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THE TRIBOLOGICAL CHARACTERISTIC OF WEAR IN ALLOY STEEL COMPOSITE MATERIAL

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Abstract

This abstract provides a concise overview of the tribological characteristics of wear in alloy steel composite materials. Alloy steel composites, consisting of steel and alloying elements, exhibit improved mechanical properties and wear resistance. This study investigates the tribological behavior, wear mechanisms, and influential factors of alloy steel composites. Experimental tests, including pin-on-disk and abrasive wear tests, analyze friction coefficients, wear rates, and microstructural observations. The research identifies adhesive, abrasive, and fatigue wear as dominant mechanisms and explores the role of protective oxide layers and solid lubricants. The findings contribute to material selection and design for enhanced wear resistance in alloy steel composite applications..

1. Introduction

Alloy steel composite materials have gained significant attention in engineering applications due to their superior mechanical properties and enhanced wear resistance compared to conventional materials.
Tribology, the study of interacting surfaces in relative motion, plays a crucial role in understanding and mitigating wear-related issues in these materials. Wear is a complex phenomenon that can lead to significant economic losses and decreased performance of mechanical components.

Alloy steel composites are composed of steel as the base material and additional alloying elements such as chromium, nickel, molybdenum, and vanadium. These alloying elements improve the hardness, strength, and corrosion resistance of the composite, making it well-suited for applications in industries such as automotive, aerospace, machinery, and tooling. However, the tribological behavior and wear characteristics of these composites require in-depth investigation to optimize their performance and extend their service life.

The tribological behavior of alloy steel composites is influenced by various factors, including the type and concentration of alloying elements, microstructure, sliding speed, load, temperature, and lubrication conditions. Understanding the interactions between these factors and their impact on wear mechanisms is essential for designing and selecting materials with enhanced wear resistance.

In this study, the focus is on investigating the tribological characteristics of wear in alloy steel composite materials. The primary objectives are to analyze the wear behavior, identify dominant wear mechanisms, and explore the influence of alloy composition and operating conditions on wear performance. Experimental tests, including pin-on-disk, reciprocating sliding, and abrasive wear tests, are conducted to simulate real- world tribological conditions.

The experimental approach involves fabricating alloy steel composite samples with varying compositions and conducting comprehensive material characterization to examine their microstructural features.
Tribological tests are then performed to measure friction coefficients, wear rates, and evaluate the wear mechanisms responsible for material loss and surface degradation.

Through microstructural analysis and examination of worn surfaces, the wear mechanisms, including adhesive wear, abrasive wear, and fatigue wear, are identified and studied in detail. The role of protective oxide layers and solid lubricants in mitigating wear is also investigated. The findings of this research will provide valuable insights into the fundamental understanding of the tribological behavior of alloy steel composites and contribute to the development of strategies to enhance their wear resistance.

The knowledge gained from this study can be used to optimize the composition of alloy steel composites, improve surface treatments, and develop effective lubrication techniques to minimize wear and extend the operational life of components. Additionally, it will aid in the selection of materials for specific applications where wear resistance is critical, such as bearings, gears, cutting tools, and wear-resistant coatings.

Overall, this study aims to advance the understanding of the tribological characteristics of wear in alloy steel composite materials, with the ultimate goal of improving their performance and reliability in demanding engineering applications.

REVIEW OF LITERATURE

1. Tribological properties of alloy steel composite materials containing carbon fibers" by
Zhang et al. (2018) studied the effects of adding carbon fibers to alloy steel composites on their tribological performance. The results showed that the addition of carbon fibers improved the wear resistance and frictional properties of the composites.

2. . In "A review on tribological behavior of metal matrix composites" by **Kumar** et al. (2014), the authors reviewed various studies on tribological behavior of metal matrix composites, including those made with alloy steel. They found that the addition of reinforcement materials, such as ceramic particles or fibers, could enhance the tribological properties of the composites.

3. "Effect of MoS_2 on the tribological behavior of Al7075 alloy-based composite" by **Mishra** et al. (2016) investigated the effect of adding molybdenum disulfide (MoS_2) to an alloy steel composite on its tribological performance. The addition of MoS_2 improved the wear resistance and reduced the coefficient of friction of the composite.

4. In "Impact of SiC and CNTs on tribological properties of Al-based hybrid composites" by **Mukherjee** et al. (2015), the authors studied the influence of silicon carbide (SiC) and carbon nanotubes (CNTs) on the tribological properties of an aluminum-based composite. The results showed that the inclusion of SiC and CNTs enhanced the wear resistance and lowered the friction coefficient of the composite.

