification.

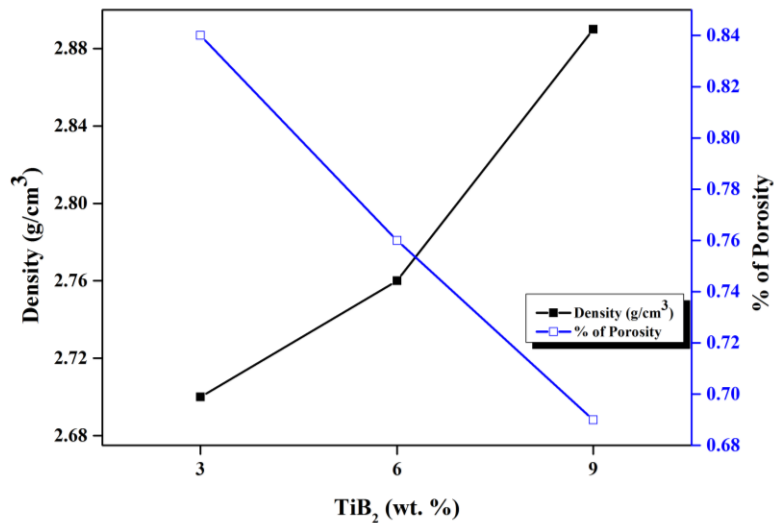


Fig. 3 - Effect of TiB₂ on density and porosity.

3.3 Tensile strength.

The test samples for the Al7075/TiB₂ composites underwent tensile testing in compliance with ASTM-E8 standards, and the outcomes are shown on a graph. The tensile strength of a composite with different proportions of TiB₂ weight is shown in Fig. 4(a). A homogeneous dispersion of hard TiB₂ particles could be one reason for the observed improvement in strength in the resultant composites. The mechanical characteristics of the created MMCs are greatly improved by hard reinforcing particles. They increase the material's resistance to deformation and tensile strength. Furthermore, hard particles extend the usable life of the resulting composites under high stress conditions by improving their fatigue and creep resistance. Since the reinforced particles handled the majority of the load, their strength increased as the weight percentage of reinforcement increased. The tensile strength of the Al7075-TiB₂ composite was noticeably higher than that of the

monolithic. The capacity of the hard particles to adhere securely to the matrix is the cause of this. Second, variations in the finished composite's coefficient of thermal expansion have an impact on the method used to strengthen it. The addition of hard TiB_2 particles to composites enhanced their strength but reduced their ductility throughout the deformation phase because they served as micro-crack initiators. Harder TiB_2 particulates are often more brittle and stronger. During deformation, the incredibly hard TiB_2 particles create two different types of microcracks. If the hard TiB_2 particulates and the matrix material have a successful interface unit, the dislocation density, strain, as well as stress all reaches critical values at large concentrations. When the matrix material placed between the two materials emerges with nucleated micro-cracks, the hard titanium diboride particles will eventually shatter if there is inadequate interfacial contact between them. Thus, weak interfaces lead to the onset of microcracks under low external stress, while strong interfaces increase the composite's strength and flexibility [13]. The tensile strength of 6 % and 9 % TiB_2 reinforced samples increased by 7.81 % and 11.94 % respectively when compared to the 3 % TiB_2 reinforced composite.

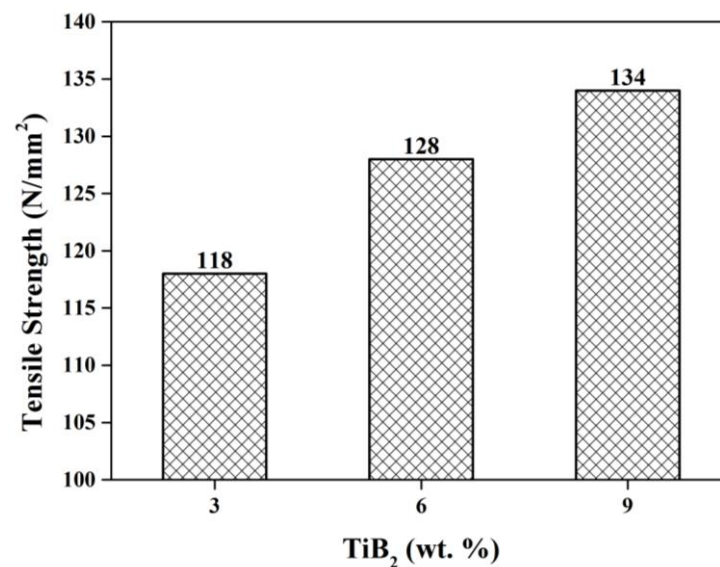


Fig. 4(a) - Influence of TiB_2 on tensile strength.

