Indian Institute of Technology Kanpur

Project Report On:

Comparative Wear Analysis of SS304 Stainless Steel and LM6/ALSi10Mg Against AISI 52100 Bearing Steel Under Varying Loads

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Presentation Outline

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Objectives of the Study

- Analyze the wear behavior of **SS304 stainless steel** and LM6/ALSi10Mg using a ball-on-disk tribometer setup with a stationary AISI 52100 bearing steel ball as the counter face material.
- Investigate the **effect of controlled normal loads** (1N, 3N, and 5N) on the wear performance of these materials.
- Investigate critical **performance indicators** such as:
  - Specific wear rate
  - Coefficient of friction
  - Predominant wear mechanisms
- Derive insights into the **tribological suitability of each material** under defined operating conditions.

Motivation

Frequent wear seen in aluminum track buckets used for sand transport

Comparison of hardness of LM6/ALSi10Mg , 5083-H116 and SS304		
LM6/ALSi10Mg	5083-H116	SS304
60-80HV	75-100HV	150-200HV

Comparison of hardness of AISI52100 steel ball and Quartz Sand	
AISI52100 steel ball	Quartz Sand
800-900HV	800-1000HV

Wear Fundamentals

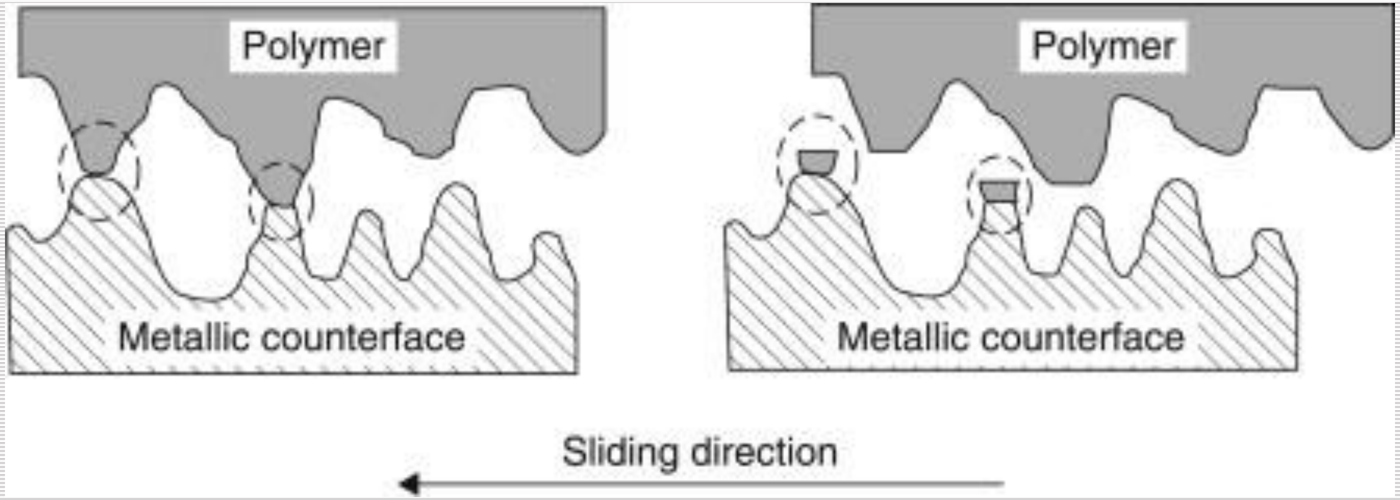
- Wear is the gradual deterioration of a material caused by repeated contact and relative motion between surfaces.
- A fundamental concern in tribology, it significantly impacts the functionality and service life of mechanical systems.

Fig – 1 Corrosive wear on iron tube [1]