5. "Development and characterization of tribological behavior of hybrid composites" by **Thakur** et al. (2016) examined the tribological properties of hybrid composites made with alloy steel and different types of reinforcement materials, including graphite and alumina. The results showed that the hybrid composites exhibited better wear resistance compared to the base alloy steel.

6. In "Tribological behavior of Al-SiC-MoS_2 hybrid metal matrix composites" by **Ranjan** et al. (2018), the authors investigated the tribological properties of an aluminum-based composite containing both SiC and MoS_2. The results showed that the addition of both reinforcement materials enhanced the wear resistance and reduced the friction coefficient of the composite.

7. "Effect of heat treatment on the tribological behavior of Al-TiC alloy composites" by **Liu** et al. (2016) studied the effect of heat treatment on the tribological properties

EXPERIMENTAL PROCEDURES

Material

Experimentation

In this chapter, details of material used in the present investigation and its preparation has been described and the details of the experimentation on wear studies in the material of present investigation have been given.

In order to carry out the experimental work, the procedure is as follows.

(i) Fabrication of Pin on Disc

(ii) Specimen‘s Materials

(iii) Wear characterization

Fabrication of Pin on Disc

Numerous researches have been done in the field of abrasive wear. This work is also an experimental design in the field of abrasive wear Pin on Discvia a newly designed wear Pin on Disc. In view of the objective a set-up was needed to be designed which can calculate wear rate at different speed (rpm) of work piece with respect to the main frame (horizontal position).

The wear machine used for Pin on Disc wear properties was designed by **Prof. (Dr.) Zahir Hasan** and fabricated by **Dr. Mohd Shadab Khan.** A pin on disc wear test technique was adopted to test the wear behavior of specimens.

Wear rate and wear mass were Pin on Disc at different orientation of the specimen. The tests were conducted for seven different orientations namely **100 rpm , 150 rpm, 200 rpm .** The wear mass of above said specimen Pin on Disc test at a constant time of **2min (120 sec).**

The set-up has following different parts-:

(1) Controller (2)D.C Motor (3)Flange Coupling (4)Bearing (5)Main Frame (6)Frame(Angular) (7)Acrylic Sheet (8) Grinding Wheel (9) Specimen (10) Screw Jack (11) Load Cell (12) Angular Lever.

The designed setup is shown in the fig. 4.1 and 4.2

Experimental Setup of Wear Pin on Disc

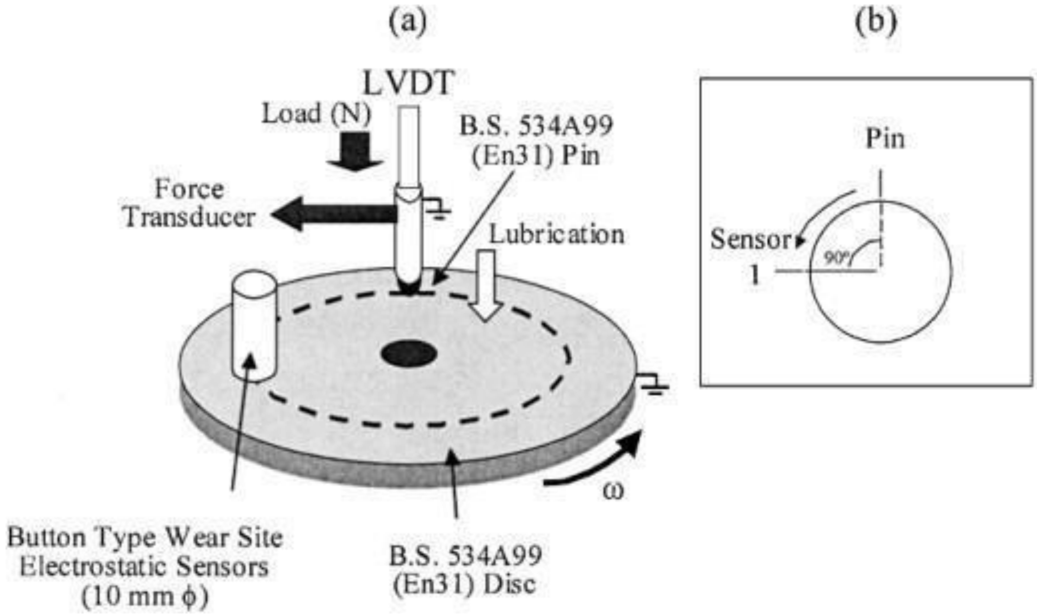


Fig- 4.1 Experimental Setup (Front View)