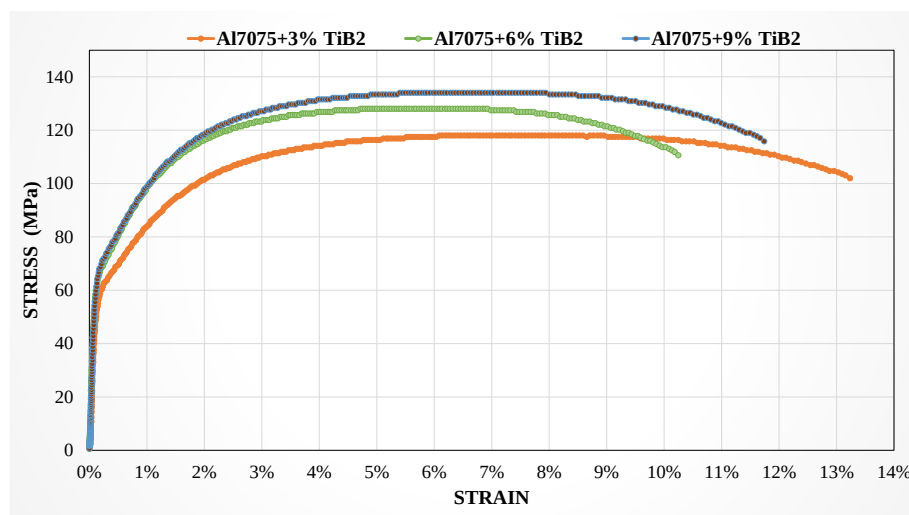


Fig. 4(b) - Stress-strain graph for the developed composites

Fig. 4(b) displays the stress-strain graph of the created composite. The main features of these curves are the increases in ultimate tensile strength and the decreases in fracture strain brought on by the increased particle content. Because of their greater tensile strength and reduced flow stresses, the developed composites show the maximum plastic strain and the lowest resistance to deformation. This is due to a variety of factors, such as particle strengthening and fine particle refining.

While the hard TiB_2 particles provide a high load bearing capacity, mismatch strengthening results in a significant increase in tensile strength.

Fig. 5 shows the fracture surface of test specimens composed of base alloy and composite materials. As seen in Fig, the fracture is mostly a dimple rupture. Overload failure and micro-void merging are the usual causes of this [14]. There is a noticeable increase in the size of the dimples in the monolithic sample. Furthermore, the broken representations of the underlying substance show the numerous cup-shaped dimples. The development and accumulation of micro-voids (grain boundaries) at particular strain zones led to the production of dimples. The 9% TiB_2 composite material's fracture picture reveals more dimples and smaller widths, which may indicate the formation of micro-voids. It requires that the reinforcements and the matrix make a strong bond. The degree to which reinforcing particles connect is often determined by their size and shape. The size of the dimples as well as the composite strength is generally precisely proportionate. Hard ceramic particles are present near the interface, as seen by the fracture surfaces of tensile test specimens. It was asserted that particle fracture and withdrawal worked together to create the fracture. As shown in Fig. 5, the matrix alloy transitioned from ductility to cleavage, with the fracture process being regulated by voids and the development and propagation of microcracks.

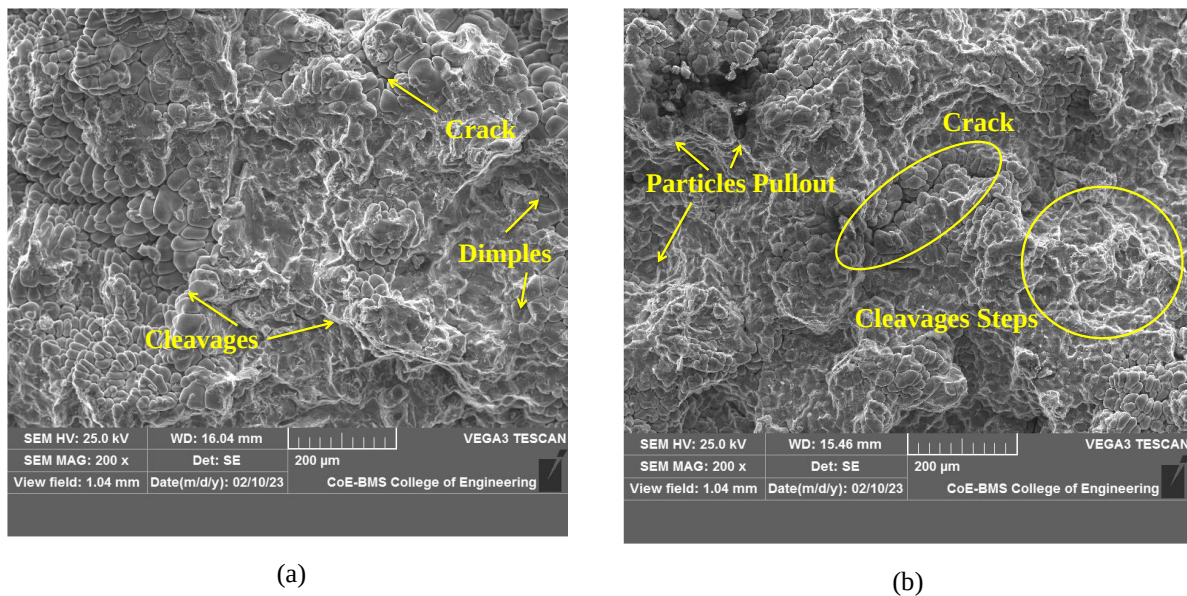


Fig. 4 - Fractured surface of (a) base alloy and (b) Al7075 reinforced with 9% TiB_2 .

3.4 Wear Behavior by statistical analysis

Evaluating the significance of the parameters used in the current investigation and the combination of factors influencing the behavior of composite wear was the main objective of the analysis. Pilot tests were used to determine each parameter's levels. The weight percentage of the reinforcements, different levels for applied load, and sliding distance were chosen to assess the wear behavior of created MMCs based on the authors' preliminary testing and literature review. The process factors employed in this study are listed in Table 2, along with the values that correspond to them. In addition to the Taguchi, analysis, or examination of L27 OA, Table 3 shows wear loss and COF responses. This shows that experimental trials were conducted on the specimens at ambient temperature (27°C).

Table 2 - Levels of parameters.

