Journal of Mines, Metals and Fuels, *73(10): 3227-3235; 2025. DOI: 10.18311/jmmf/2025/49561*

Online ISSN : 0022-2755

Journal of Mines, Metals and Fuels

Contents available at: *www.informaticsjournals.co.in/index.php/jmmf*

Tribological Behaviour of Aluminium LM6 Reinforced with Hematite MMCs

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Abstract

The ongoing research evaluated the impact of applied load, sliding velocity, and reinforcement on the tribological behaviour of LM6 aluminium strengthened with hematite MMCs. The liquid metallurgical approach has been used to produce the composites. In steps of three weight per cent, the percentage weight of hematite particles considering series from 0wt% to 12wt%. The tribological properties of unheated and heat-treated alloys were examined using a pin-on-disc test machine. The relationship between the wear rate and applied load and sliding velocity was investigated. Using a scanning electron microscope, the wear surface morphology and pin wear behaviour were examined.

Major Findings: *Key influencing factors like the effect of applied load, effect of sliding distance, effect of reinforcement on wear characteristics and SEM analysis of worn-out surfaces.*

Keywords: *Al LM6, Hematite, Stir Casting*

1.0 Introduction

Composite materials are the most inventive and versatile engineering materials, used extensively in infrastructure, automotive, aircraft, healthcare and military industry. Various methods can produce composites depending on the reinforcement and morphology[1,2]. Metal Matrix Composites (MMC) are made using a wide range of techniques, including liquid infiltration, squeeze casting, stir casting, spray deposition, and powder metallurgy[3,4]. The composites demonstrated improved resilience to wear and hardness, along with reduced density[5,6]. Under atmospheric pressure, metal borides, nitrides, and oxides are distributed throughout the molten matrix as reinforcement during the method of stir casting[7,8]. For the progress of MMC with a greater volume proportion of reinforcement at lower pressure, the liquid metallurgical process is employed[9,10]. According to reports from the most recent studies, the homogenous mixture can be created by using the appropriate processing parameters, including the temperature, speed, and stirring time of the molten metal[11,12]. The desired amount and dispersal of reinforcement elements, the matrix alloy and its intended use all influence the choice of an appropriate engineering technique[13,14]. Al 7075 and 6061 are the most often used aluminium alloys as matrix materials for creating MMCs because of their excellent qualities and aspects of formability and the option of modification of strength of composite through heat treatment[15,16]. The mechanical characteristics and wear of MMCs are significantly influenced by the reinforcement's particle size[17] . Compared to traditional alloys, the inclusion of

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ceramic particles such as AlN, SiC, Al2O3, B4C, etc, increases wear resistance and the strength-to-weight ratio[18]. The study aims to observe the impact of heat treatment on the wear characteristics of aluminium LM6 composites reinforced with hematite particles based on the aforementioned concerns.

2.0 Experimentation Procedure

2.1 Preparation of Composite Materials

Hematite was employed as a reinforcing element, and aluminium LM6 alloy was used as a matrix to create composites. The matrix materials and reinforcement composition of chemicals is revealed in Table 1 and 2. In addition to having high thermal and physical properties and adequate interfacial adhesion without any interfacial reaction, hematite was more compatible with aluminium. As reinforcement, hematite with a mean particle size of 90–150 µ µm was utilised. The composite material was prepared using the liquid metallurgical technique. Hematite particle weight percentages are selected in increments of 3 weight per cent, ranging from 0 weight per cent to 12 weight per cent. In an electrical resistance furnace, the Al LM6 alloy was melted to 750°C while being constantly agitated at 550rpm. After being heated to 400°C, the hematite particles were added to the Al LM6 alloy's molten metal. Lastly, constant stirring is conducted to enhance the wetting between the matrix and reinforcement.

3.0 Specimen Preparation

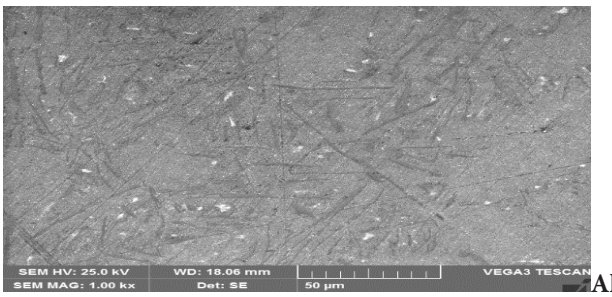
The T6 heat-treated specimens were made in accordance with ASTM G99-95 requirements. They were polished metallographically and machined to pin size, measuring 8mm in diameter and 30mm in height.