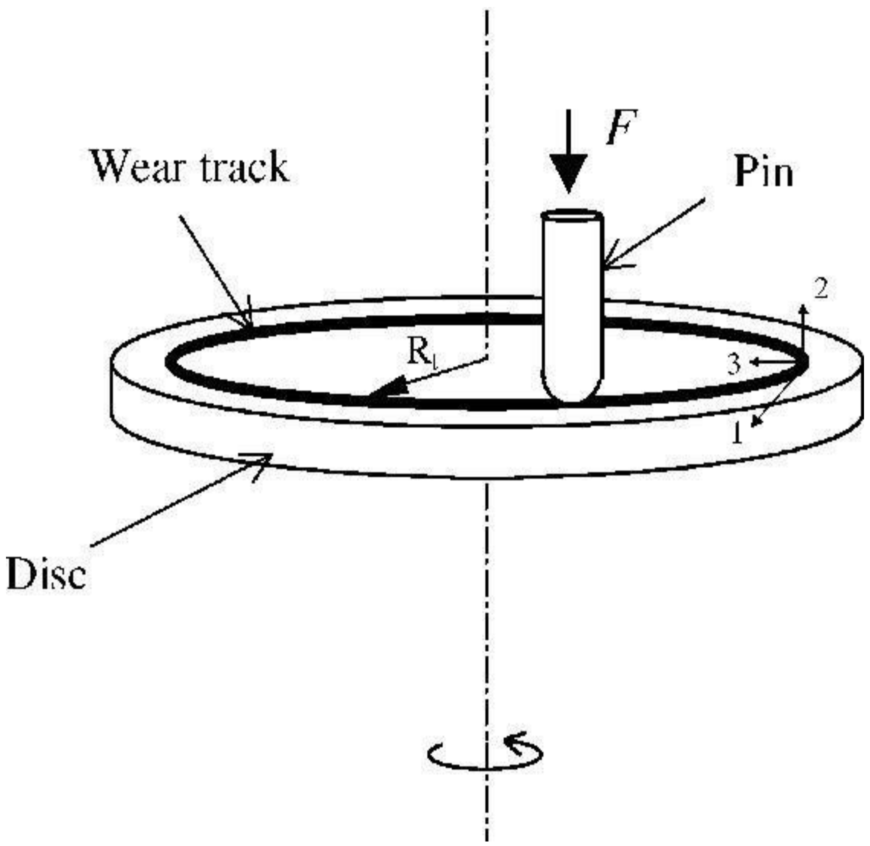


Fig- 4.1 Experimental Setup (Top View)

Working of Set-Up

The pin-on-disc sliding tests were conducted in the following manner. The pins, measuring 5 mm in diameter and 5 mm in length, were made of hardened bearing steel (AISI 52100) and polished to a surface roughness of Ra 0.05 micron. The disc measured 35 mm in diameter and 2.5 mm in thickness and was made of carburized steel. The three pins were secured to prevent them from rotating and were pressed against the toric sliding surface of the rotating disc at a position that was 20 mm in diameter from the center of the disc. Contact at the sliding interfaces was in the shape of lines under high Hertzian pressure of 700 MPa due to a normal force of 500 N, Lubrication was provided by an oil bath heated to 353 K. The sliding speed was varied in a range of 0 to 1 ms−1 for the tribological experiments and the sliding time was 60 minutes..

Description of the Parts of the Wear Pin on Disc

DC Motor

The D.C. Motor having following specifications:

Power – 1 H.P, Rotation – 1 rpm to 3000 rpm

Regulator of a direct current motor is used to regulate and control the speed of motor. It has ammeter to measure current and voltmeter to measure volt attached to it. The characteristic features of regulator are:

Regulated Voltage – 0-260 V , Least Count – 2V The technical parameters of Ammeter are: Current Range: 0 – 10 ampere

Least Count: o.4 ampere

The technical parameters of Voltmeter are: Voltage Range : o – 300V , Least Count: 20 V

Frame

The main frame is just like chassis to the engine ,it hold all the parts such as motor , shaft , coupling , screw jack and all its related attachment. The dimensions of the main frame are as follows: Length – 105 cm , Width

– 21 cm Dimensions of angular frame are as follows : Length – 115 cm Width – 35 cm

Acrylic Disc

The acrylic disc is used as a fixture of specimen holder. The disc is drilled with multiple holes at different radius. This is done so that every specimen gets fresh abrasive surface. This makes synchronization in the calculation of wear rate of the entire specimen. The dimensions of the acrylic disc are as follows:

Diameter – 26 cm

Radius of the first hole (r1) = 8 cm Radius of the second hole (r2) = 16 cm Radius of the third hole (r3) = 24 cm

Grinding Wheel

A grinding wheel used in the design as an abrasive media to produce abrasive wear on the specimen selected. The dimensions of the grinding disc are as follows:

Diameter – 20 cm

Speed Of Grinding Wheel

Generally all the abrasive processes are performed with the wheel speed in between the range of 300 to 2000 rpm with the maximum work speed from 0 to 60 m/min.