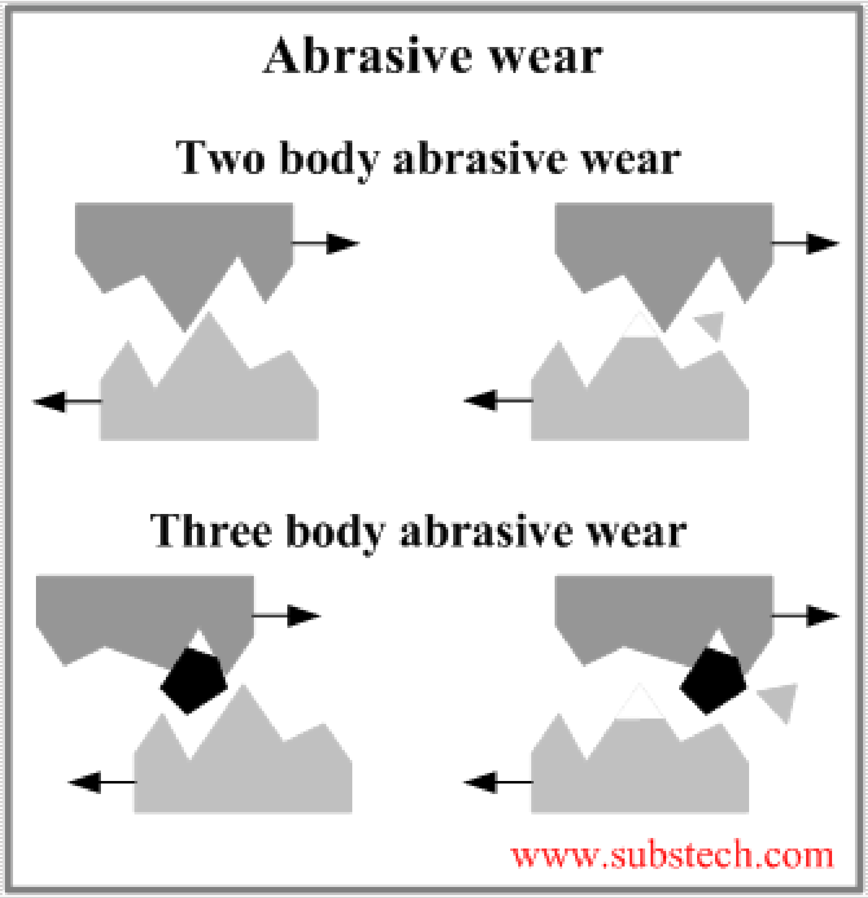
Abrasion type wear of gear

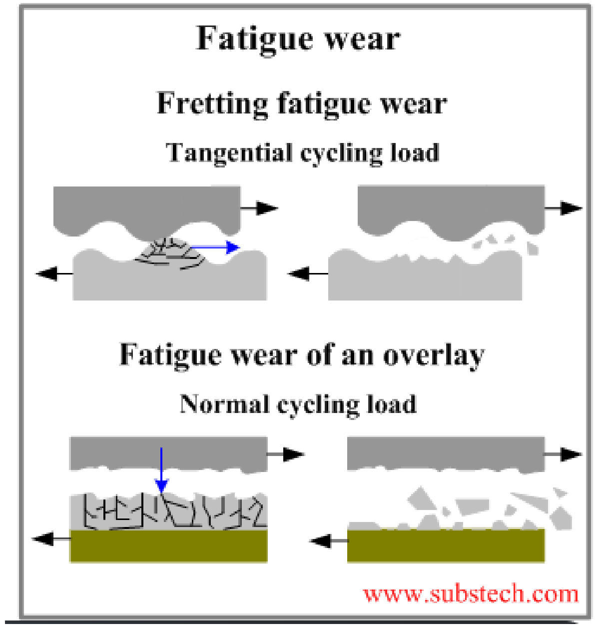
Image courtesy : Google

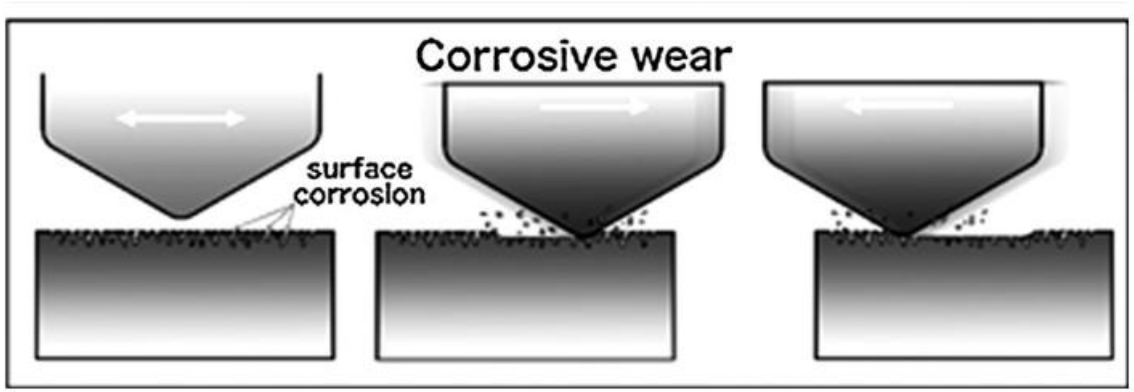
Wear Fundamentals Continued……..