Content	Level -1	Level 0	Level +1
TiB_2 (wt. %)	3	6	9
Load (N)	10	20	30
Sliding Distance (M)	500	1000	1500

Table 3 - Experimental results of wear loss and COF for L27 OA.

Sl. No.	TiB ₂ (wt. %)	Load (N)	Sliding Distance (M)	Wear Loss (g)	COF (μ)
1	3	10	500	0.035	0.84
2	3	10	1000	0.032	0.85
3	3	10	1500	0.031	0.82
4	3	20	500	0.046	0.85
5	3	20	1000	0.034	0.85
6	3	20	1500	0.029	0.70
7	3	30	500	0.048	0.79
8	3	30	1000	0.046	0.64
9	3	30	1500	0.035	0.52
10	6	10	500	0.032	0.80
11	6	10	1000	0.025	0.72
12	6	10	1500	0.015	0.74
13	6	20	500	0.038	0.75
14	6	20	1000	0.026	0.56
15	6	20	1500	0.026	0.48
16	6	30	500	0.032	0.66
17	6	30	1000	0.034	0.55
18	6	30	1500	0.026	0.43
19	9	10	500	0.021	0.62
20	9	10	1000	0.018	0.59
21	9	10	1500	0.010	0.57
22	9	20	500	0.024	0.64
23	9	20	1000	0.017	0.52
24	9	20	1500	0.025	0.40
25	9	30	500	0.028	0.72
26	9	30	1000	0.030	0.41
27	9	30	1500	0.026	0.25

The orthogonal array architecture is displayed in Table 3. For every trial, the COF and wear behavior on weight loss were computed. The difference between the experimental and predicted values was evaluated using the loss functions of the Taguchi approach. The aforementioned loss function is demonstrated using a S/N ratio. To assess quality, three different S/N ratios were used: "smaller is better," "larger is better" and "nominally better" [15]. The "smaller is better" S/N ratio was applied to both wear loss and COF in this investigation. The experimental results for wear loss and COF values, as well as the conversion method used to calculate the S/N ratio, are shown in Table 3. To do "an analysis of variance," identify the optimal circumstances, and identify the primary component impacting wear loss and COF, MINITAB 16 application was utilized. Taguchi technique [16] served as the foundation for the analysis. The wear loss as well as COF of the metal matrix composites, as well as the outcomes of the Taguchi Technique test runs, have been graphically shown in Main Effect Plots (MEPs). These MEPs, displayed in Figs. 6 and 7, illustrate the relationship between process variables affecting wear loss and COF values for manufactured MMCs. Various factors influencing wear loss and COF in MMCs are better understood thanks to these graphical representations.

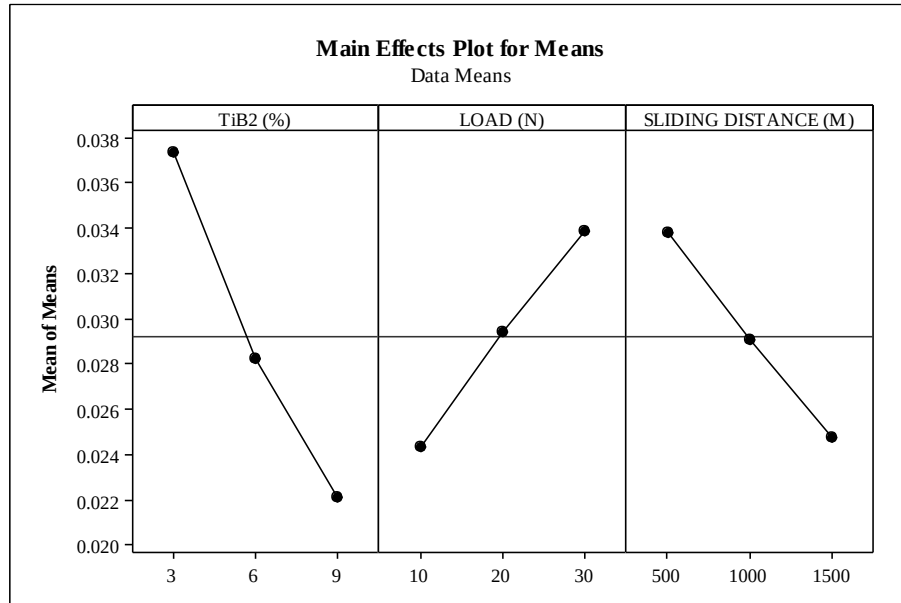


Fig. 6 - Main effect plots of wear loss for Al7075+TiB₂ composites.