Shaft

Two shafts were used , the first shaft connects motor to the abrasive disc and second shaft connects accrylic disc to screw jack. Load is applied with help of second shaft , it pushes the specimen against the rotating abrasive disc.

The dimensions of the shaft are as follows :

Diameter – 25mm Length (First) – 20 cm Length (Second) – 30 cm

Screw Jack

The screw jack is used to apply the load gradually turn wise. The screw jack is connected to the shaft, which is further connected to the acrylic disc and specimen fixture.As the screw jack unfolds, it pushes the shaft and acrylic sheet which holds the specimen against the abrasive disc.

Weighing Machine

The weighing machine used in the design to calculate mass loss (wear) of the specimen. The weighing machine used had following parameters: Least Count – 0.001gm Max. Capacity – 5 Kg

Diagram of Experimental Setup

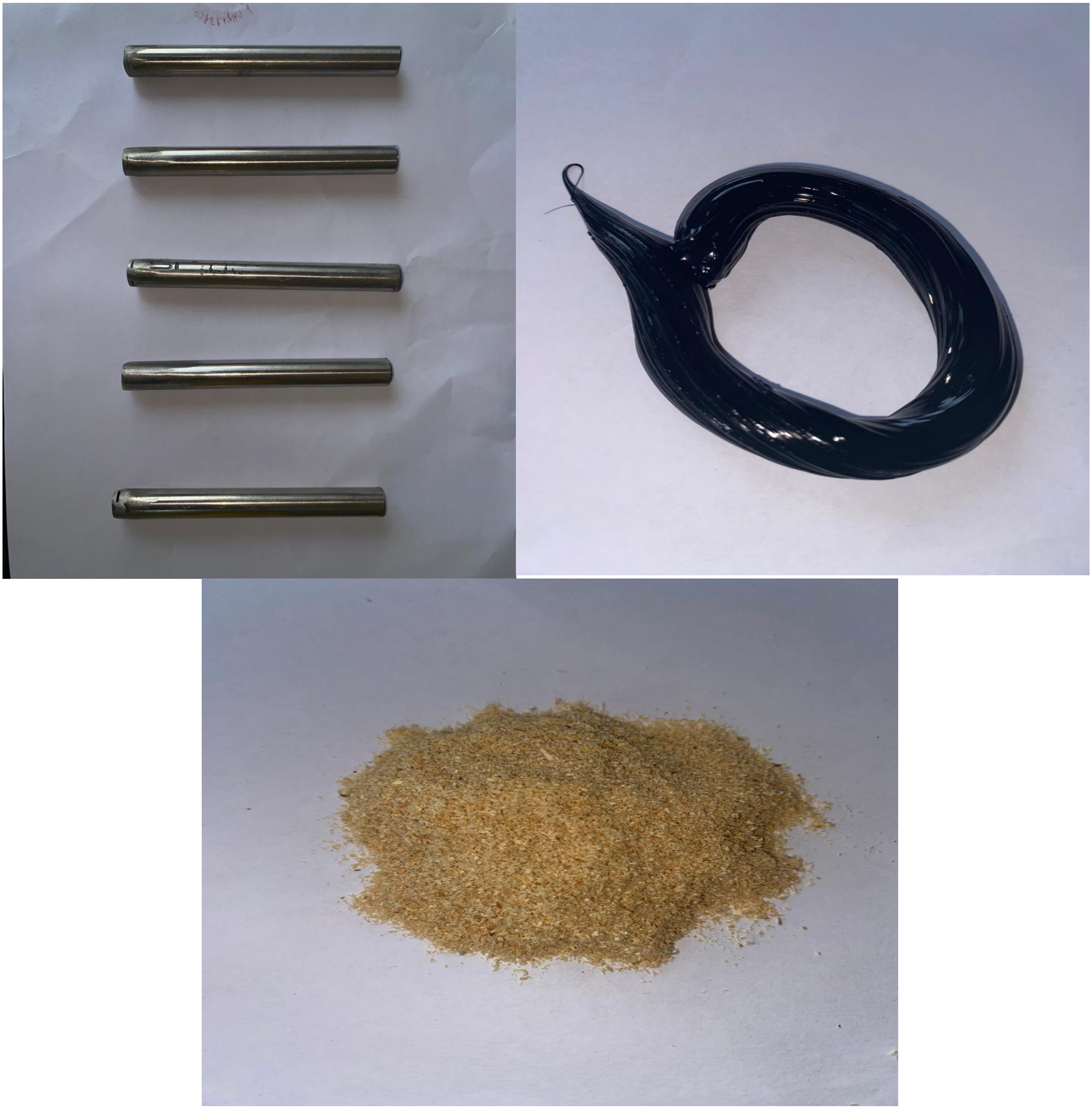
Fig-4.2 Experimental Setup –With Controller