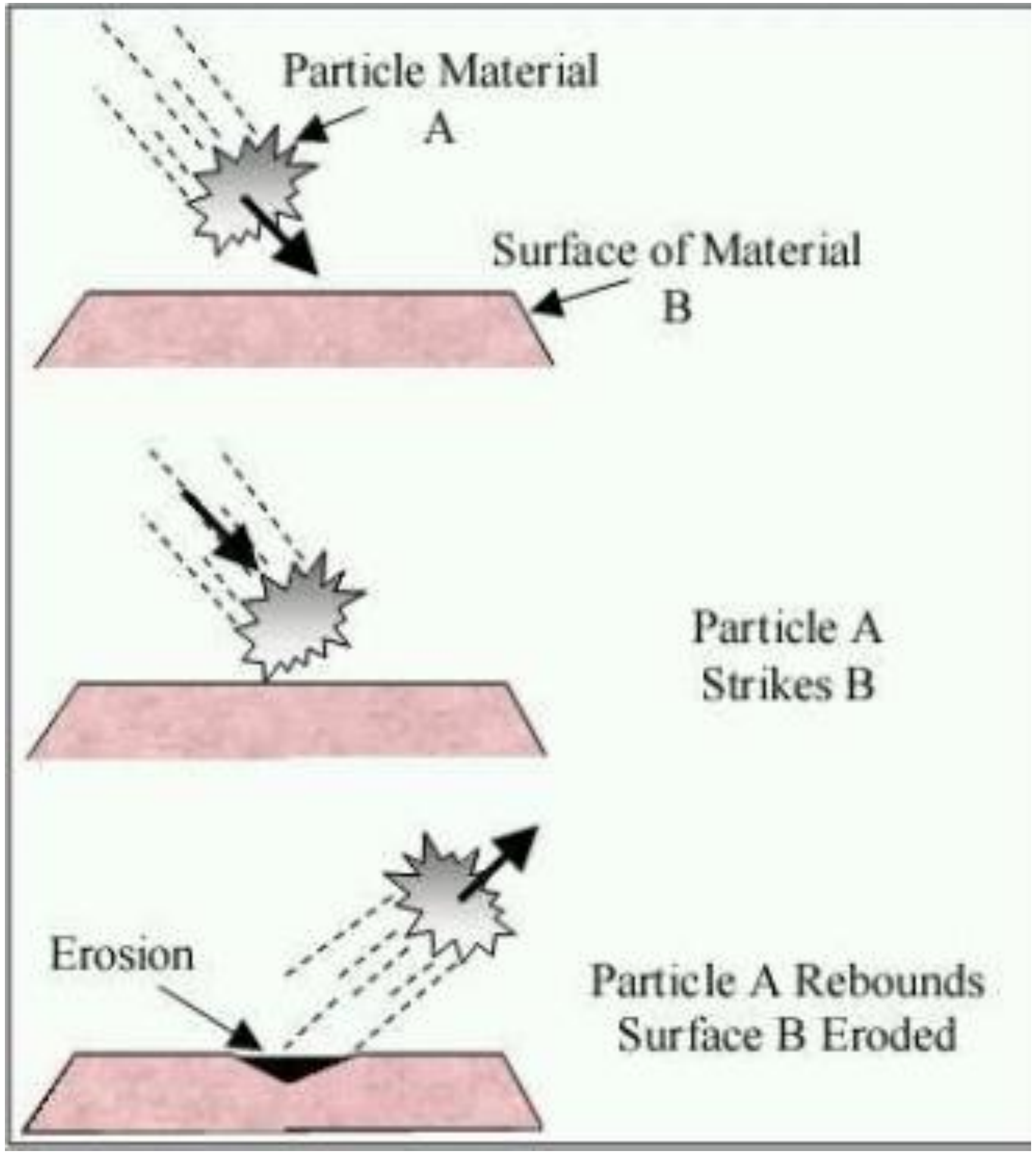


Adhesive wear









__Erosive wear__

Materials and Method

- The experimental wear analysis was conducted using LM6/ALSi10Mg and SS304 stainless steel as test specimens, with AISI 52100 bearing steel serving as the counter face material

S.No	Property	SS304 Stainless Steel	LM6/ALSi10Mg	AISI 52100 Bearing Steel
1	Yield Strength (MPa)	215	120	1200
2	Elastic Modulus (GPa)	193	70	210
3	Poisson Ratio	0.3	0.3	0.3
4	Vickers hardness (HV)	150-200	60-80	800-900
5	Density (gm/cm^3)	7.93	2.65	7.81

Sample Preparation for Wear Testing

- **Importance of Sample Preparation:** Ensures accurate and reproducible wear rate analysis by controlling surface finish, cleanliness, and dimensional consistency.
- **Sample Dimensions: 15mm × 15mm × 3mm** (for both SS304 Stainless Steel & LM6).

Polishing Process:

<table>
<tr><th>Sample</th><th>Abrasive Used</th><th>Polishing Speed (rpm)</th><th>Duration (min)</th><th>Polishing Medium</th></tr>
<tr><td rowspan="2">Steel (SS304)
(Sample 1 and 2)</td><td>G220 Abrasive
(Slightly Rough)</td><td rowspan="4">200</td><td rowspan="4">15</td><td rowspan="4">Water</td></tr>
<tr><td>G1000 Abrasive
(Fine Surface)</td></tr>
<tr><td rowspan="2">LM6
(Sample 1and 2)</td><td>G220 Abrasive</td></tr>
<tr><td>G1000 Abrasive</td></tr>
</table>

Drying & Cleaning Process:

Drying:

- Samples are dried using a blower to remove moisture and prevent contamination before wear testing.

Cleaning with Acetone:

- Removes polishing debris and contaminants to prevent artificial wear.
- Ensures accurate, consistent analysis by standardizing surface conditions

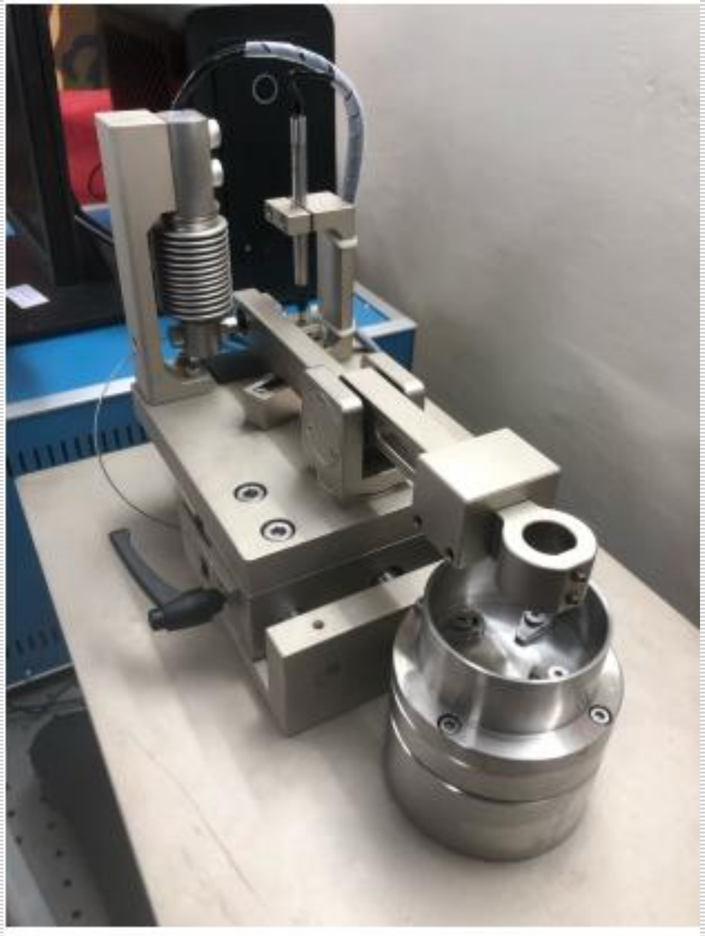
Test Procedures

01
- **Sample Mounting**
  - Secure SS304 and LM6 disks
  - Fix AISI 52100 ball in tribometer