Table 1. The matrix material's chemical composition

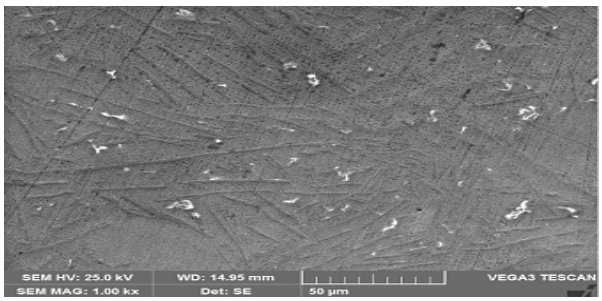
Fe_2O_3	FeO	SiO_2	Al_2O_3	MnO	TiO_2	ZnO	CuO	MgO	P_2O_5	S
92.6	0.44	2.28	1.35	0.01	0.07	<0.01	<0.01	0.11	0.02	0.001

Table 2. Reinforcement chemical composition

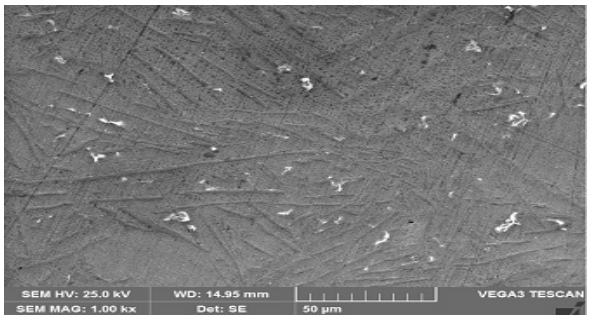
Fe_2O_3	FeO	SiO_2	Al_2O_3	MnO	TiO_2	ZnO	CuO	MgO	P_2O_5	S
92.6	0.44	2.28	1.35	0.01	0.07	<0.01	<0.01	0.11	0.02	0.001



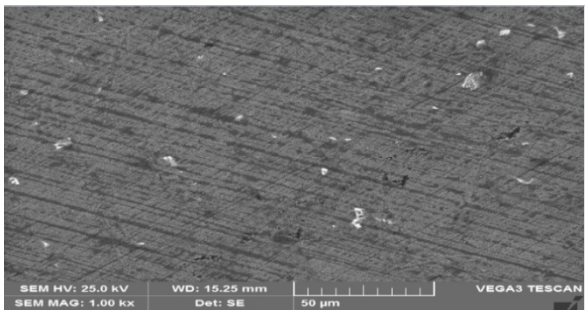
Al LM6+0% Composite



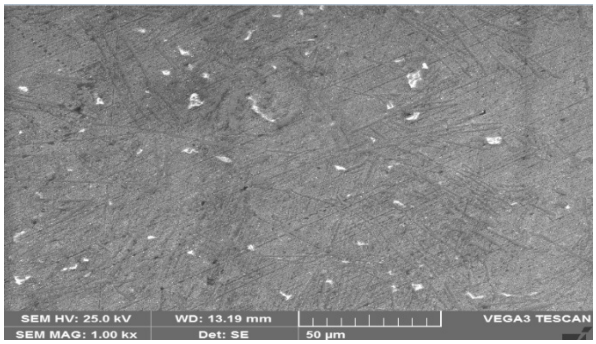
Al LM6+3% Composite



Al LM6+6% Composite



Al LM6+9% Composite



Al LM6+12% Composite

Figure 1. SEM investigation of AL Lm6 alloy and hematite reinforcement composition.

4.0 SEM Analysis

By using a killer's agent to etch, a typical metallographic process is used to do the microstructural investigation. The equal distribution of hematite particulate and minimum porosity components of the composite is evident from the optical micrograph of Al LM6-Hematite particulates of varying weight %, as illustrated in Figure 1.

5.0 Wear Characteristics

5.1 Effect of Reinforcement

The Table 3 indicate with a continual load of 40N, a sliding velocity of 2 m/s, with a steady sliding distance of 1000m. Figure 2 displays the wear rate based on by reinforcement's effect on as-cast, heat-treated composites for different weight percentages of reinforcement carried.