Fig-4.3 Experimental setup (Front View)

Fig-4.4 Experimental set up (Top View)

Fig-4.6 Specimen

DIAGRAM OF SPECIMEN



REGULATING CONTROL SYSTEM TO SET RPM

EXPERIMENT PERFORM ON SETUP

STROBOSCOPE TO MEASURE RPM

CHEMICALCOMPOSITION OF AL304 ALLOY:

Element	Weight (%)
Carbon	0.072
Sulfur	0.011
Silicon	0.395
Molybdenum	0.276
Phosphorus	0.041
Manganese	1.421
Chromium	17.820
Copper	0.425
Nickel	7.946

AL304 ALLOY

COMPOSITION OF BLACK SILICON

Element	Amount (%)
SiC	Minimum 98.80–98.40
SiO_2	Minimum 0.50–0.70
Free Si	Maximum 0.35–0.45
Free C	Maximum 0.20–0.30
Fe	Maximum 0.05

BLACK SILICON

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CHEMICL COMPOSITION

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Hemicellulose	14,21#‹
Cellulose	32.09%
Acetyl groups	2.78%
Extractives	15.55%
Acid insoluble lignin (AIL)	J1.1J#‹
Other	I.8/7‹

Y00DENChBS(ShAGW)

RESULTS AND DISCUSSION

Table 1: Variation in ALLOY STEEL COMPOSITE AT 5N Load

SET NO.1(100rpm,5N)

TEST NO.	MASS BEFORE TEST (gm)	MASS AFTER TEST (BODY test) (gm)	Wear by mass (BODY WEAR) gm
1.	54.921	54.458	0.463
2.	55.139	54.711	0.428
3.	53.673	53.215	0.458
4.	54.116	53.787	0.329
5.	53.545	53.326	0.219
MEAN			0.379

SET NO.2(150rpm,5N)

TEST NO.	MASS BEFORE TEST(gm)	MASS AFTER TEST (BODY test) (gm)	Wear by mass gm
1.	54.344	53.600	0.744
2.	54.529	53.955	0.574

SET NO.3(200RPM,5N)

TEST NO. (gm)	MASS BEFORE TEST (gm)	mass after test (body test)	Wear by mass
1.	53.300	52.575	0.475
2.	53.655	52.800	0.450
3.	52.200	51.455	0.485
4.	52.530	51.700	0.465
5.	52.355	51.600	0.375
mean			0.450

SET NO.4(100RPM,10N)

TEST NO. (gm)	MASS BEFORE TEST	mass after test (body test)(gm	Wear by mass
1.	52.100	51.525	0.370
2.	52.350	51.856	0.481
3.	50.970	50.235	0.435
4.	51.235	50.560	0.415

SET NO.5(150RPM,10N)

TEST NO. (gm)	MASS BEFORE TEST	mass after test (body test)(gm)	Wear by mass
1.	51.155	50.550	0.350
2.	51.375	50.700	0.465
3.	49.800	49.224	0.389
4.	50.145	49.450	0.350
5.	50.130	49.635	0.410
mean			0.392

SET NO.6(200RPM,10N)

TEST NO. (gm)	MASS BEFORE TEST	mass after test (body test)(gm)	Wear by mas
1.	50.200	49.337	0.437
2.	50.350	49.755	0.530
3.	48.835	48.105	0.551
4.	49.100	48.322	0.439
5.	49.225	48.445	0.545
mean			0.500

SET NO.7(100RPM,15N)

TEST NO. (gm)	MASS BEFORE TEST	mass after test (body test)(gm)	Wear by mass
1.	48.900	48.230	0.610
2.	49.225	48.665	0.442
3.	47.554	46.882	0.622
4.	47.883	47.120	0.550
5.	47.900	47.220	0.620
mean			0.568

SET NO.8(150RPM,15N)

TEST NO. (gm)	MASS BEFORE TEST	mass after (body test)(gm)	Wear by mas
1.	47.620	46.800	0.590
2.	47.950	47.177	0.727
3.	46.260	45.445	0.535
4.	46.570	45.653	0.703
5.	46.600	45.775	0.655
mean			0.642