02
- **Load Application:**
  - Set desired load using tribometer controls

03
- **Test Configuration:**
  - Define rotational speed, duration, and track radius
  - Ensure ball-disk contact under applied load

04
- **Data Collection:**
  - Acquire real-time data
  - Calculate wear volume and rate



Experimental Parameters

- Wear tests were performed using a ball-on-disk setup.
- AISI 52100 steel ball used against SS304 and LM6 disks.
- Test duration fixed at 25 minutes for all conditions.
- **Rotational speed and radius** adjusted to maintain a constant sliding distance.

Load (N)	Rotational Speed (RPM)	Track Radius (mm)	Hertzian contact Pressure for LM6 (MPa)	Hertzian contact Pressure for SS304 (MPa)	Test Duration (min)
1	300	3	597	907	25
3	180	5	860	1305	25
5	225	4	1022	1550	25

Test Procedure Continued….

05

- After testing, Profilometer provides micron-level resolution for:
  - Track depth
  - Track width
  - Volume of material lost

06

- Measurements help correlate surface degradation with:
  - Load conditions
  - Material properties
  - Dominant wear mechanisms

Wear Rate and Wear Volume Calculation

Wear Volume Formula:

$$V = \bar{a} \times 2\pi r$$

$$\bar{a} = (a_1 + a_2 + a_3) / 3 \text{ (average cross-section)}$$

Where ,

$\bar{a}$ is the average cross-sectional area of wear track

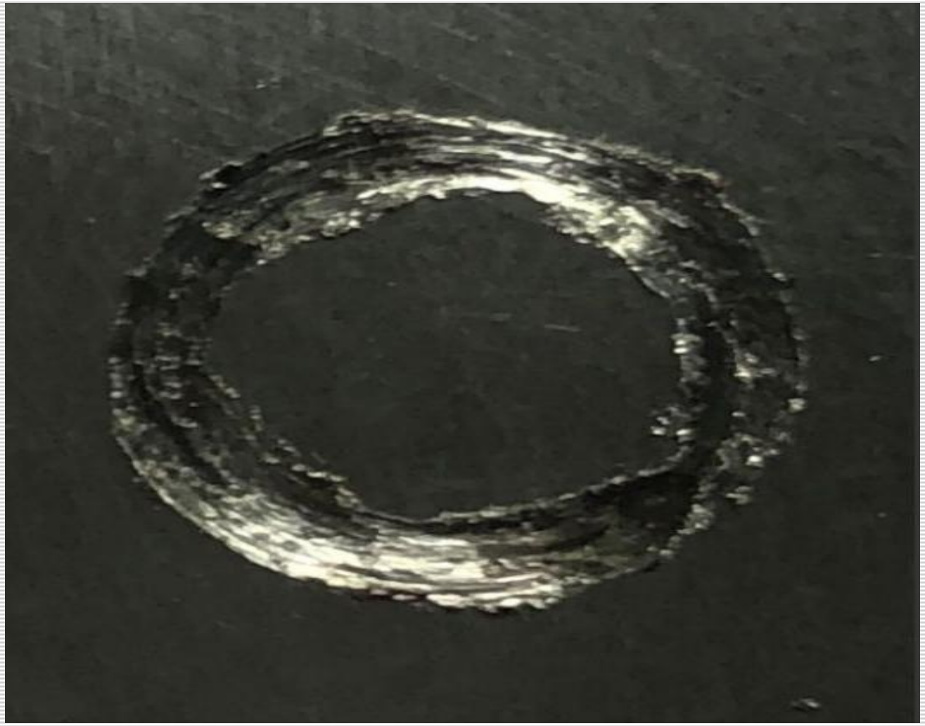
Sliding Distance (ls):

$$l_s = (2\pi \times N \times r \times t) / 60$$

Final Wear Rate:

- $Q = V / l_s = (60 \times \bar{a}) / (N \times t)$
- $W_s = Q / W = (60 \times \bar{a}) / (W \times N \times t)$

Wear analysis and experimental Results



Experimental Results

Wear Analysis of Al against AISIE 52100 Bearing steel ball

Experimental Results –LM6 at 1N

Cross Section No.	Wear Depth (μm)	Wear Width (mm)	Cross-Sectional Area ($\times 10^{-3} mm^2$)
1	-16.7282	0.8374	26.1180
2	-17.9534	0.6680	20.6330
3	-22.9983	0.8737	27.4940

Table 2: Wear track measurements from optical profilometer for Al disk under 1N normal load.

