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Study on Tribological Performance of Nano Particle Reinforced Metal Matrix Composite

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ABSTRACT

Metal matrix composites (MMCs) have gained significant attention in various engineering applications due to their enhanced mechanical and tribological properties. In recent years, the incorporation of nanoparticles into the metal matrix has emerged as a promising approach to further improve the performance of MMCs. This study aims to investigate the tribological performance of nanoparticle-reinforced metal matrix composites. To evaluate the tribological performance, a series of experiments are conducted using a pin-on-disk tribometer under controlled test conditions. The tribological parameters, such as friction coefficient and wear rate, are measured and compared between the nanoparticle-reinforced MMCs and the conventional metal matrix composites. The influence of factors such as load, sliding speed, and temperature on the tribological behavior is also investigated. In addition to experimental investigations, characterization techniques such as scanning electron microscopy (SEM) and energy-dispersive X-ray spectroscopy (EDS) are employed to analyze the worn surfaces and understand the wear mechanisms. The microstructural analysis provides insights into the interaction between the nanoparticles and the metal matrix, as well as their role in improving the tribological performance. The results of this study will contribute to the understanding of the tribological behavior of nanoparticle-reinforced metal matrix composites. The findings will help in optimizing the composition and processing parameters to achieve superior tribological properties in various engineering applications, including automotive, aerospace, and manufacturing industries.

Keywords: Metal matrix composites, nanoparticles, tribological performance, friction coefficient, wear rate, wear mechanisms, scanning electron microscopy, energy-dispersive X-ray spectroscopy.

I. INTRODUCTION

Metal matrix composites (MMCs) have garnered significant interest in recent years due to their unique combination of properties, including high strength, stiffness, and thermal conductivity. These composites consist of a metal matrix reinforced with various types of particles or fibers. The incorporation of nanoparticles as reinforcements in MMCs has emerged as a promising strategy to further enhance their mechanical and tribological performance.

Tribology, the science of studying friction, wear, and lubrication, plays a crucial role in the performance and reliability of engineering systems. In many applications, such as automotive engines, aerospace components, and industrial machinery, the tribological properties of materials are critical for ensuring efficient operation and minimizing wear-related failures. Therefore, there is a growing demand for developing MMCs with improved tribological characteristics.

Nanoparticles, with their unique size-dependent properties and high surface area-to-volume ratio, offer several advantages as reinforcements in MMCs. They can interact with the metal matrix at the atomic and molecular level, leading to enhanced mechanical and tribological properties. For instance, nanoparticles can strengthen the metal matrix, improve its hardness, and reduce friction and wear.

The incorporation of nanoparticles into the metal matrix can alter the contact behavior at the sliding interface, modify the wear mechanisms, and influence the transfer film formation. The choice of nanoparticles, their concentration, and the fabrication technique used to prepare the MMCs can all have a significant impact on the tribological performance. Therefore, a systematic investigation is required to understand the effects of nanoparticle reinforcement on the tribological behavior of MMCs.

The aim of this study is to explore the tribological performance of nanoparticle-reinforced metal matrix composites. Through a comprehensive experimental investigation, we will evaluate the influence of various factors, such as nanoparticle type, concentration, applied load, sliding speed, and temperature, on the tribological properties of these composites. Additionally, microstructural analysis techniques will be employed to examine the worn surfaces and elucidate the underlying wear mechanisms.

The findings of this study will provide valuable insights into the tribological behavior of nanoparticle-reinforced MMCs and contribute to the development of advanced materials with superior tribological performance. These materials can find wide-ranging applications in industries where friction, wear, and energy consumption need to be minimized, leading to more efficient and durable mechanical systems.

II. RELATED WORKS

Amal E Nassar et al [1]. The journal of King Saud University engineering Science. Pure aluminum Nano composite reinforced with Nano titanium dioxide was produced by powder metallurgy route.

Ganesh raja I et al [2]. International Journal of Applied Engineering Research. Characterization of Al based MMC with TiO_2 and TiC reinforcement using powder metallurgy technique. Addition of small amounts of TiO_2 and TiC in Al matrix increased hardness, density and wear resistance.

Maninder Singh et al [3]. Universal Journal of Mechanical Engineering. Fabrication of Al based MMC with TiO_2 and SiO_2 reinforcements using stir casting methods. In this research work, different composite materials with different proportions of silicon oxide/titanium oxide reinforcement particles have been successfully fabricated and the following conclusions have been made.

Padmanabhan K K et al [4]. International Journal of Pharmaceutical Studies and Research. Study the mechanical properties of cast aluminium alloy composite containing TiO_2 particle of size 30-50 pm and of contents ranging from 0% to 20% by weight using vortex method. The aim of this paper is to focus on the effect of cryogenic treatment on the microstructure, mechanical and wear properties of Al 6061 and Al 8011.

Padmavathi K R et al [5]. International Journal of Engineering and Technology (IJET). Metal Matrix Composites (MMCs) have a prospective for improved wear resistance over the unreinforced alloy and are the most capable in achieving enhanced mechanical properties.

Ramesh C S et al [6]. the wear journal. Prediction of wear coefficient of Al6061 with maximum of 10% of nano TiO_2 matrix composite prepared by liquid metallurgy method.

Ravichandran M et al [7]. SSRG International journal of Mechanical Engineering. The Al–TiO2 composite was successfully synthesized through powder metallurgy technique and the forming behavior during cold upsetting under plane stress conditions was studied.

Siddesha S et al [8]. International Journal of Applied Engineering Research. Prediction of mechanical characteristic on aluminium based
reinforcement with SiC and TiO2. The tensile strength, flexural strength of the aluminium metal matrix composite has improved in aluminium reinforcement.

Simon C Tung et al [9]. Tribology International. This keynote address will provide a comprehensive overview of various lubrication aspects of a typical power train system including the engine, transmission, driveline, etc., as well as the integration of these lubrication and surface engineering concepts into a unified automotive power train system.

III. EXPERIMENTAL PROCEDURE

3.1 MATERIAL

The material used in the composite material is divided into two categories, they are matrix and the reinforcement. Here we use the following materials for the specimen perpetration

1. Aluminium
2. Titanium Dioxide

The specimen is made in different ratio based on the literature survey made. The specimen is made in 4 different compositions with the varying percentages by weight. The following table represents the various ratios of the aluminium and titanium di oxide

Table 1: Combination of composite

PERCENTAGE	COMPOSITION IN % BY WEIGHT	
	ALUMINIUM	NANO TiO_2
S1	95	5
S2	90	10
S3	85	15
S4	100	0

3.2 SPECIMEN

The specimen was prepared to undergo a tribological test on pin on disc tribometer. The preparation of pin was done using a die set. The diameter of the pin is 10 mm and the minimum height was 25 mm. powder metallurgy technique was adopted in fabricating specimens.