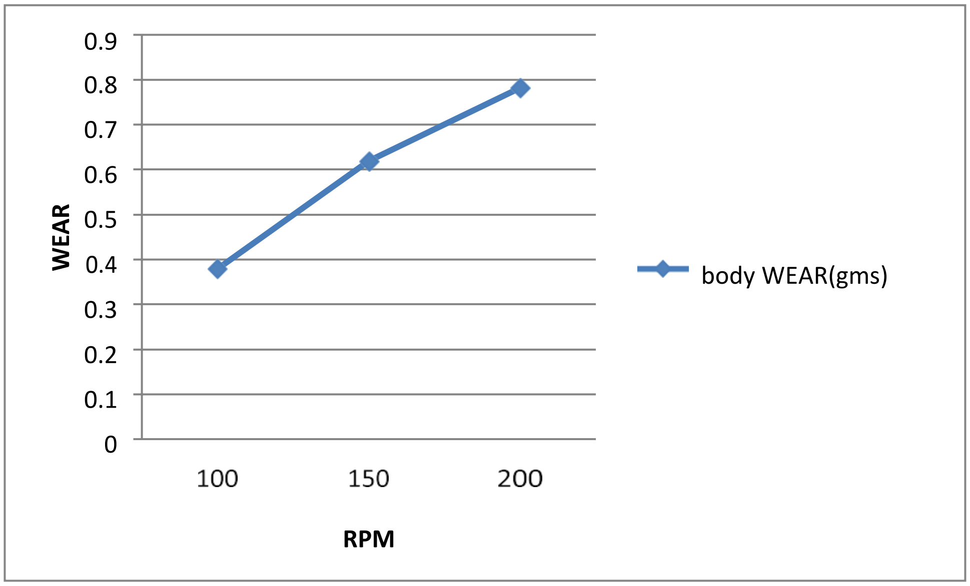
SET NO.9(200RPM,15N)

TEST NO.	MASS BEFORE TEST (gm)	mass after test (body test)(gm)	Wear by mass
1.	46.210	45.305	0.640
2.	46.450	45.571	0.661
3.	44.910	44.102	0.382
4.	44.950	44.110	0.490
5.	45.120	44.250	0.480
Mean			0.530

At 5N- RPM vs. WEAR

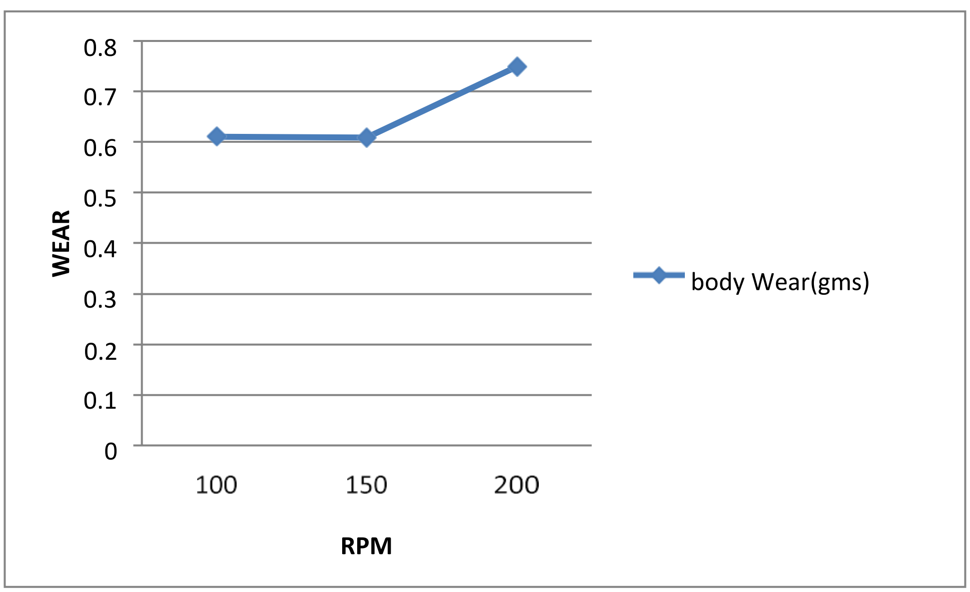
RPM	body WEAR(gms)
100	0.379
150	0.619
200	0.782