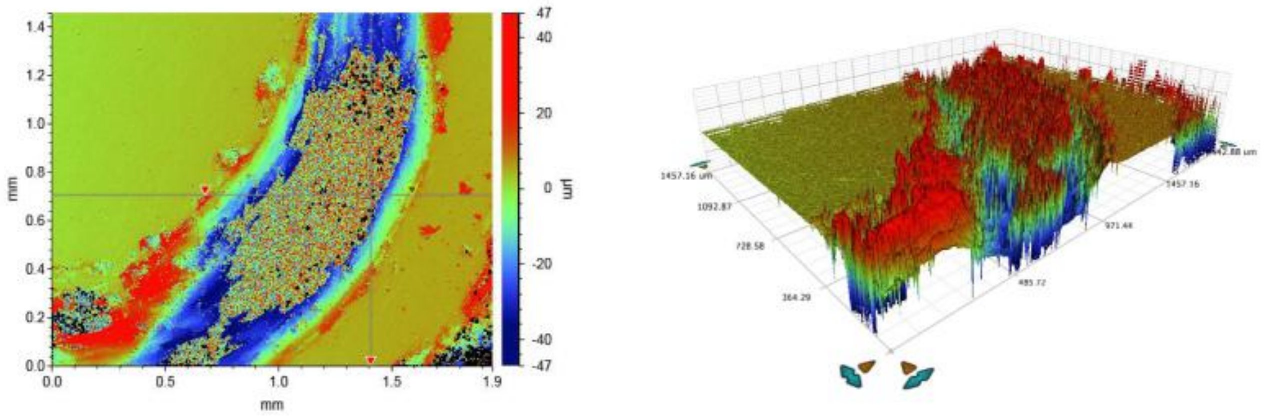
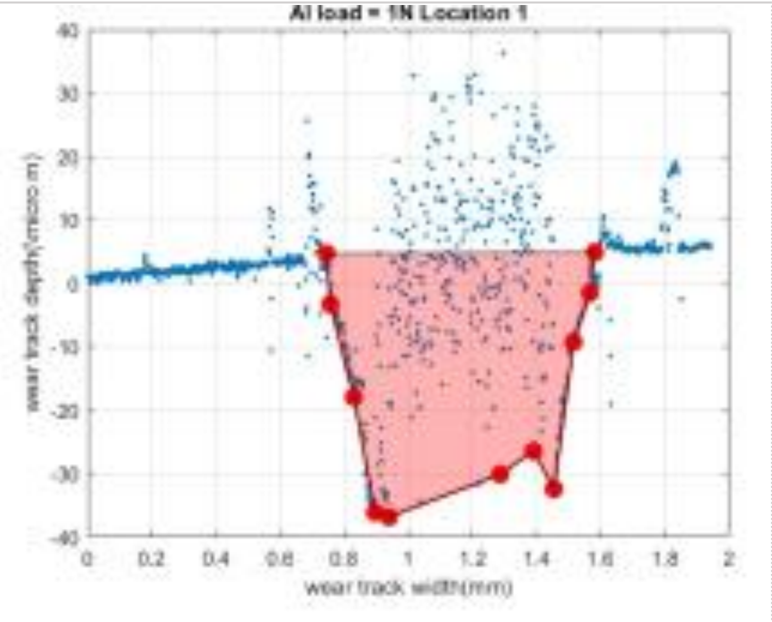
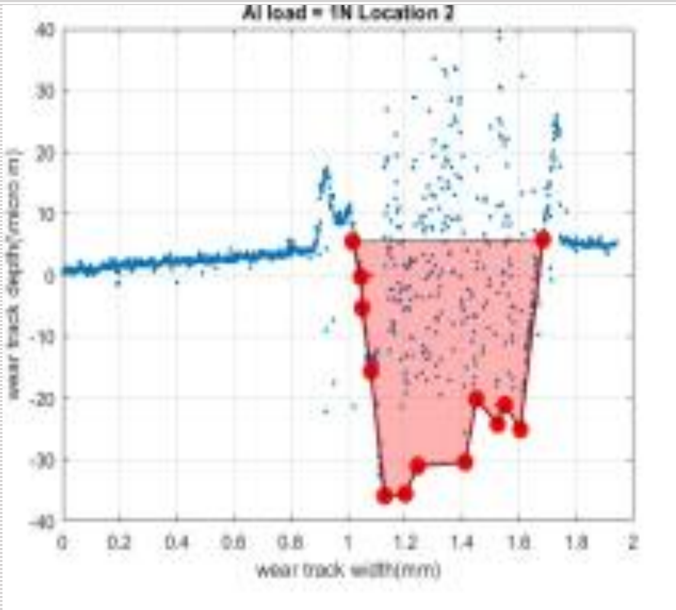


Figure 4: 2D (left) and 3D(right) images of wear track on Al disk under 1N load obtained from optical profilometer.

Experimental Results Continued….





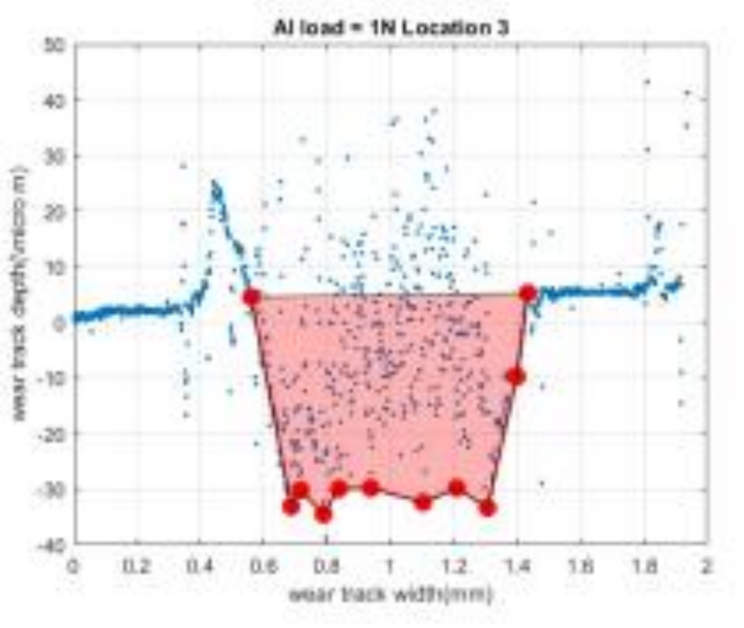


Figure 5: Cross sectional view of wear track at three locations for Al disk under 1N load obtained from optical profilometer.