Table 3. Slide velocity (2m/s), distance (1000m) and load (40N) wear loss before and after heat treatment

Sl No	% Reinforcement	Un heat treated wear rate	Heat treated wear rate
1	0	0.00357	0.00335
2	3	0.00342	0.00331
3	6	0.00328	0.00327
4	9	0.00315	0.00311
5	12	0.00310	0.00305

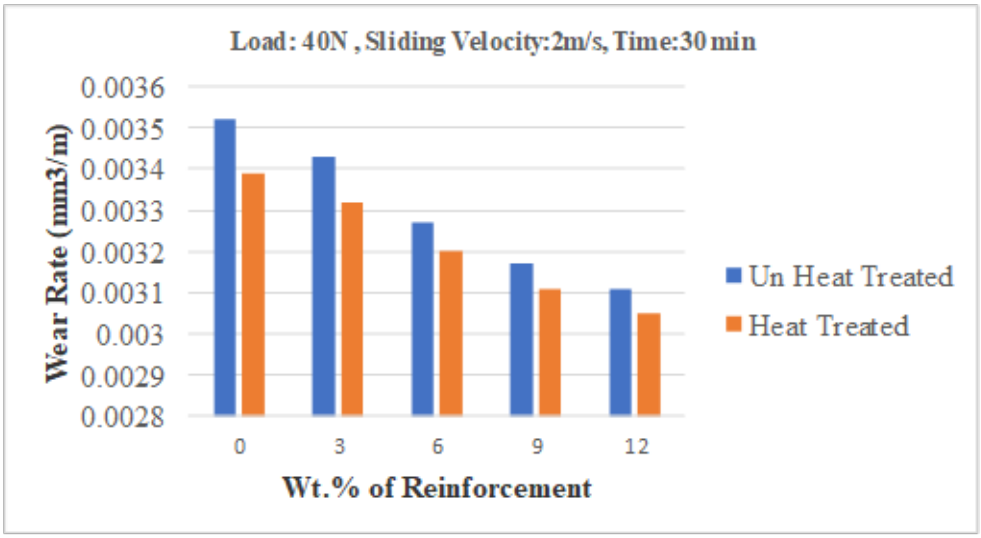


Figure 2. Effect of reinforcement on the wear rate of Al LM6 and its composites.

A mixture of heat treatment and extra matrix improving has been found to diminish the composite's wear rate.

5.2 Effect of Applied Load

The Table 4 and 5 indicates Ssamples under various load circumstances, ranging from 10 to 40N, a consistent

Table 4. Sliding distance (1000m), sliding velocity (2m/sec) and time (30min) wear loss of un heat treated specimens

Sl No	Applied load	% of Reinforcements				
		0	3	6	9	12
1	10	0.0026	0.0023	0.0019	0.0015	0.0013
2	20	0.0029	0.0026	0.0022	0.0017	0.0011
3	30	0.0035	0.0031	0.0028	0.0022	0.0018
4	40	0.0041	0.0038	0.0034	0.0031	0.0029

Table 5. Sliding distance (1000m), sliding velocity (2m/sec) and time (30min) wear loss of heat-treated specimens

Sl No	Applied load	% of Reinforcements				
		0	3	6	9	12
1	10	0.0022	0.0018	0.0015	0.0013	0.0011
2	20	0.0022	0.0021	0.002	0.0015	0.0012
3	30	0.0028	0.0022	0.0021	0.0019	0.0017
4	40	0.0033	0.0031	0.0028	0.0025	0.0021