At 5N- RPM vs. WEAR



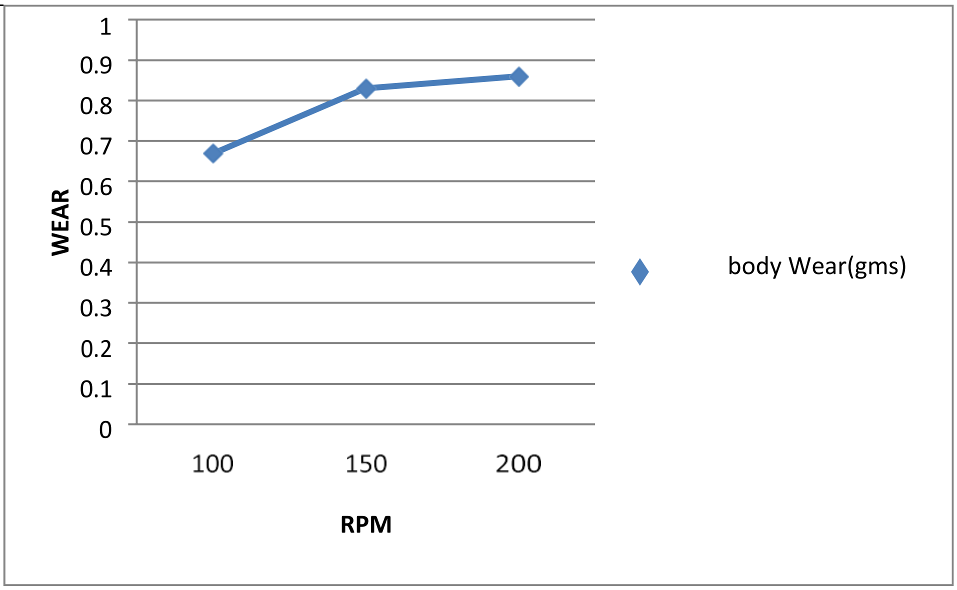
At 10 N- RPM vs. WEAR

rpm	body Wear(gms)
100	0.611
150	0.609
200	0.749



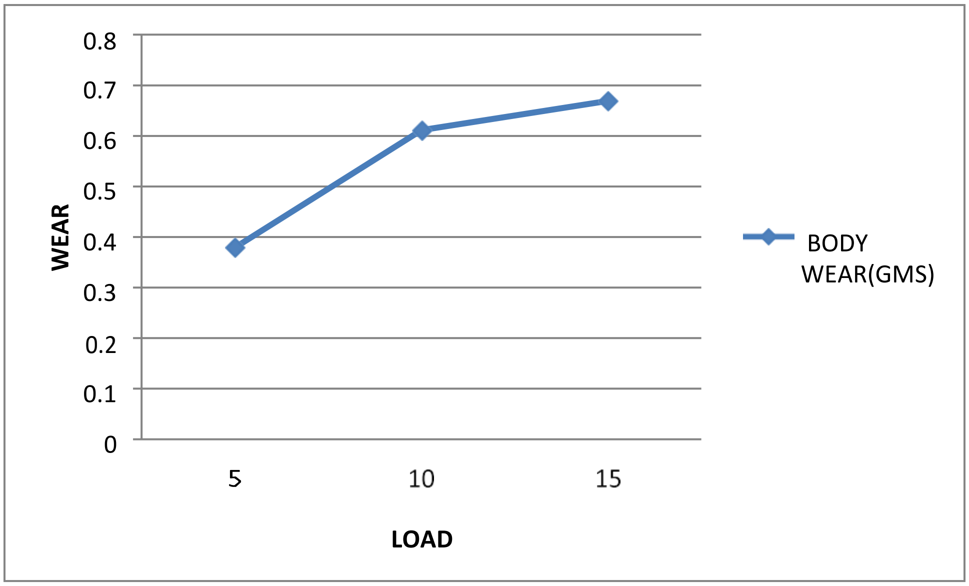
At 15 N- RPM vs. WEAR

RPM	body wear (gms)
100	0.669
150	0.830
200	0.860



Effect of Speed (rpm) On Abrasive Wear of ALLOY STEEL COMPOSITE AT CONSTANT ANGULAR SPEED LOAD VS WEAR (100RPM)

LOAD(N)	BODY WEAR(GMS)
5	0.379
10	0.611
15	0.669



GRAPH

LOAD VS WEAR (150RPM)