- **Calculated Specific Wear Rate , $W_s \approx 3.30 \times 10^{-3}$ mm³/mN**

Experimental Results Continue - LM6 at 3N

Cross Section No.	Wear Depth (µm)	Wear Width (mm)	Cross-Sectional Area ($\times 10^{-3}$mm^2)
1	-24.6560	0.7796	33.7782
2	-17.2497	0.8320	21.1780
3	-26.4581	0.8737	33.8908

Table 3: Wear track measurements from optical profilometer for Al disk under 3N normal load.

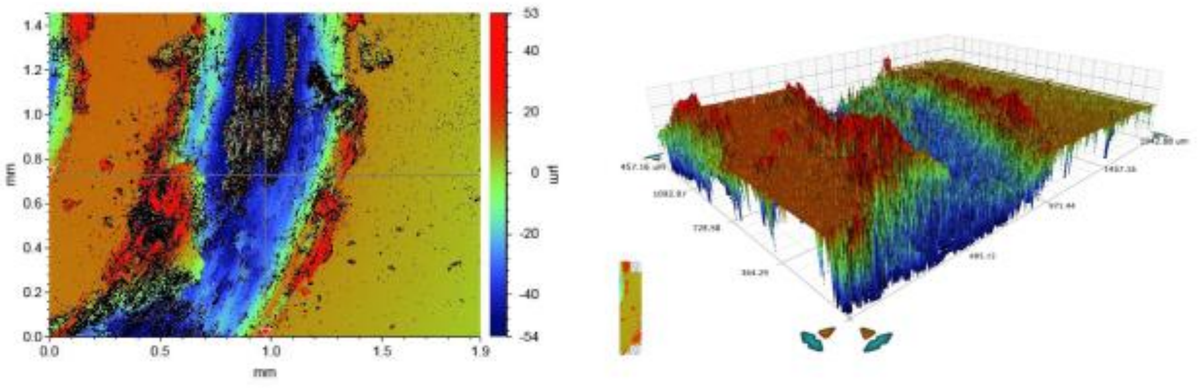


Figure 6: 2D (left) and 3D(right) images of wear track on Al disk under 3N load obtained from optical profilometer.

Experimental Results Continued…..

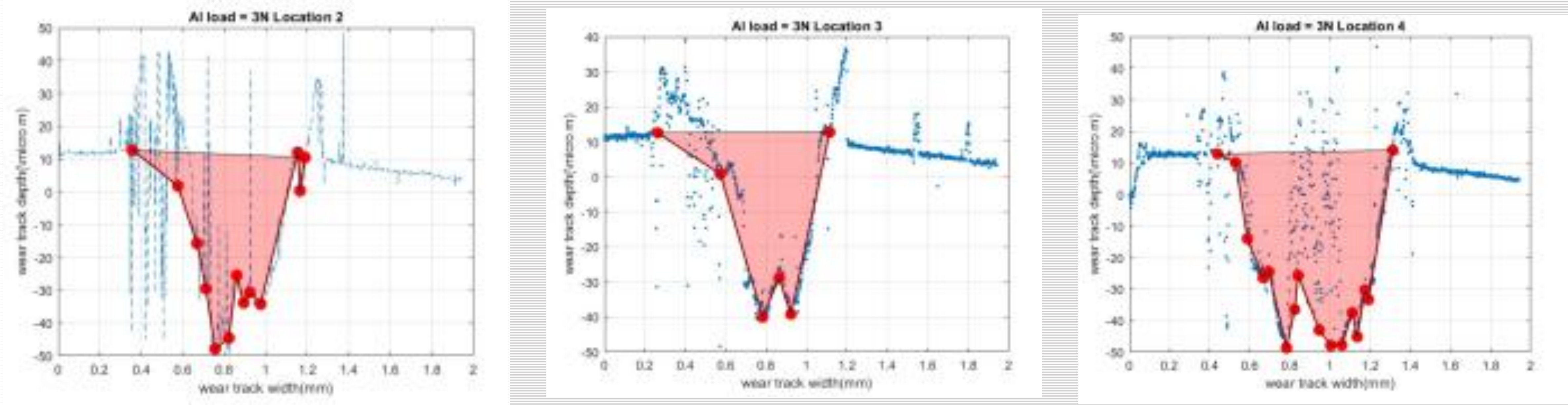


Figure 7: Cross sectional view of wear track at three locations for Al disk under 3N load obtained from optical profilometer.

Calculated Specific Wear Rate: $W_s \approx 2.19 \times 10^{-3}\ \mathrm{mm^3/mN}$

Experimental Results Continue - LM6 at 5N

Cross Section No.	Wear Depth (μm)	Wear Width (mm)	Cross-Sectional Area ($\times 10^{-3}$mm^2)
1	-32.3832	0.9834	42.7578
2	-33.6729	0.9503	44.7054
3	-30.1090	0.9908	40.9516

Table 4: Wear track measurements from optical profilometer for Al disk under 5N normal load.