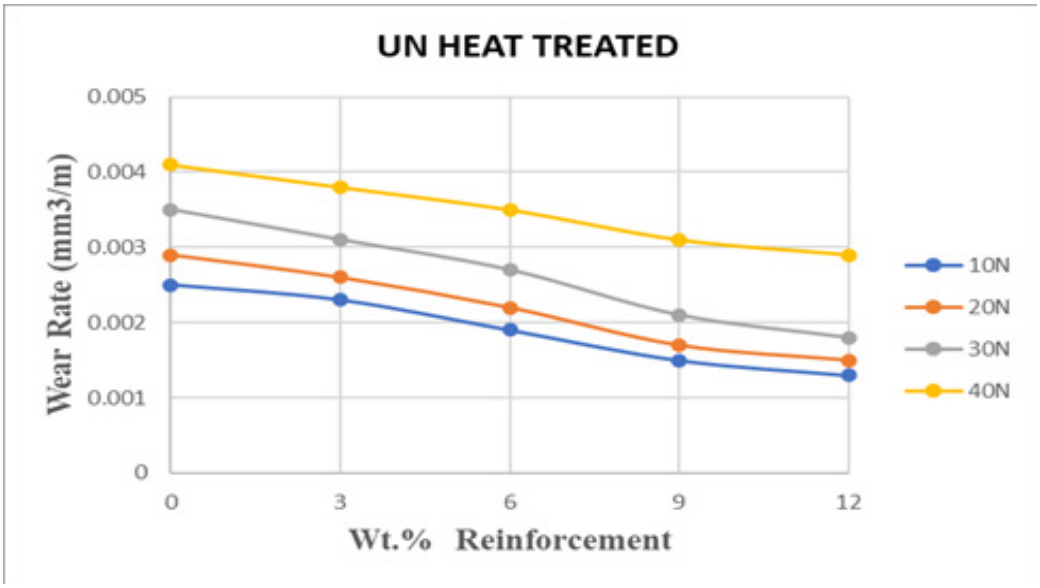


Figure 3. Variation of wear rate at different loads Un heat treated Al LM6 alloy and its composites.

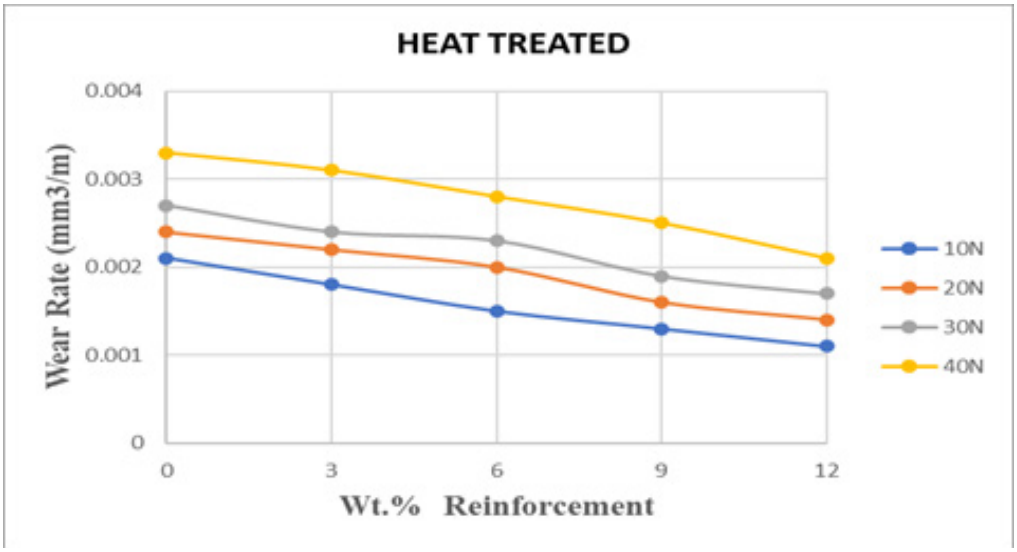


Figure 4. Variation of wear rate at different loads of Heat-treated Al LM6 alloy and its Composites.

sliding distance of 1000m and sliding velocity of 2m/s for both unheated and heat-treated conditions are revealed in Figures 3 and 4. As the weight increases, the composites' wear rate also increases in both unheated and heated conditions.

5.3 Effect of Sliding Velocity

The Table 6 and 7 indicates sliding velocity increases from 1m/s to 4m/s for a 40N applied load, and a continual sliding distance of 1000m is maintained. the rate of wearing of the Al LM6 alloy and its composites

Table 6. Sliding distance (1500m), applied load (40N) and time (30min) wear loss of un heat-treated specimens

Sl No	Sliding distance (m/s)	% of Reinforcements				
		0	3	6	9	12
1	1	0.0052	0.0047	0.0044	0.0042	0.004
2	2	0.005	0.0046	0.0042	0.004	0.0036
3	3	0.004	0.0042	0.004	0.0036	0.0035
4	4	0.0043	0.004	0.0038	0.0033	0.0034