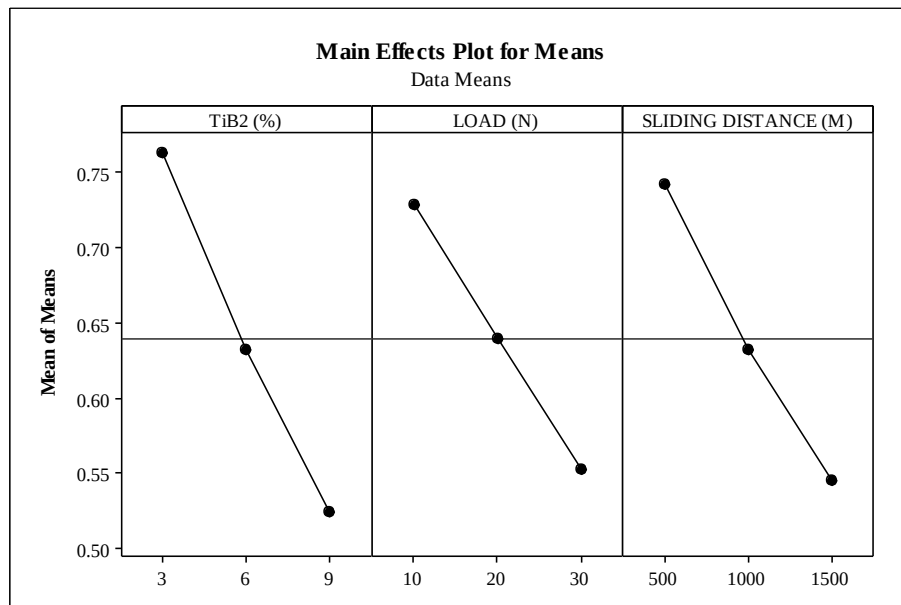


Fig. 7 - Main effect plots of COF (μ) for Al7075+TiB₂ composites.

The relationship between the weight percentage of TiB₂ and the wear loss of the manufactured MMCs is shown in Fig. 6. As the TiB₂ concentration rises, the wear rate decreases because the hardness of these composites increases in proportion to the counter disc surface. TiB₂ reinforcement can improve the mechanical, microstructural, and physical properties of the aluminum alloy. Furthermore, the addition of TiB₂ particles to the matrix alloy resulted in an increase in both matrix deformation and the number of dislocations [17]. Figure 6 illustrates how load affects the wear loss of the developed MMCs. It has been noted that the rate of wear first increases as the load increases. Since the contact pressure between the tribo-pairs has increased, the additional load later has a linear effect on the rate of increase when the load grows even further. Less material is removed from the interfaces as a result of lower loads producing less pressure. Because of the increasing material loss in the form of debris, wear rates increased as applied stress increased. Because of the greater deformation brought on by the development of high pressure between the interfaces, a higher rate of wear between the tribo-pairs is consequently seen under increased load [18]. Furthermore, Fig. 6 shows how the sliding distance influences the wear loss of the MMCs. The figure illustrates the inverse relationship between sliding distance and wear rate. Because the soft materials on the sample's surface are removed as soon as the sensitive part of the worn-out sample comes into

contact with the steel disc, a notable wear rate was observed during the first sliding phase. The hard reinforced TiB_2 particles become apparent on the surface at longer sliding distances when the matrix is eliminated. Because there are more hard particles in the matrix, the rate of wear lowers as the sliding distance increases. Because of their better bond with the matrix, the reinforcing particles' protrusion did not result in abrasion [19]. The impact of the weight TiB_2 percentage on the COF of the produced MMCs is displayed in Fig. 7. The use of very hard reinforced particles decreased the composite material's friction coefficient during the stable stage. Furthermore, as the amount of additive increases, the friction coefficient decreases more noticeably. This is because adding reinforced particles to the matrix reduced the contact area between the matrix material and the friction pair material during the friction process [19]. Fig. 7 shows how load affects the COF of the generated MMCs. It is evident that there is an inverse relationship between the measured coefficient of friction and the applied normal load, with the friction coefficient falling as the normal load increased. Additionally, it was demonstrated that the load affected the wear rate more than the friction coefficient. Discs with a greater range of reinforcement experienced more friction, highlighting the clear influence of the reinforcement's size distribution once more. Furthermore, the load's impact on wear rate was negatively correlated with its impact on its friction coefficient. A later part of this section discusses potential reasons for the inverse proportionality [18]. Fig. 7 also shows the effect of sliding distance on the COF of generated MMCs. The COF appears to diminish with increasing sliding distance (Fig. 7). At closer ranges, the solid reinforcement is the sharp asperity. This leads to dispersion stiffening across the sliding surface. Evidence of improved bonding at the matrix reinforcement interface was presented by Ferhat Gul [20].

The S/N ratio data (Tables 4 and 5) can be used to determine which control component has the biggest effect on wear loss and COF. The S/N ratios shown in Tables 4 and 5 can be used to determine the optimal wear loss and COF characteristics of these controlled variables.

Table 4 - Response Table for wear loss.

Level	TiB_2	Load	Sliding Distance
1	0.03733	0.02433	0.03378
2	0.02822	0.02944	0.02911
3	0.02211	0.03389	0.02478
Delta	0.01522	0.00956	0.00900
Rank	1	2	3

Table 5 - Response Table for COF (μ).

Level	TiB_2	Load	Sliding Distance
1	0.7622	0.7278	0.7411
2	0.6322	0.6389	0.6322
3	0.5244	0.5522	0.5456
Delta	0.2378	0.1756	0.1956
Rank	1	3	2

ANOVA was used to analyze the experiment results, ranking the significance of the factors that might have affected wear loss [21]. The ANOVA findings are shown in Tables 6 and 7. To explain the impact of COF and wear loss, we used ANOVA data. These results also provide insight into how each of these elements influences the final composites' overall wear properties. The ANOVA results shown in Table 6 make it evident how important wear loss is to the overall composite picture. The percentage of weight of TiB_2 stands out as being the most important factor among all process components, making up the largest proportion (48.43%). This lessens the significance of hard particles TiB_2 in determining wear loss. On the other hand, the least significant results were found for sliding distance (16.93%) and load (19.08%). The overall error, including several contributing factors, is 15.54 percent. Al composite materials provided higher wear resistance than traditional materials because they contained strong reinforcing particles. The relevance of the factors affecting COF was evaluated by utilizing ANOVA analysis on the investigation's findings [22]. TiB_2 particles had the highest percentage (37.68%) of all the components as shown in Table 7, indicating their significant influence on COF. On the other hand, it

was shown that sliding distance and load had the least relevance, with corresponding contributions of 25.49% and 20.54%. With a number of contributing factors being taken into account, the total inaccuracy is 16.27%.