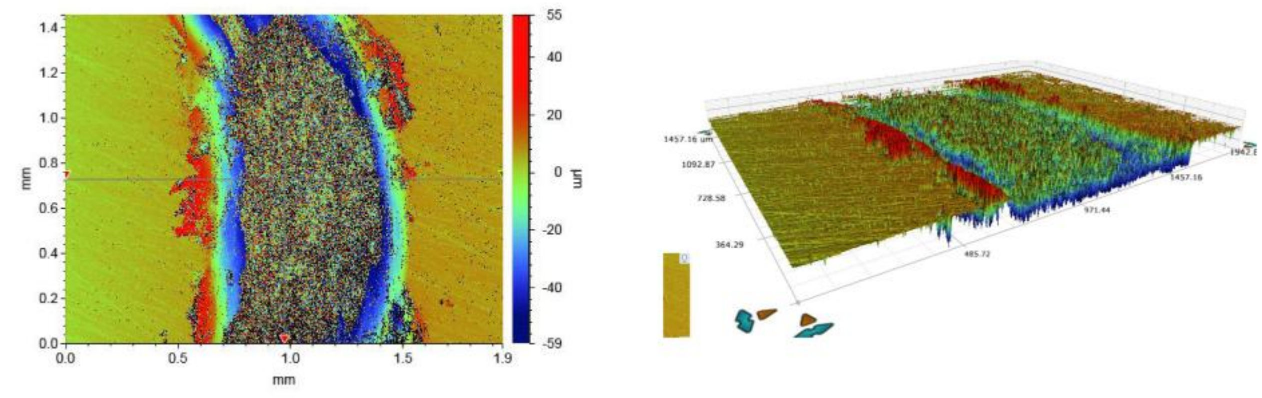
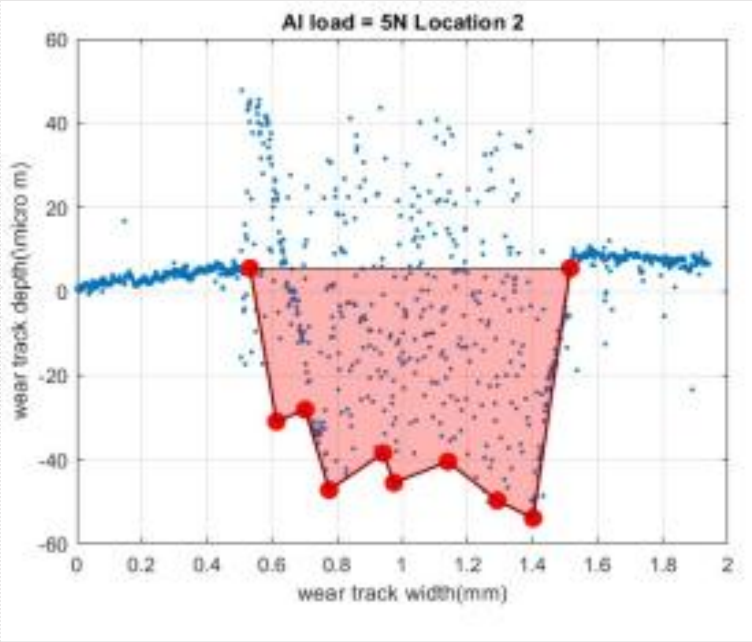
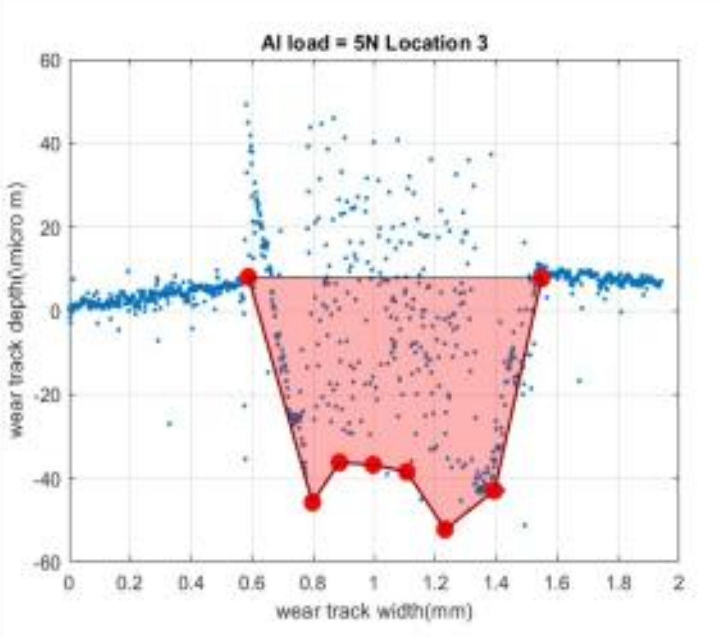


Figure 8: 2D (left) and 3D(right) images of wear track on Al disk under 5N load obtained from optical profilometer.

Experimental Results Continued….





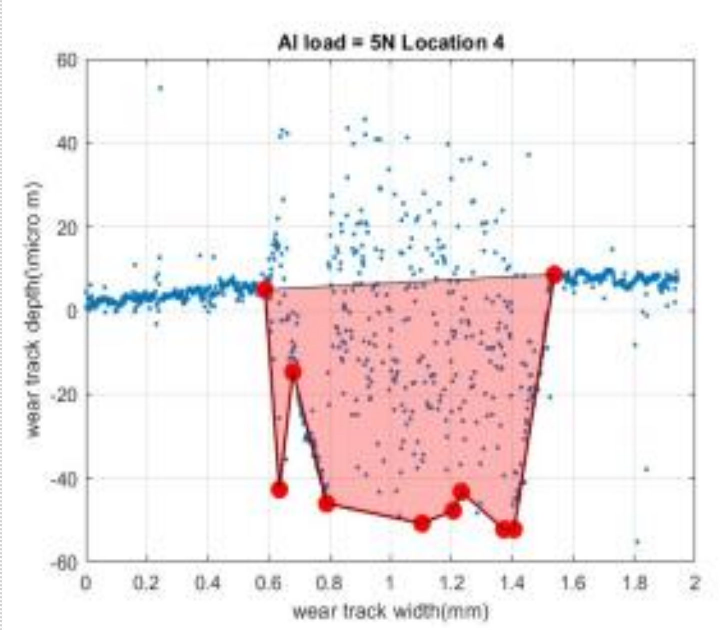


Figure 9: Cross sectional view of wear track at three locations for Al disk under 5N load obtained from optical profilometer.