Table 7. Sliding distance (1500m), applied load (40N) and time (30min) wear loss of heat-treated specimens

Sl No	Sliding distance (m/s)	% of Reinforcements				
		0	3	6	9	12
1	1	0.0049	0.0045	0.0042	0.004	0.0038
2	2	0.0047	0.0044	0.004	0.0039	0.0037
3	3	0.0044	0.004	0.0038	0.0035	0.0034
4	4	0.0043	0.0039	0.0037	0.0034	0.0032

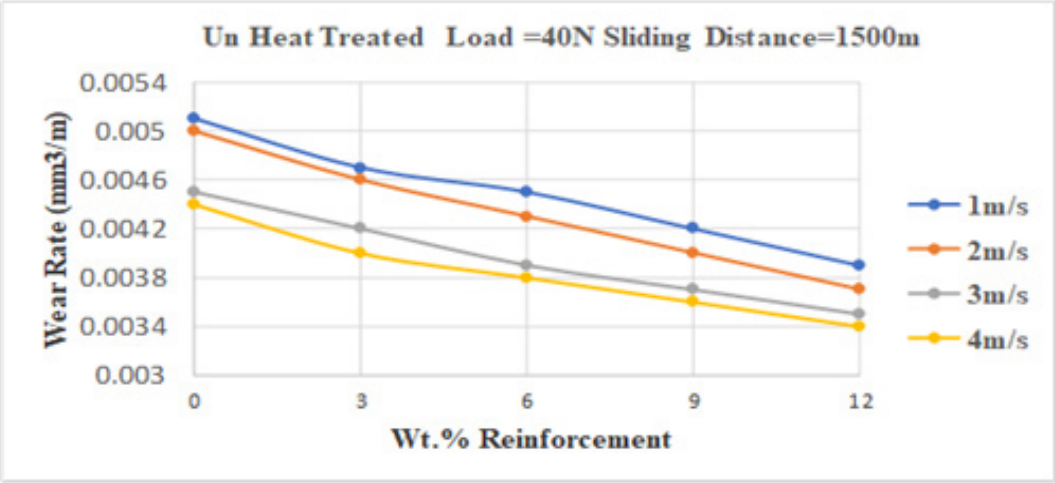


Figure 5. Variation of wear rate at changed sliding velocity of Un heat-treated Al LM6 alloy and its composites.

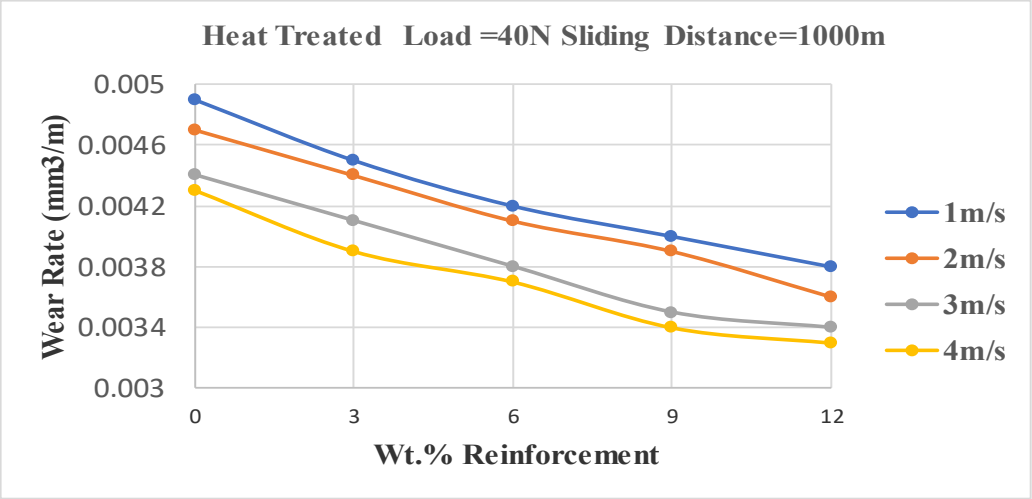


Figure 6. Variation of wear rate at changed sliding velocity of heat-treated Al LM6 alloy and its composites.