Table 6 - Analysis of Variance (ANOVA) results of wear loss.

Sources	DOF	Seq-SS	Adj-SS	Adj-MS	F-Value	P-Value	% of Cont.
TiB ₂	1	0.0010427	0.0010427	0.0010427	71.6850	0.0000000	48.43
Load	1	0.0004109	0.0004109	0.0004109	28.2478	0.0000214	19.08
Sliding Distance	1	0.0003645	0.0003645	0.0003645	25.0586	0.0000460	16.93
Error	23	0.0003346	0.35706	0.01552			15.54
Total	26	0.0021527					99.98

Table 7 - Analysis of Variance (ANOVA) results of COF (μ).

Sources	DOF	Seq-SS	Adj-SS	Adj-MS	F-Value	P-Value	% of Cont.
TiB ₂	1	0.254422	0.254422	0.254422	53.2476	0.0000002	37.68
Load	1	0.138689	0.138689	0.138689	29.0260	0.0000179	20.54
Sliding Distance	1	0.172089	0.172089	0.172089	36.0162	0.0000040	25.49
Error	23	0.109896	0.109896	0.109896			16.27
Total	26	0.675096					99.98

Fig. 8 shows the interaction charts between the different machinability process parameters. The wear loss shows increased interaction graphs due to the strong influence of parameter interaction. The interaction charts in Fig. 9 show the factors affecting COF in addition to the sliding speed (m), applied load (N), and weight percentage for TiB₂. The impacts and combinations of each component were investigated. There hasn't been any interaction between the parameters if the interaction line on the plots is parallel. On the other hand, it shows that the variables are interacting if the plots are not running parallel to one another. The significance of every process parameter is shown by the slope on the lines in these Figs. Significant interactions between all the components result in variations of wear loss and COF levels. Through the examination of residuals generated to evaluate the model fit quality, fundamental assumptions including the applicability to the model were reviewed. The non-normality was assessed using a normal probability graph; if the framework is successful in fitting the data, its residuals ought to have less structure. A sample residual against Order chart showed how the residuals changed over time. With the residuals in the ordinate and the response in the circumferential, Residual versus Fits graph was plotted. The residuals' histogram graph can be used to assess if the data were skewed. Figs. 10 and 11 display the residual plots based on wear loss and COF value, respectively. The straight lines that represent the residuals of the usual probability plots in Figures 10 and 11 indicate that errors are spread uniformly. This shows the residuals' normal distribution and goodness-of-fit.

The significance of the variance analysis was unaffected because the data contains no outliers and the points are regularly spaced from a straight line with no signs of departures from normalcy. The non-linear relationship is typically depicted by the random pattern of the residual versus fitted values graph. Further evidence that the residual density was believed to be roughly equal comes from the fact that the residuals are evenly dispersed on both sides of the zero line. The advantages of sequential data collection are demonstrated by the residuals' lack of pattern on either side of the zero line in the residual against order graph. The histogram using standardized residual for the current study shows that the skewness is lower and that there are no outliers. Since residuals were identified from the smallest to the highest range, the results clearly show that the data gathered are extremely exact and precise [23].