The various steps involved in specimen preparation are as follows:

3.2.1 Blending of powder

The blending process is done by ball milling method. A ball milling is a type of grinding cylindrical device used to grind and blend materials. Different materials are used as media, including ceramic, flint pebbles and stainless steel . An internal cascading effect reduces the material to a fine powder. Industrial ball mills can operate continuously fed at one end and discharged at the other end. Large to medium-sized ball mills are mechanically rotated on their axis, but small ones normally consist of a cylindrical capped container that sits on two drive shafts. It works on the principle of impact and attrition. The ball size ranges from 10 mm and the milling is done for 1 hour at the speed of 300 r.p.m.

3.2.2 Compaction

Powder compaction is the process of compacting metal powder in a die through the application of high pressures. Typically the tools are held in the vertical orientation with the punch tool forming the bottom of the cavity. The powder is then compacted into a shape and then ejected from the die cavity.

The principle goal of the compaction process is to apply pressurize and bond the particles to form a cohesion among the powder particle which is termed as the green strength. It is done at the room temperature and at the high pressure. The measured amount of aluminium and nano titanium di oxide powders is taken in the die cavity and applying pressure. The compaction was done in the universal testing machine with a pressure of 8.5 MPa (85 bar).

3.2.3 Sintering

Sintering involves raising the temperature of the green compact, to a certain level and keeping it at that temperature for a certain amount of time. The sintering temperature is usually between 70% and 90% of the melting point of the powder metal. Sintering occurs by diffusion of atoms through the microstructure. This diffusion is caused by a gradient of chemical potential atoms move from an area of higher chemical potential to an area of lower chemical potential. The different paths the atoms take to get from one spot to another are the sintering mechanisms.

3.3 TESTING PROCEDURE

The tribometer is an instrument that measures tribological quantities, such as coefficient of friction, frictional force and volume, between two surfaces in contact. This machine or device is used to perform test and simulations of wear, friction and lubrication which are the subject of the study of tribology. A pin on disc tribometer consists of a stationary pin under an applied load in contact with rotating disc. The pin can have any shape to simulate a specific contact, but spherical tips are often used to simplify the contact geometry. Coefficient of friction is determined by the ratio of the frictional force to the loading force on the pin.

3.4 PROCESS PARAMETERS OF THE TRIBOLOGICAL STUDY

To perform a tribological study it is necessary to have the values of normal load, sliding velocity and sliding distance. Here various compositions of aluminium and nano titanium di oxide were use. The combinations of the following parameters were used for tribological study in the present work.

Table 2: Process parameter of the tribology test

LEVEL	1	2	3
NORMAL LOAD (N)	9.8	29.4	49
SLIDING VELOCITY (m/s)	1.5	2.0	2.5
PERCENTAGE OF COMPOSITION (weight)	5%	10%	15%

IV. RESULTS AND DISCUSSION

4.1 MICRO HARDNESS TESTING

The hardness was tested using the micro hardness testing machine. It was observed that the hardness was increasing with the increase in percentage of nano titanium di oxide powder particle. The hardness is tested in the Vickers scale and the readings are stated below.

Table 3: Micro hardness test readings

SAMPLE	TEST 1 (VH)	TEST 2 (VH)	TEST 3 (VH)	TEST 4 (VH)
S1	34.2	35.2	33.6	34.333
S2	39.9	40.6	38.3	39.667
S3	39.9	48.2	40.8	42.967
S4	34.7	33.5	31.3	33.167

4.2 WEAR

The tribological test was conducted with the above combinations on a pin on disc apparatus. In this experiment we consider the abrasive wear as the most dominant of all. Since the pin is made of the high wear resistant material we consider this type of wear.

4.3 CALCULATION

The calculation of the specific wear rate is done in order to find the values of the wear rate and specific wear rate. Model calculations for the Specific wear rate (SWR). The values of the Sample S1, Pin 1 is given below

W1 = 6.000g
W2 = 5.856g
H1 = 30.00mm
H2 = 29.54mm
Normal load (F)=9.8N
Sliding velocity= 1.5m/s
Sliding distance (L) = 1000m
Radius of the pin (r) = 5.00mm

Formulas used are given below:

Weight loss $(\Delta W) = W1 - W2$

Height loss $(\Delta H) = H1 - H2$

Volume $(v) = \pi \times r2 \times H1$

Density $(\rho) =$ mass / volume

Volume loss $(\Delta v) = \Delta W / \rho$

Wear rate $(W) = \Delta v / 1000$

Specific wear rate $= W / F$

Table 4 : Wear calculations for sample S1

SAMPLE S1						
PIN	WETGHT BEFORE TEST (W1)	WEIGHT AFTER TEST (W2)	WEIGHT LOSS (W1-W2)	HEIGHT BEFORE TEST (H1)	HEIGHT AFTER TEST (H2)	HEIGHT LOSS (H1-H2)
-	**g**	**g**	**g**	**mm**	**mm**	**mm**

1	6.000	5.856	0.144	30	29.54	0.46
2	6.000	5.801	0.199	30	29.16	0.84
3	6.000	5.770	0.230	30	28.96	1.04
4	6.000	5.765	0.235	30	28.89	1.11
5	6.000	5.715	0.285	30	28.13	1.87
6	6.000	5.570	0.430	30	27.95	2.05
7	6.000	5.675	0.325	30	28.54	1.46
8	6.000	5.649	0.351	30	28.91	1.09
9	6.000	5.535	0.465	30	27.63	2.37

Table 5: Wear calculations for sample S2

SAMPLE S2						
PIN	WETGHT BEFORE TEST (W1)	WEIGHT AFTER TEST (W2)	WEIGHT LOSS (W1-W2)	HEIGHT BEFORE TEST (H1)	HEIGHT AFTER TEST (H2)	HEIGHT LOSS (H1-H2)
-	**g**	**g**	**g**	**mm**	**mm**	**mm**
1	6.50	6.399	0.101	30	29.874	0.126
2	6.50	6.394	0.106	30	29.856	0.144
3	6.50	6.383	0.117	30	29.793	0.207
4	6.50	6.360	0.140	30	29.745	0.255
5	6.50	6.355	0.145	30	29.739	0.261
6	6.50	6.338	0.162	30	29.727	0.273
7	6.50	6.350	0.150	30	29.738	2620.
8	6.50	6.340	0.160	30	29.726	0.274
9	6.50	6.330	0.170	30	29.709	0.291