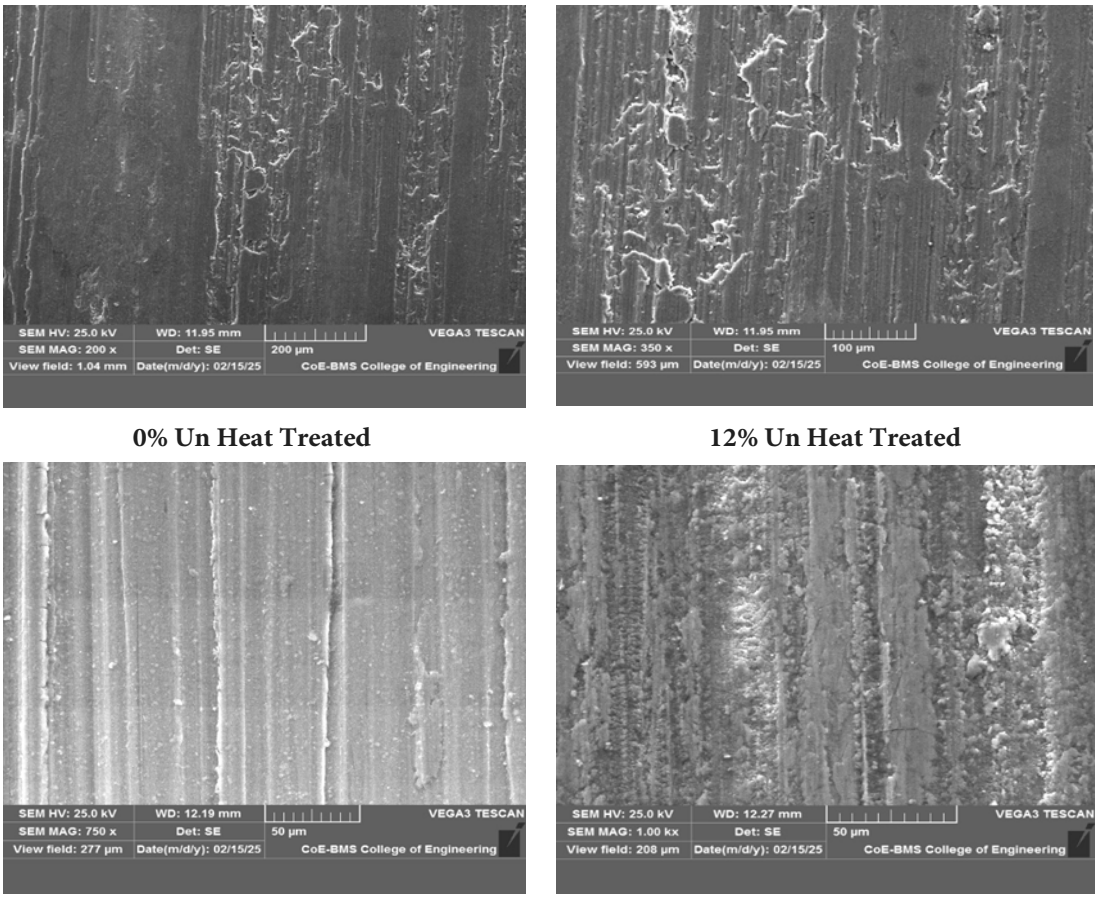


Figure 7. The worn surface SEM analysis of unheated and heat-treated Al LM6-hematite MMCs.

in the unheated conditions decreases, as revealed in Figures 5 and 6. Additionally, the rate of wearing of the unheated condition is larger compared to the solutionised alloys and their derivatives. Finally, as the sliding velocity is increased, the lowest wear rate is observed.

6.0 SEM Analysis of Worn-Out Surface

Figure 7 displays the worn structures of Al LM6-hematite. Both unheated and heat-treated Al LM6 alloys deteriorate due to plastic deformation. The heat-treated composite had a lower wear rate than the unheated composite, and the Scanning Electron Microscopy (SEM) confirmed that the heat-treated alloy had less groove formation during wear testing.

7.0 Conclusion

- Stir casting was used to produce Al LM6-Hematite reinforced composites.
- As the amount of hematite reinforcement particles in the Al LM6 matrix alloy increased, correspondingly, the resistance to wear of dry sliding improved.
- The matrix alloy, as well as its derivatives, deteriorated quickly as the applied load rose. When compared to unheated composites, the rate of wearing was greatly reduced by the heat treatment approach.
- As the sliding velocity rose, the rate of wear of the heat-treated alloys and their composite decreased.

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