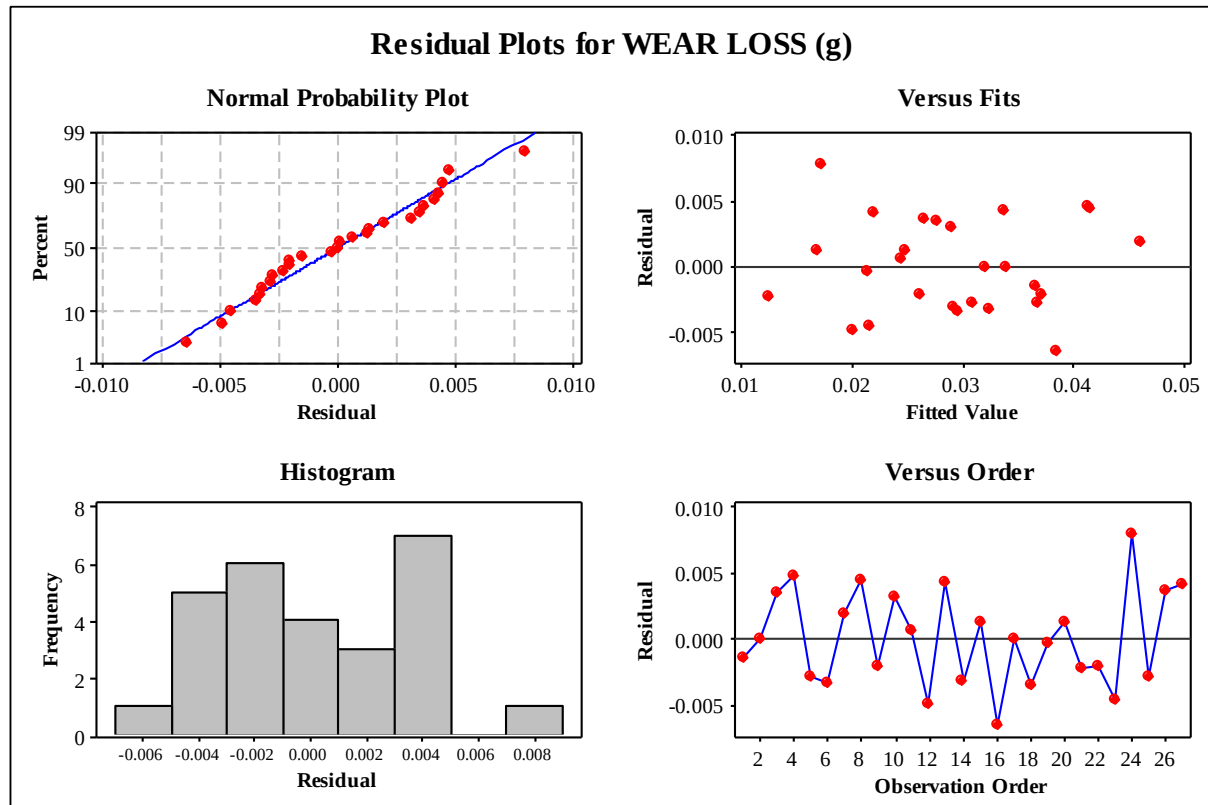


Fig. 10 - Residual plot for wear loss of Al7075+TiB₂ composites.

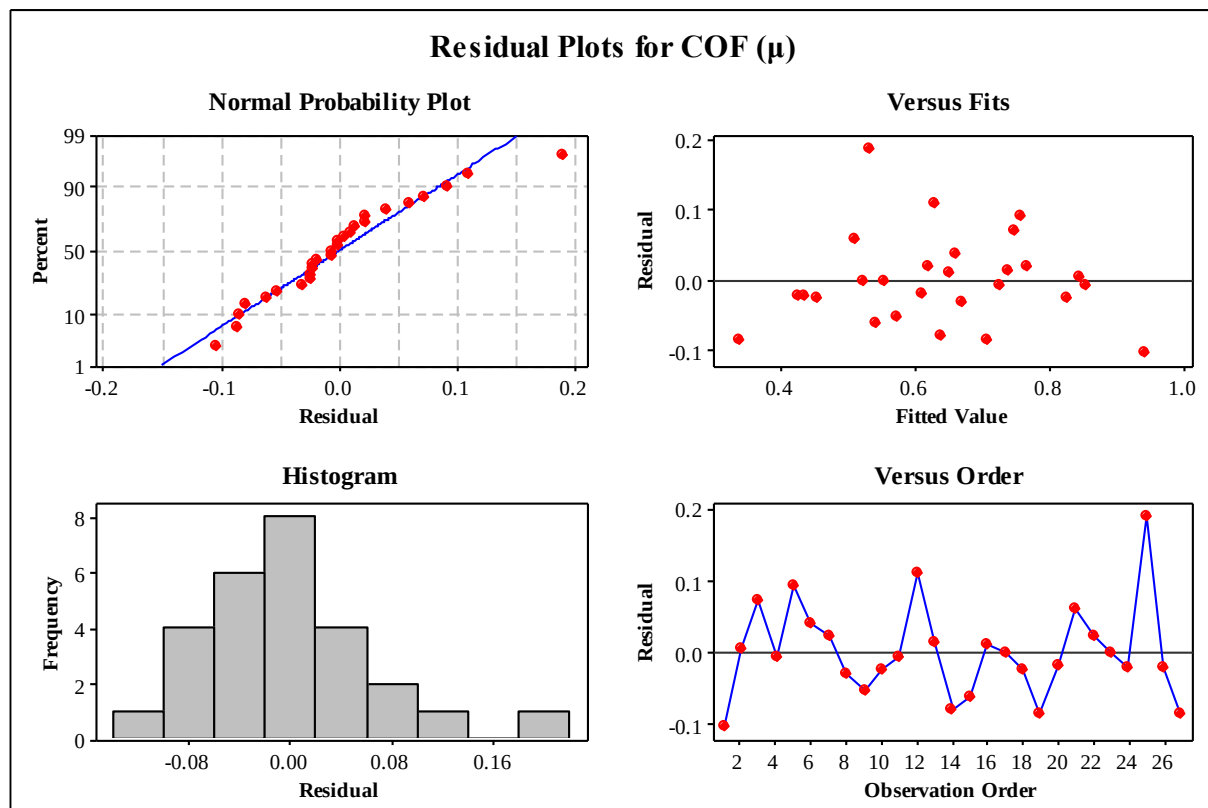


Fig. 11 - Residual plot for COF (μ) of Al7075+TiB₂ composites.

A regression model was used to predict the characteristics of MMCs [24]. Wear loss and COF values were calculated using regression equations among the parameters. The following regression equations were used to estimate the wear loss and COF values.

$$\text{Wear Loss (g)} = 0.0438889 - 0.00253704 \text{ TiB}_2 (\%) + 0.000477778 \text{ LOAD (N)} - 9\text{e-}006 \text{ Sliding Distance (M)} \quad (1)$$

$$\text{COF } (\mu) = 1.24852 - 0.0396296 \text{ TiB}_2 (\%) - 0.00877778 \text{ LOAD (N)} - 0.000195556 \text{ Sliding Distance (M)} \quad (2)$$

A number of tests were conducted to confirm the validity of the test trials, and the differences between the expected and actual experimental outcomes were visually represented. Figs. 12(a) and (b) show the experimental data points compared to the estimated values for wear loss as well as COF at each variable level. The ability to visually compare the observed outcomes with the projected values supplied by these graphical representations facilitates the evaluation of the precision and efficacy of the experimental procedures. Scientists can verify the robustness and reproducibility of the results of experiments by meticulously scrutinizing these graphs to identify any deviations or discrepancies among the expected as well as actual outcomes [25, 26].