Table 6: Wear calculations for sample S3

SAMPLE S3						
PIN	WETGHT BEFORE TEST (W1)	WEIGHT AFTER TEST (W2)	WEIGHT LOSS (W1-W2)	HEIGHT BEFORE TEST (H1)	HEIGHT AFTER TEST (H2)	HEIGHT LOSS (H1-H2)
-	**g**	**g**	**g**	**mm**	**mm**	**mm**

1	7.00	6.925	0.075	30	29.985	0.015
2	7.00	6.922	0.078	30	29.983	0.012
3	7.00	6.918	0.082	30	29.978	0.022
4	7.00	6.923	0.077	30	29.984	0.016
5	7.00	6.893	0.107	30	29.967	0.033
6	7.00	6.881	0.119	30	29.959	0.041
7	7.00	6.901	0.099	30	29.976	0.024
8	7.00	6.885	0.115	30	29.956	0.044
9	7.00	6.861	0.139	30	29.923	0.077

Table 7: Wear calculations for sample S4

SAMPLE S4						
PIN	WETGHT BEFORE TEST (W1)	WEIGHT AFTER TEST (W2)	WEIGHT LOSS (W1-W2)	HEIGHT BEFORE TEST (H1)	HEIGHT AFTER TEST (H2)	HEIGHT LOSS (H1-H2)
-	**g**	**g**	**g**	**mm**	**mm**	**mm**
1	5.80	5.338	0.462	30	29.754	0.246
2	5.80	5.312	0.488	30	29.736	0.264
3	5.80	5.278	0.522	30	29.707	0.293
4	5.80	5.315	0.485	30	29.785	0.215
5	5.80	5.261	0.539	30	29.751	0.249
6	5.80	5.168	0.632	30	29.699	0.301
7	5.80	5.266	0.534	30	29.756	0.244
8	5.80	5.174	0.626	30	29.691	0.309
9	5.80	5.105	0.695	30	29.645	0.355

The table gives us the various combinations used for the test as well as the wear in micron level. The sliding distance is kept constant as 1000 meters for all the samples.

Table 8: Wear rate calculations

PIN	WEIGHT LOSS (ΔW)				LOAD (F)	SLIDING VELOCITY	TIME (T)	WEAR RATE (W) $\times 10^{-6}$			
	S1	S2	S3	S4				S1	S2	S3	S4
-	g	g	g	g	N	m/s	minutes	mm^3/m	mm^3/m	mm^3/m	mm^3/m
1	0.14	0.10	0.07	0.46	9.8	1.5	11	56.39	36.83	25.87	182.70
2	0.19	0.10	0.07	0.48	9.8	2.0	8.27	78.70	39.16	26.93	192.45
3	0.23	0.11	0.08	0.52	9.8	2.5	7.01	91.45	43.34	28.34	205.39
4	0.23	0.14	0.07	0.48	29.4	1.5	11	91.05	51.04	26.50	191.05
5	0.28	0.14	0.10	0.53	29.4	2.0	8.27	112.68	52.26	36.70	212.60
6	0.43	0.16	0.11	0.63	29.4	2.5	7.01	168.53	59.76	40.47	248.90
7	0.32	0.15	0.09	0.53	49	1.5	11	128.49	54.01	34.36	208.03
8	0.35	0.16	0.11	0.62	49	2.0	8.27	142.45	58.26	39.03	246.65
9	0.46	0.17	0.13	0.69	49	2.5	7.01	182.91	62.66	48.53	272.50

Table 9: Specific wear rate calculations

Pin	Load (F)	Sliding Velocity	Wear Rate (W)				Specific Wear Rate (SWR)			
			S1	S2	S3	S4	S1	S2	S3	S4
-	(N)	(m/s)	mm^3/m	mm^3/m	mm^3/m	mm^3/m	mm^3/m	mm^3/m	mm^3/m	mm^3/m
1	9.8	1.5	56.39	36.83	25.87	182.70	5.7	3.7	2.55	18.5
2	9.8	2.0	78.70	39.16	26.93	192.45	7.9	3.9	2.65	19.6
3	9.8	2.5	91.45	43.34	28.34	205.39	9.2	4.3	2.80	20.9
4	29.4	1.5	91.05	51.04	26.50	191.05	3.1	1.7	0.88	6.49
5	29.4	2.0	112.68	52.26	36.70	212.60	3.8	1.7	1.22	7.2
6	29.4	2.5	168.53	59.76	40.47	248.90	5.7	2.0	1.36	8.4
7	49	1.5	128.49	54.01	34.36	208.03	2.6	1.10	0.69	4.24
8	49	2.0	142.45	58.26	39.03	246.65	2.8	1.18	0.79	5.02
9	49	2.5	182.91	62.66	48.53	272.50	3.7	1.26	0.95	5.55

The readings from the above table is plotted in a graph, this helps to analyze the parameters and the wear characters if the samples. The graphs are plotted in two different types. They are as follows,

- ✓ Specific wear rate versus sliding velocity for the samples with varying loads for all the four specimens.
- ✓ Specific wear rate versus sliding velocity for the different loads with different specimens.