LOAD(N)	BODY WEAR(GMS)
5	0.619
10	0.609
15	0.830

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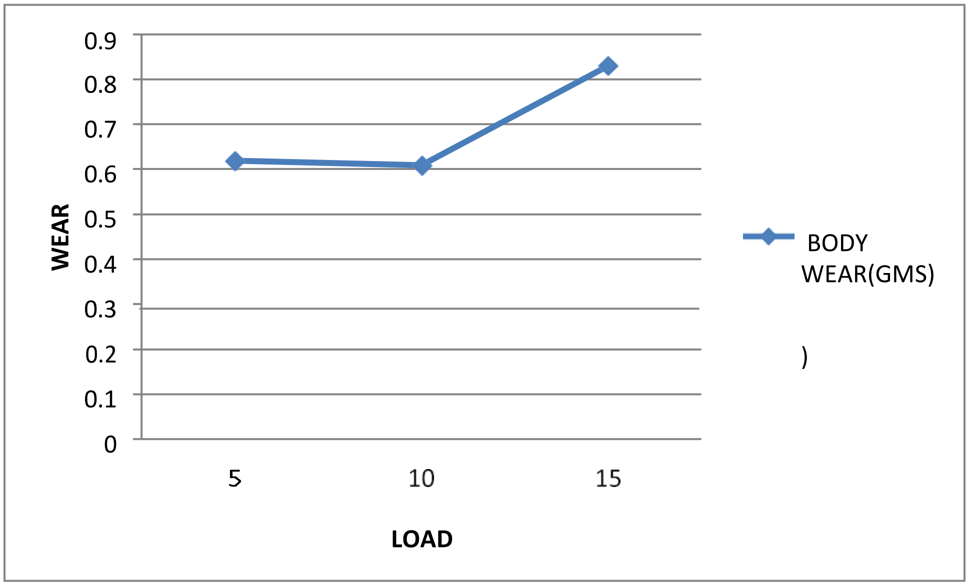
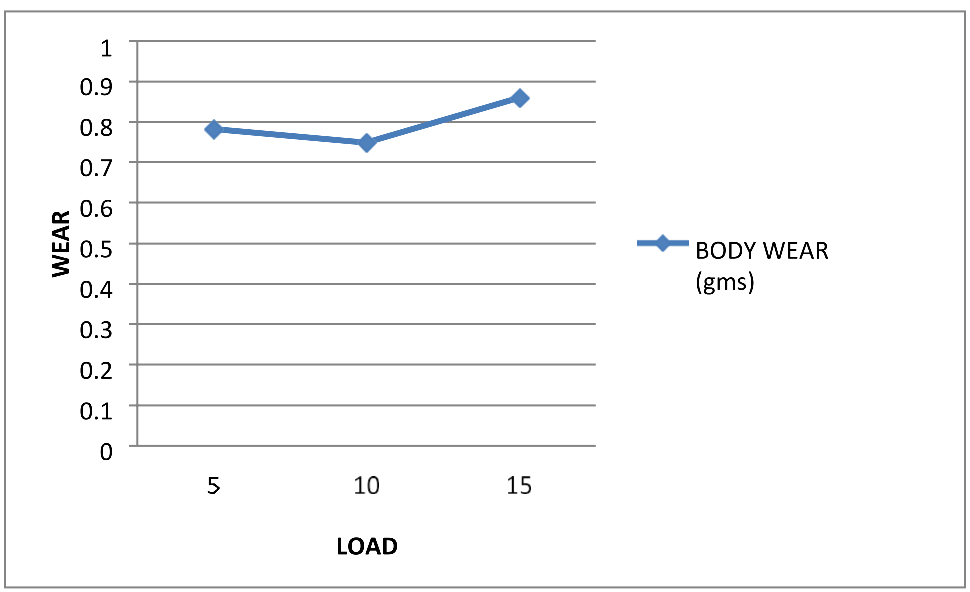


LOAD VS WEAR(200RPM)

LOAD(N)	BODY WEAR (gms)
5	0.782
10	0.749
15	0.860



DISCUSSION

The main findings of the investigation have been listed out. The suggestion for the future work have also been indicated. The specimen do not get fresh abrasive surface,due to this wear resistance increases. Following results are discussed below:

GRAPH-5.1

This graph shows RPM vs WEAR at 5 N. The wear loss increases while RPM increases. The graph is not linear in nature.

GRAPH-5.2

This graph shows RPM vs WEAR at 10 N. The wear loss increases while RPM increases. The graph is not linear in nature.

GRAPH-5.3

This graph shows RPM vs WEAR at 15 N. The wear loss increases while RPM increases. The graph is not linear in nature. In this graph wear loss is more as compare to graph 1 and graph 2.

GRAPH-5.4

This graph shows LOAD vs WEAR at 5 N. The wear loss increases while load increases. The graph is linear in nature , this shows linear relationship between load and wear.

GRAPH-5.5

This graph shows LOAD vs WEAR at 10 N. The wear loss increases while load increases. The graph is linear in nature , this shows linear relationship between load and wear.

GRAPH-5.6

This graph shows LOAD vs WEAR at 15 N. The wear loss increases while load increases. The graph is linear in nature , this shows linear relationship between load and wear. In this graph wear loss is more as compare to graph 1 and graph 2.

CONCLUSION

It is concluded from the above discussion that wear is function of applied load. Initially, it was understood that wear depends upon applied load, surface parameters and mechanical properties such as hardness, toughness etc. Thus it can be concluded that:

- There is a linear relationship between wear and load
- The wear loss increases while load increases. Wear loss is more at 15 N load as compare to 5 N and 10 N load.
- The wear loss increases while RPM increases.
- The wear loss in first minute is more as compare to last minute while increasing the RPM

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