Fig. 13 shows the Al7075-TiB₂ composites' base material and worn-out surface images. The worn-out surface image of the foundation material shows certain damaged areas, which may have an impact on the development of coarse debris [27]. Conversely, fine grooves are visible in composites reinforced with 9% TiB₂. Furthermore, it appears that the scale in these grooves becomes finer as the TiB₂ material content increases, suggesting that the existence of TiB₂ particles reduces the intensity of wear [28]. The wear debris on the worn surfaces observed in the SEM photographs illustrates the frequency of both abrasive and adhesive wear as determined by the wear research [29].

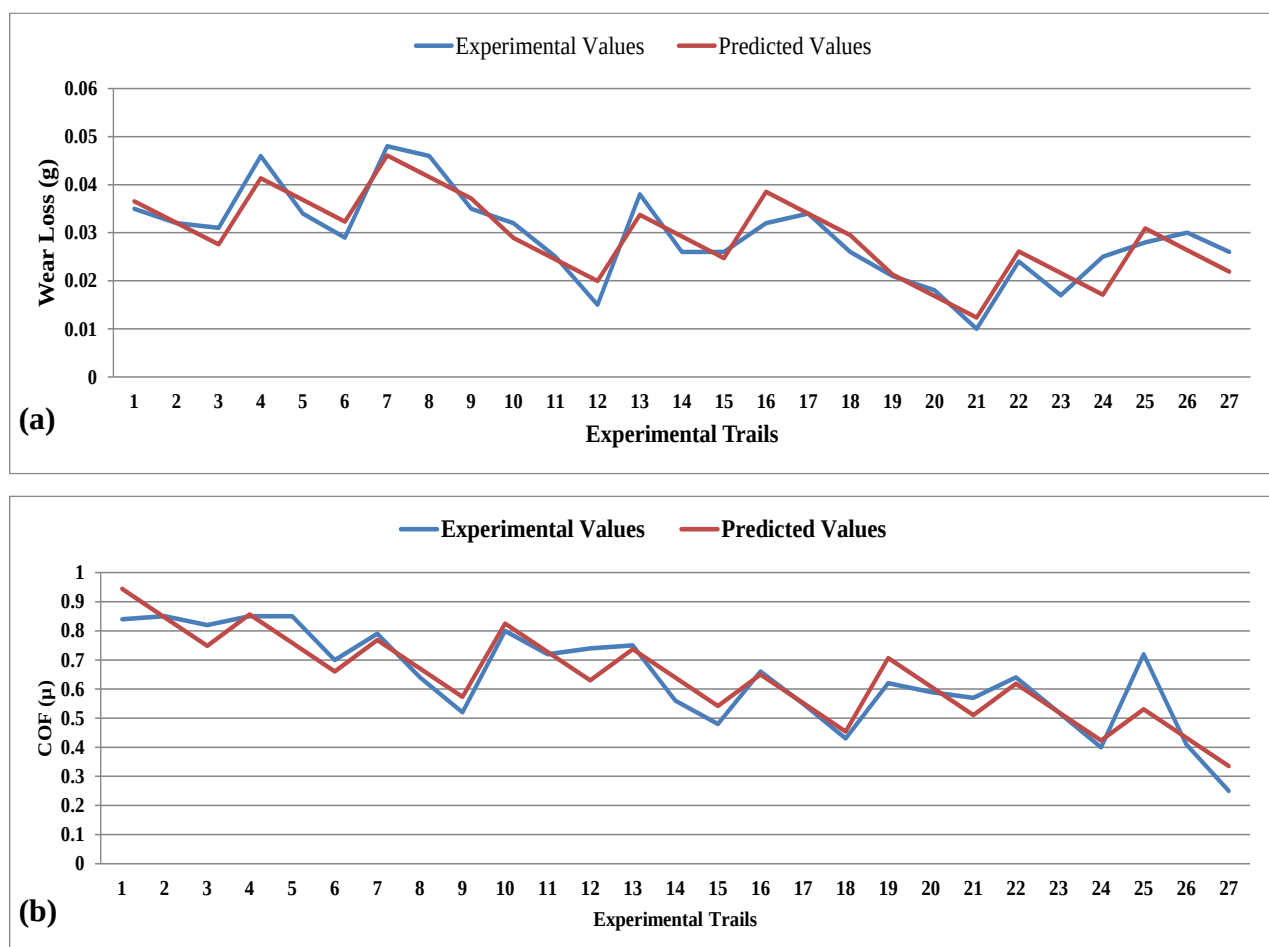


Fig. 12 - Comparison outcomes for (a) wear loss and (b) COF of Al7075+TiB₂ composites.