4.2.1 Specific wear rate Vs sliding velocity with varying loads

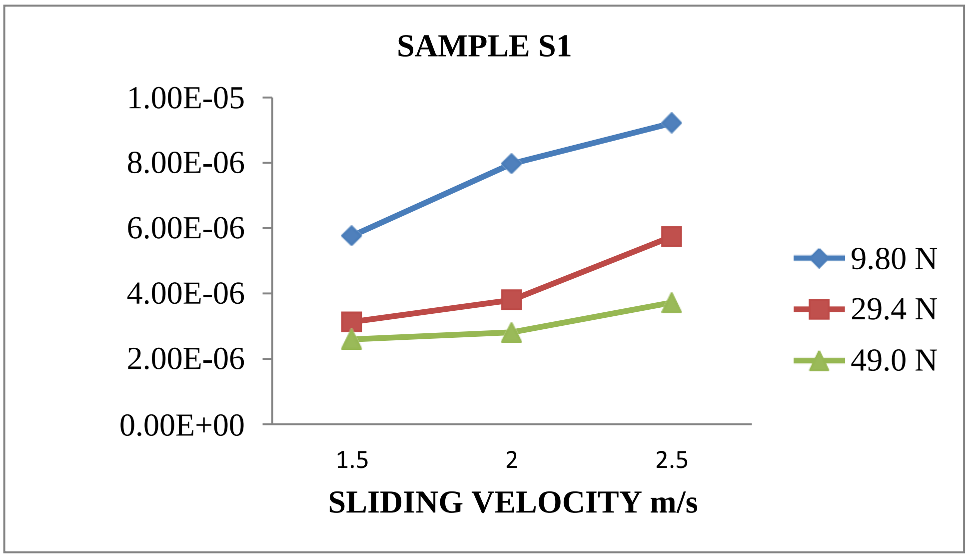

Figure 1: Graph for sample S1

The graph with sliding velocity on x-axis and wear on y-axis for the specimen with 5% weight nano TiO2 + 95% weight pure aluminium. Here the maximum specific wear occurs at the sliding velocity of 2.5 m/s and at the load of 9.8 Newton. The minimum specific wear rate occurs at the sliding velocity of 1.5 m/s and at a load of 49.0 Newton. The minimum and maximum specific wear rates for this specimen are 5.7mm3/Nm and 3.7mm3/Nm respectively.

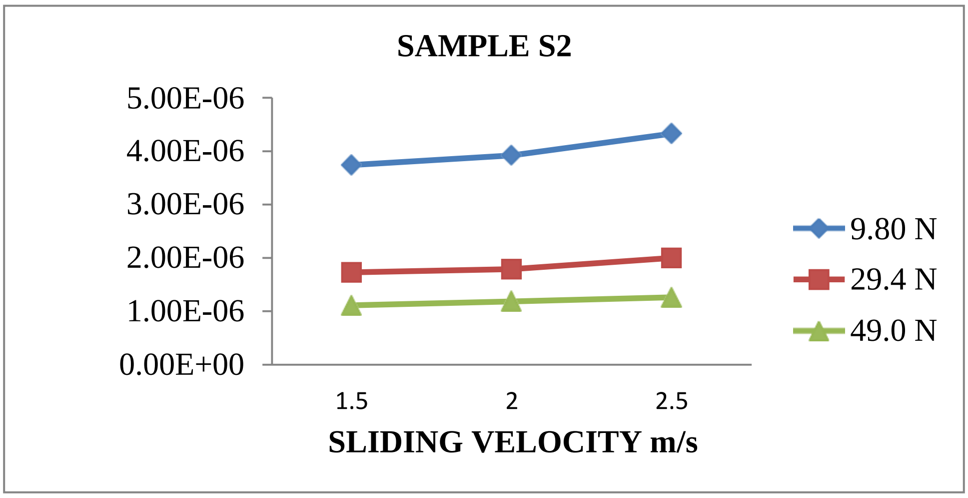

Figure 2: Graph for sample S2

The graph with sliding velocity on x-axis and wear on y-axis for the specimen with 10% weight nano TiO2 + 90% weight pure aluminium. Here the maximum specific wear occurs at the sliding velocity of 2.5 m/s and at the load of 9.8 Newton. The minimum specific wear rate occurs at the sliding velocity of 1.5 m/s and at a load of 49.0 Newton. The minimum and maximum specific wear rates for this specimen are 1.10mm3/Nm and 4.3mm3/Nm respectively.

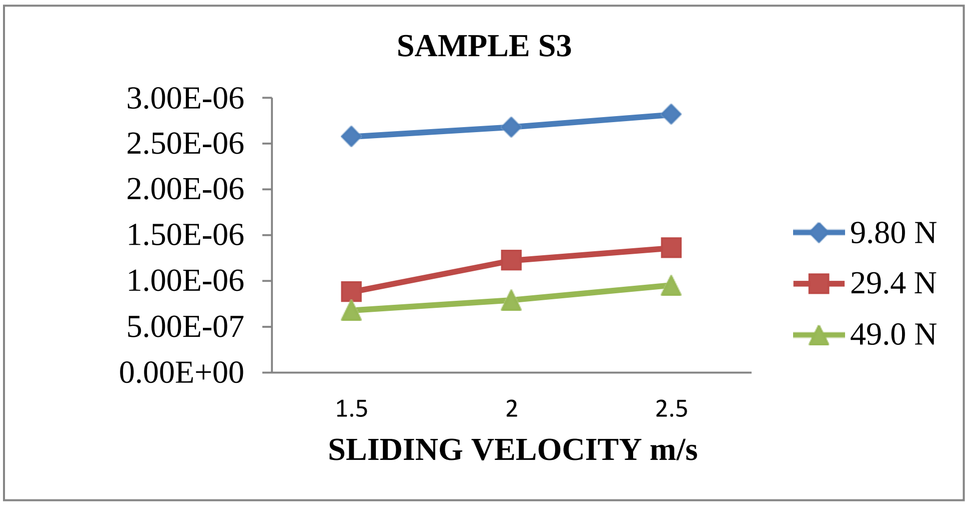

Figure 3: Graph for sample S3

The graph with sliding velocity on x-axis and wear on y-axis for the specimen with 15% weight nano TiO2 + 85% weight pure aluminium. Here the maximum specific wear occurs at the sliding velocity of 2.5 m/s and at the load of 9.8 Newton. The minimum specific wear rate occurs at the sliding velocity of 1.5 m/s and at a load of 49.0 Newton. The minimum and maximum specific wear rates for this specimen are 0.69 mm3/Nm and 2.8mm3/Nm respectively.

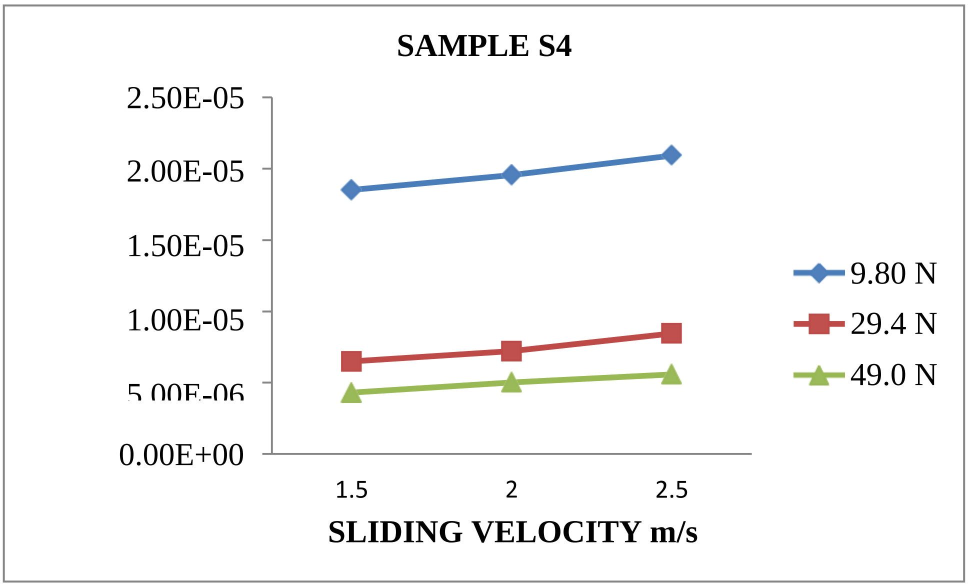

Figure 4: Graph for sample S4

The graph with sliding velocity on x-axis and wear on y-axis for the specimen with 0% weight nano TiO2 + 100% weight pure aluminium. Here the maximum specific wear occurs at the sliding velocity of 2.5 m/s and at the load of 9.8 Newton. The minimum specific wear rate occurs at the sliding velocity of 1.5 m/s and at a load of 49.0 Newton. The minimum and maximum specific wear rates for this specimen are 20.9mm3/Nm and 4.24mm3/Nm respectively.

4.3.2 Sliding velocity Vs Specific wear rate with varying samples

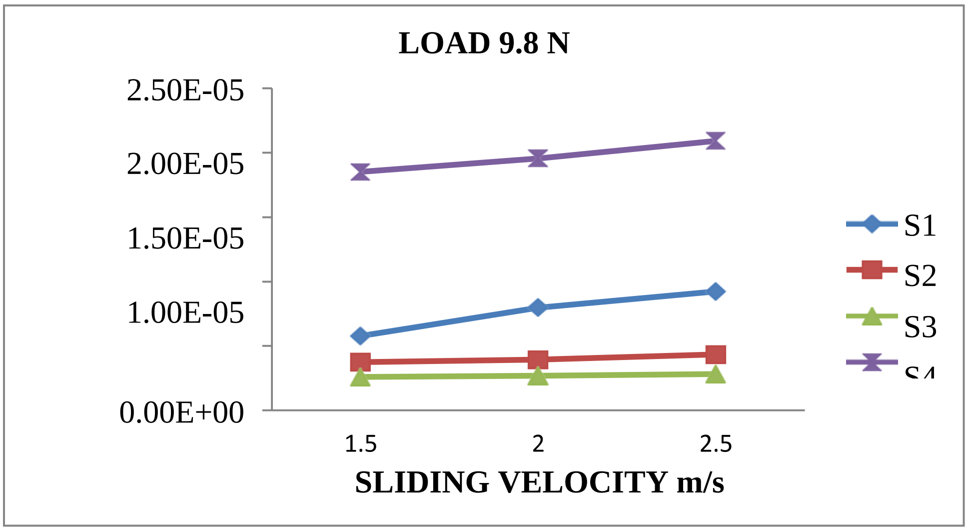

Figure 5 : Sliding velocity Vs SWR for load at 9.8 N

The analysis of the above graph gives the following interpretation given below, for the load of 9.8 N,

Table 10 : SWR analysis table for 9.8 N load

SAMPLE	SPECIFIC WEAR RATE		SLIDING VELOCITY	
-	Maximum	Minimum	Maximum	Minimum
S1	9.2 mm^3/Nm	5.7 mm^3/Nm	2.5 m/s	1.5 m/s
S2	4.3 mm^3/Nm	3.7 mm^3/Nm	2.5 m/s	1.5 m/s
S3	2.8 mm^3/Nm	2.55 mm^3/Nm	2.5 m/s	1.5 m/s
S4	20.9mm^3/Nm	18.5 mm^3/Nm	2.5 m/s	1.5 m/s

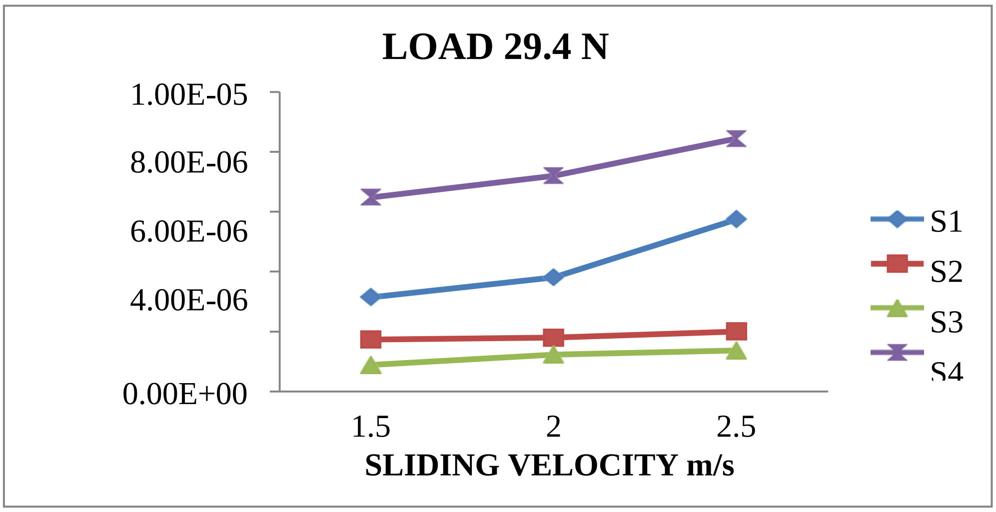

Figure 6 : Sliding velocity vs SWR for load at 29.4 N

The analysis of the above graph gives the following interpretation given below, for the load of 29.4 N,

Table 11: SWR analysis table for 29.4 N load

SAMPLE	SPECIFIC WEAR RATE		SLIDING VELOCITY	
-	Maximum	Minimum	Maximum	Minimum
S1	9.2 mm^3/Nm	5.7 mm^3/Nm	2.5 m/s	1.5 m/s
S2	4.3 mm^3/Nm	3.7 mm^3/Nm	2.5 m/s	1.5 m/s
S3	2.8 mm^3/Nm	2.55 mm^3/Nm	2.5 m/s	1.5 m/s
S4	20.9mm^3/Nm	18.5 mm^3/Nm	2.5 m/s	1.5 m/s