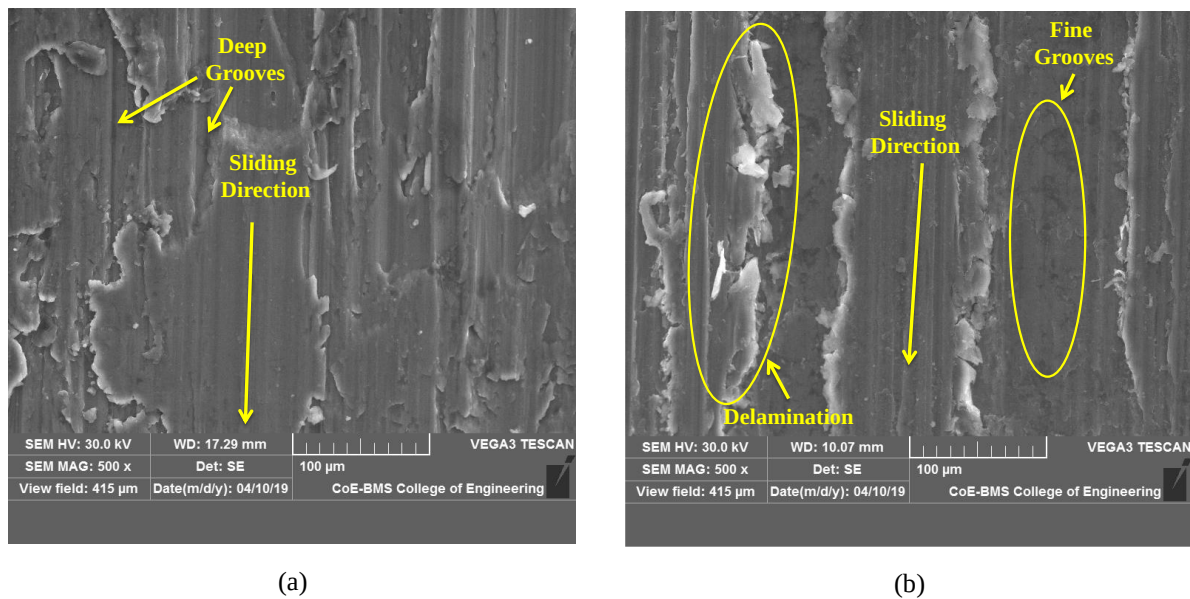


Fig. 13 - Wornout surface of (a) base alloy and (b) Al7075 reinforced with 9% TiB₂ particulates.

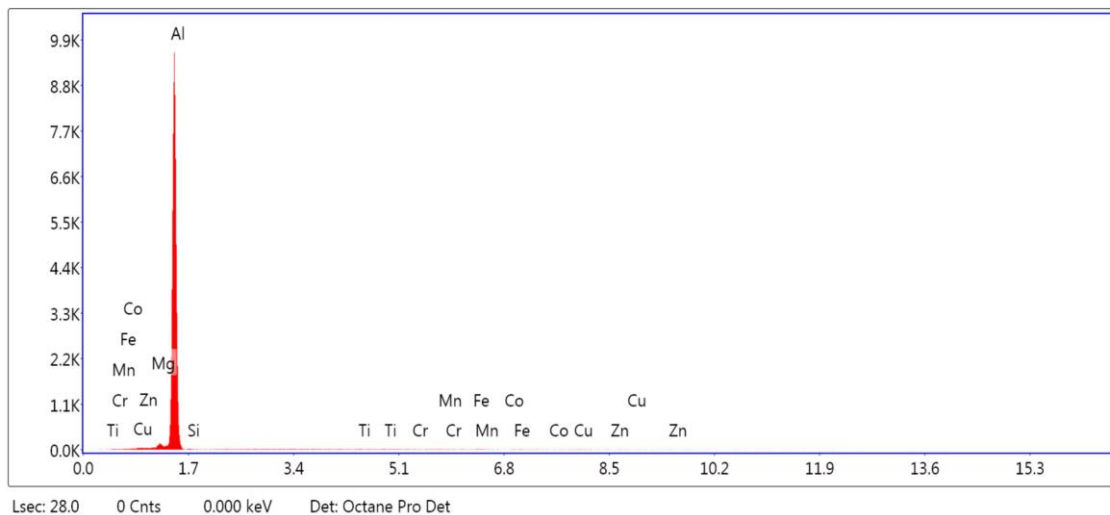


Fig. 14 - EDS spectrum of developed composites.

4 Conclusions

The following are the findings of this study on how weight percentage TiB₂ affects the mechanical and wear properties of Al7075/TiB₂ composites:

Stir casting is one of the best techniques for creating Al7075/TiB₂ composites. Strong matrix-reinforcement bonding and homogeneous reinforcement dispersion were features of all the produced composites. The microstructure demonstrates that TiB₂ is present in the matrix material in a homogeneous distribution. As the weight percentage of TiB₂ particles rose, the density values of the produced composites rose linearly. The density of 6 % and 9 % TiB₂ reinforced samples increased by 2.17 % and 4.49 % respectively when compared to the 3 % TiB₂ reinforced composite. Similarly, the porosity of 6 % and 9 % TiB₂ reinforced samples decreased by 9.52 % and 9.21 % respectively when compared to the 3 % TiB₂ reinforced composite.

The produced composites' tensile strength increased with increase in TiB₂ particles. A maximum strength of 134 MPa was achieved by composites reinforced by 9% TiB₂. The tensile strength of 6 % and 9 % TiB₂ reinforced samples increased

by 7.81 % and 11.94 % respectively when compared to the 3 % TiB₂ reinforced composite. The fracture surfaces of test specimens reveal that the fracture is generally a dimple rupture. Overload failure and micro-void merging are typically the causes of this.

Wear resistance of the produced composites reduced with increase in applied load regardless of TiB₂ content. However, wear loss of Al7075/9Wt% TiB₂ composites dropped significantly compared to the 3 and 6 Wt. % of TiB₂ composites. The ANOVA shows that weight percentage TiB₂ has the greatest impact on wear rate (48.43%), followed by load (19.08%). The largest impact on the COF is caused by the weight percentage of TiB₂, which is 37.68%, followed by sliding distance (20.54%). By examining the worn-out surfaces morphologically, the wear mechanism was determined, and it was determined that the surface had mild abrasion and delamination.

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