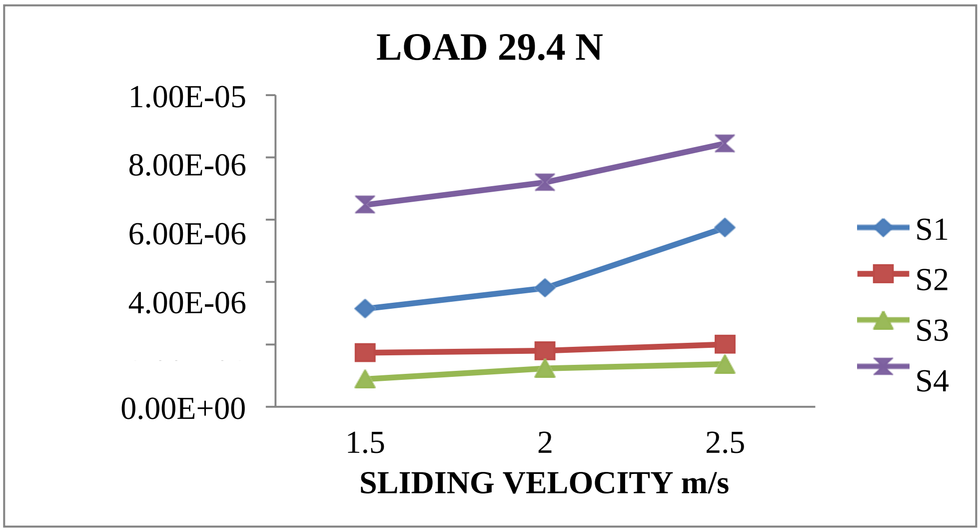

Figure 6 : Sliding velocity vs SWR for load at 29.4 N

The analysis of the above graph gives the following interpretation given below, for the load of 29.4 N,

Table 11: SWR analysis table for 29.4 N load

SAMPLE	SPECIFIC WEAR RATE		SLIDING VELOCITY	
-	Maximum	Minimum	Maximum	Minimum
S1	5.7 mm^3/Nm	3.1 mm^3/Nm	2.5 m/s	1.5 m/s
S2	2.0 mm^3/Nm	1.7 mm^3/Nm	2.5 m/s	1.5 m/s
S3	1.36mm^3/Nm	0.88 mm^3/Nm	2.5 m/s	1.5 m/s
S4	8.40mm^3/Nm	6.49 mm^3/Nm	2.5 m/s	1.5 m/s

From this we come to know that the value of the wear rate is decreasing with the increasing percentage of reinforcement titanium di oxide.

This graph indicates that the maximum wear is at the maximum sliding velocity and minimum wear is at the minimum sliding velocity.

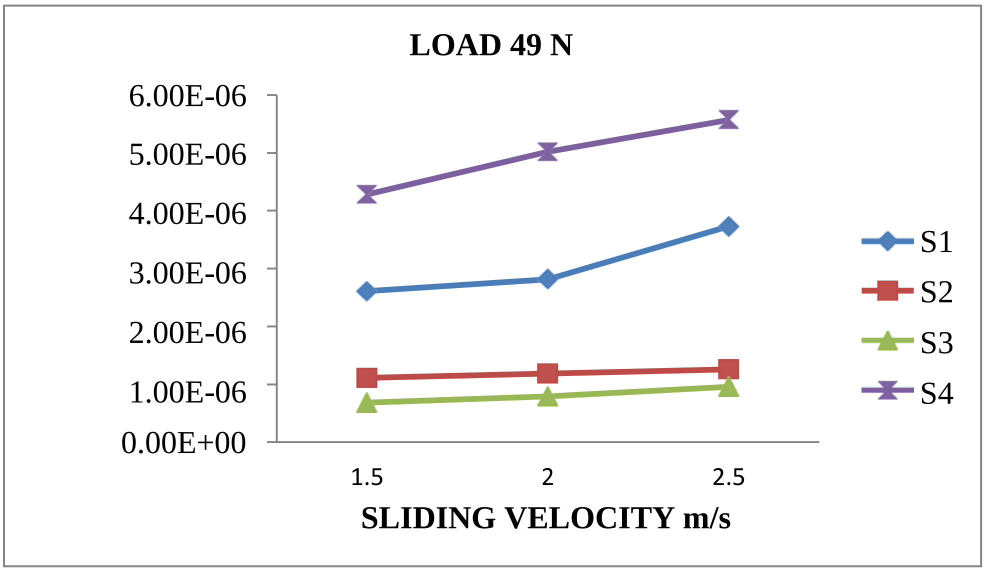

Figure 7 : Sliding velocity vs SWR for load of 49.0 N

The analysis of the above graph gives the following interpretation given below, for the load of 49.0 N,

Table 12 : SWR analysis table for 49 N load

SAMPLE	SPECIFIC WEAR RATE		SLIDING VELOCITY	
-	Maximum	Minimum	Maximum	Minimum
S1	3.7 mm^3/Nm	2.6 mm^3/Nm	2.5 m/s	1.5 m/s
S2	1.26mm^3/Nm	1.10 mm^3/Nm	2.5 m/s	1.5 m/s
S3	0.95mm^3/Nm	0.69 mm^3/Nm	2.5 m/s	1.5 m/s
S4	5.55mm^3/Nm	4.24 mm^3/Nm	2.5 m/s	1.5 m/s

4.4 OPTICAL MICROSCOPIC IMAGES

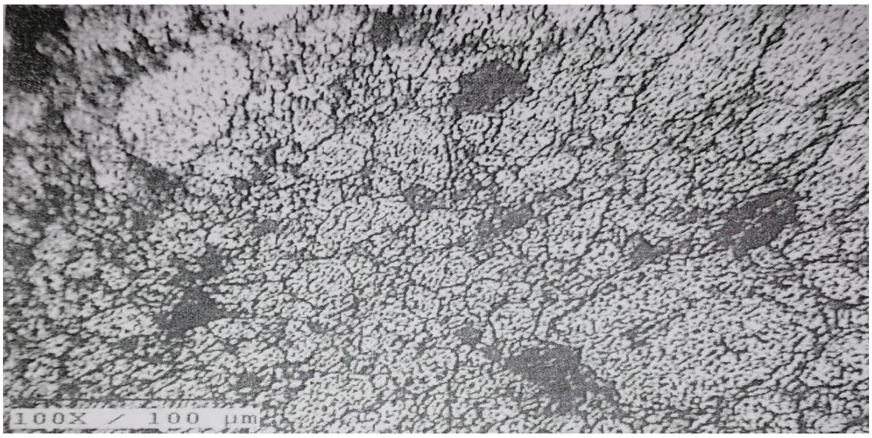

Figure 8: Micro structure of Sample S1

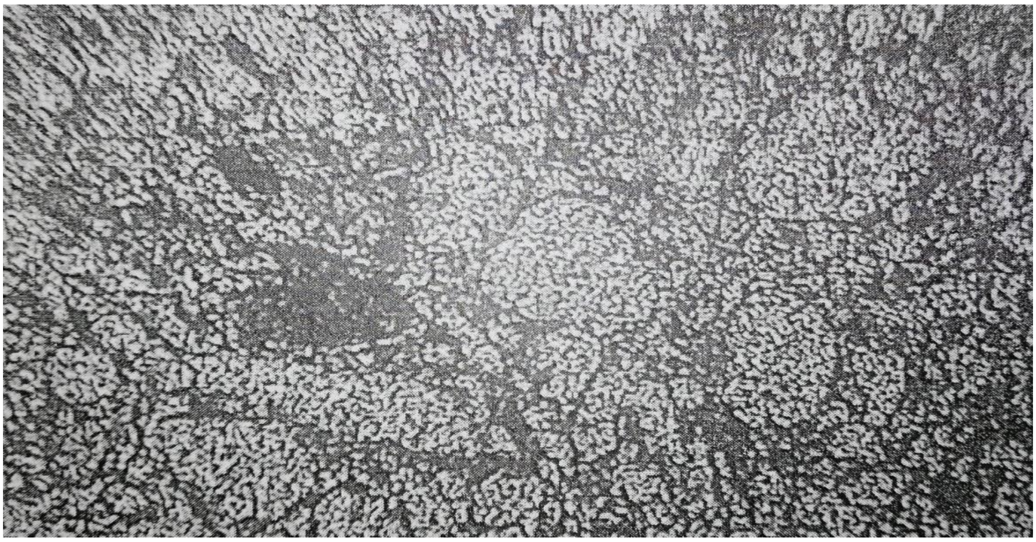

Figure 9: Microstructure of sample S2

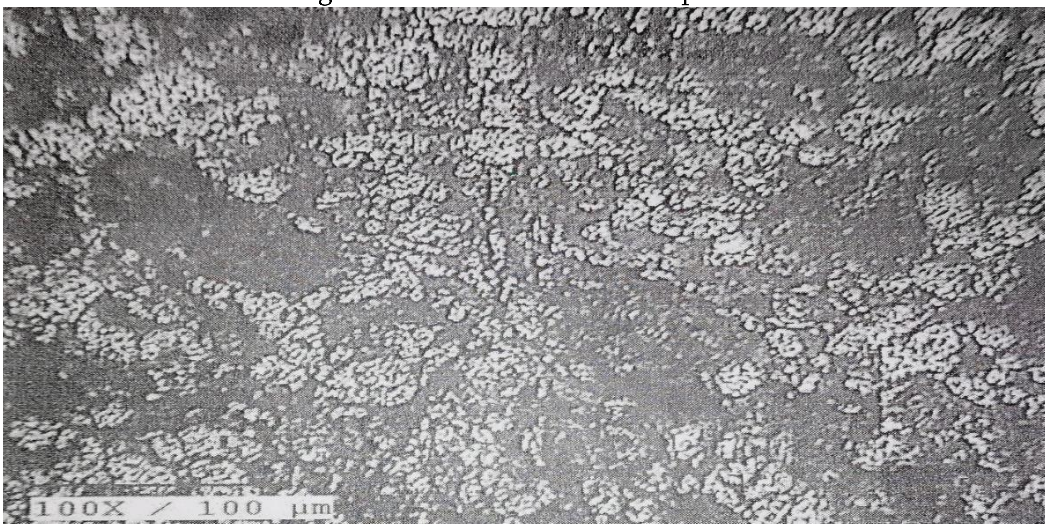

Figure 10: microstructure of sample S3

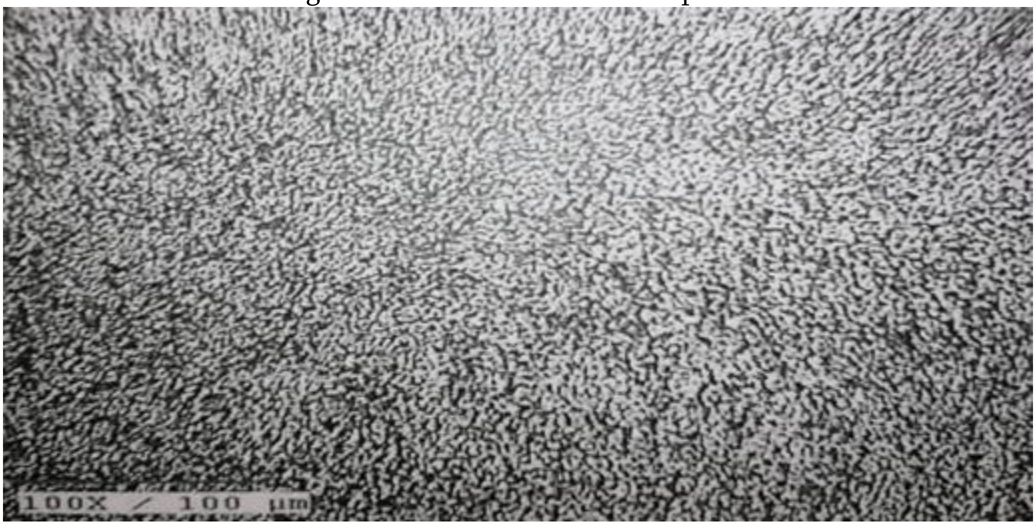

Figure11: Microstructure of sample S4

The specimens is given below as a whole as well as an individual.

Figure 12: Sample S1

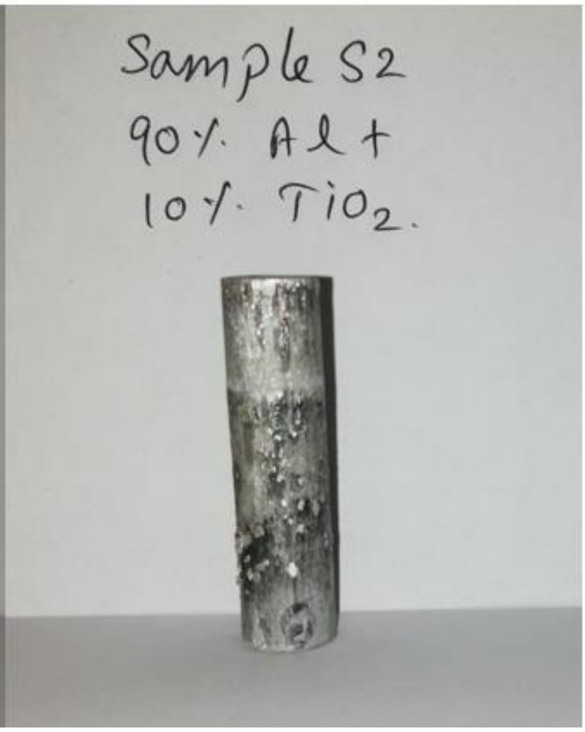

Figure 13: Sample S2

Figure 14: Sample S3

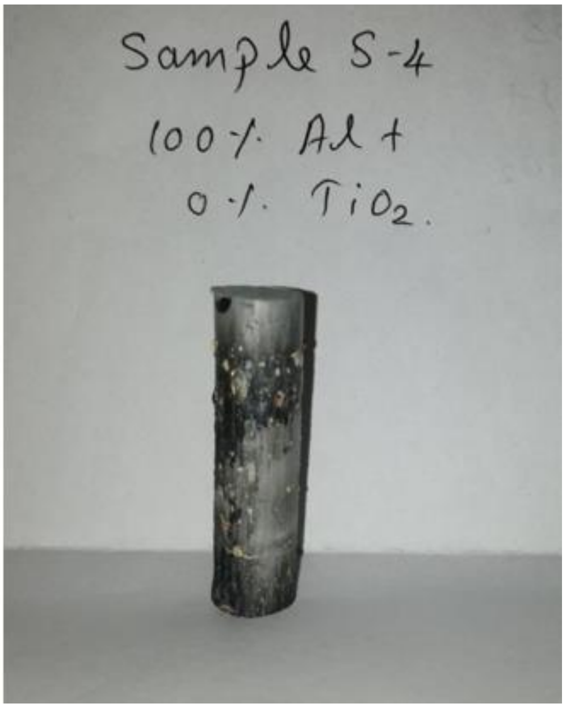

Figure 15: Sample S4

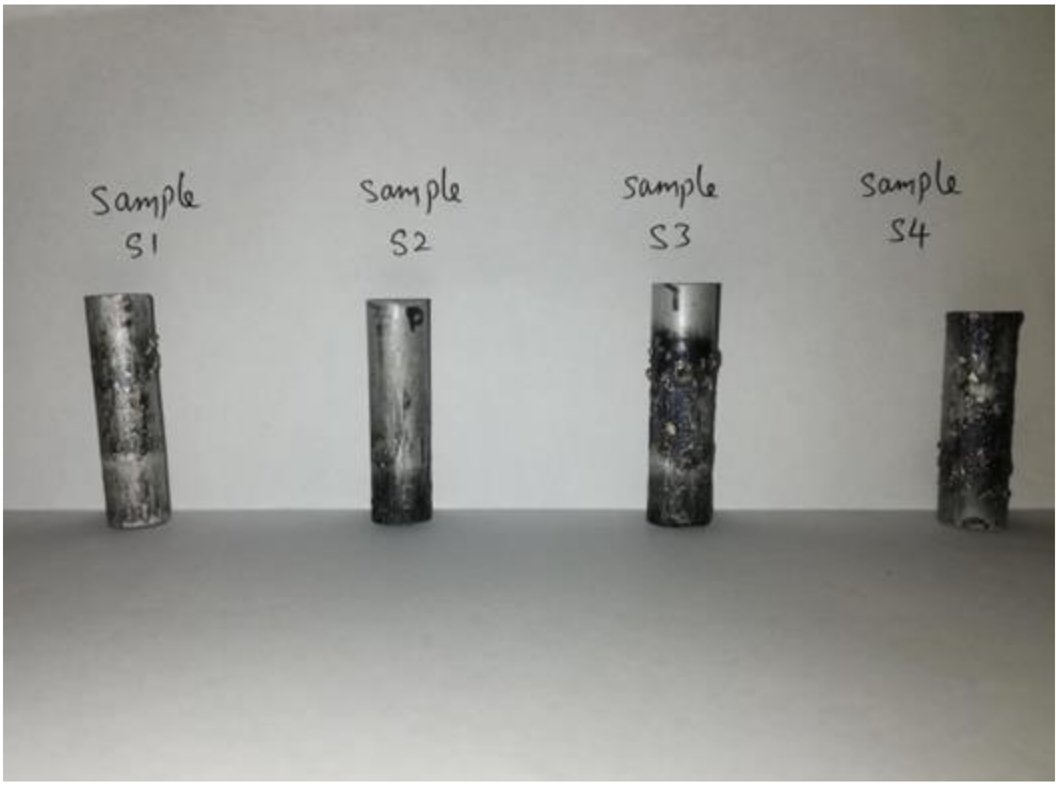

Figure 16: Sample pins S1,S2,S3,S4

V. CONCLUSION

The powder metallurgy technique can be used to produce pure aluminum Nano composite in which the nanoTiO_2 particles are uniformly distributed within the matrix alloy with a low degree of porosity and better hardness. Nano particles addition results in a significant improvement in the specific wear resistance and hardness of composites. Hard Nano particles protect the surface, so the wear resistance is enhanced, as the nano TiO_2 particles act as obstacles for the dislocation motion.

From the present work we have found out that,

- The nano TiO2 particle in various weight percentages were homogenously dispersed in the aluminium matrix.
- When the weight percentage of nano TiO2 particle increased, the Vickers hardness of the composite also improved.
- As the percentage of nano TiO2 particle increased, the wear and specific swear rate of the component also dropped down.
- As the sliding velocity increases, the wear of the composite also increased.
- As the load increase, the wear also increases

Scope of the future work is to investigate the coefficient of friction and the wear coefficient and to optimize the process parameters.

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