Calculated Specific Wear Rate: $W_s \approx 1.52 \times 10^{-3}$ **mm³/mN**

Experimental Results

Wear Analysis of HS304 SS against AISIE 52100 Bearing steel ball

Experimental Results Continues SS304 at 1N Load

Cross Section No.	Wear Depth (μm)	Wear Width (mm)	Cross-Sectional Area ($\times 10^{-3} mm^2$)
1	-19.6527	0.2689	6.0591
2	-18.8155	0.1640	4.4883
3	-17.1407	0.2231	4.4360

Table 5: Wear track measurements from optical profilometer for HS304 Stainless steel disk under 1N normal load.

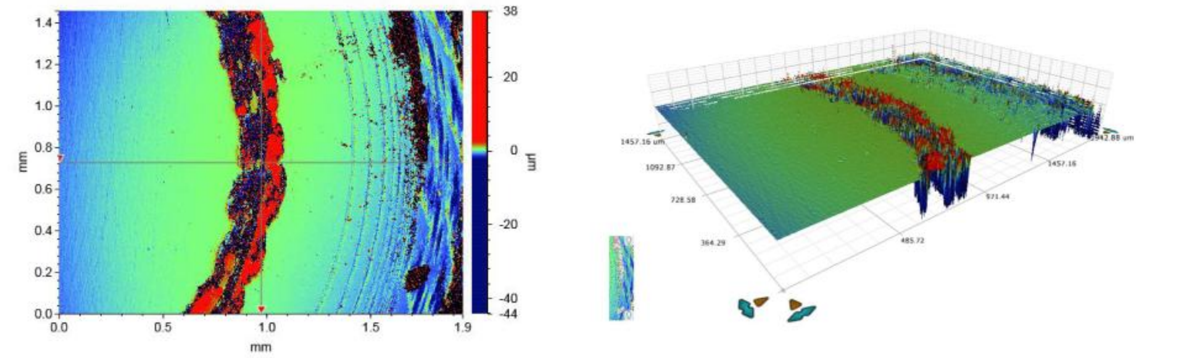


Figure 11: 2D (left) and 3D(right) images of wear track on HS304 SS disk under 1N load obtained from optical profilometer.

Experimental Results Continued….

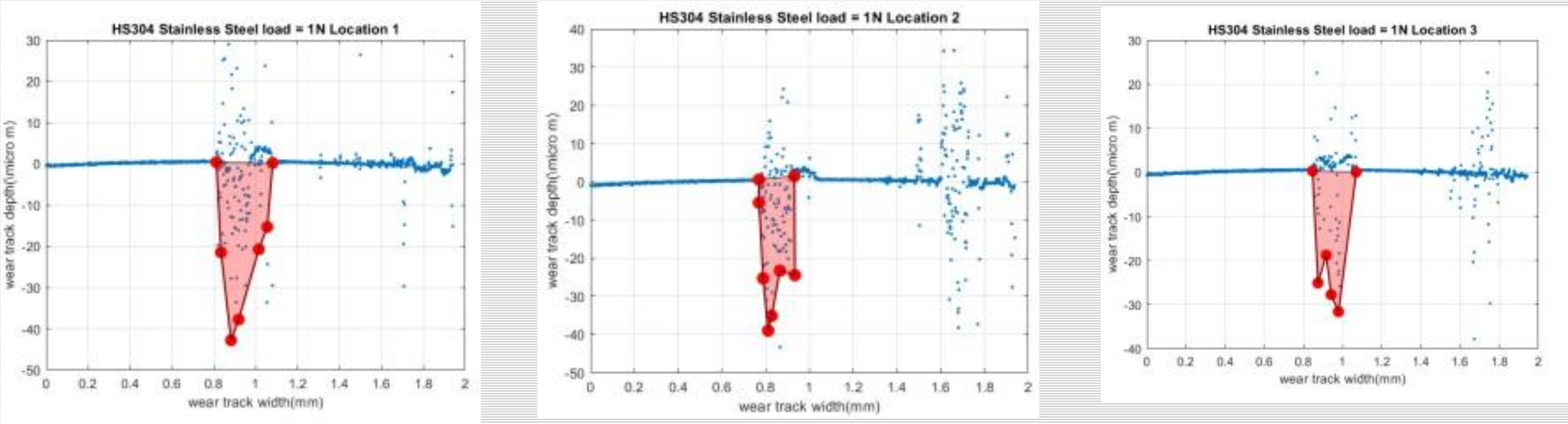


Figure 12: Cross sectional view of wear track at three locations for HS304 SS disk under 1N load obtained from optical profilometer.

Calculated Specific Wear Rate: $W_S \approx 0.044 \times 10^{-3}$ mm³/mN

Experimental Results Continues SS304 at 3N Load

Cross Section No.	Wear Depth (μm)	Wear Width (mm)	Cross-Sectional Area ($\times 10^{-3} mm^2$)
1	-27.1562	0.3352	11.0249
2	-15.6907	0.3278	7.9452
3	-22.3231	0.2799	7.9186

Table 6: Wear track measurements from optical profilometer for HS304 Stainless steel disk under 3N normal load.

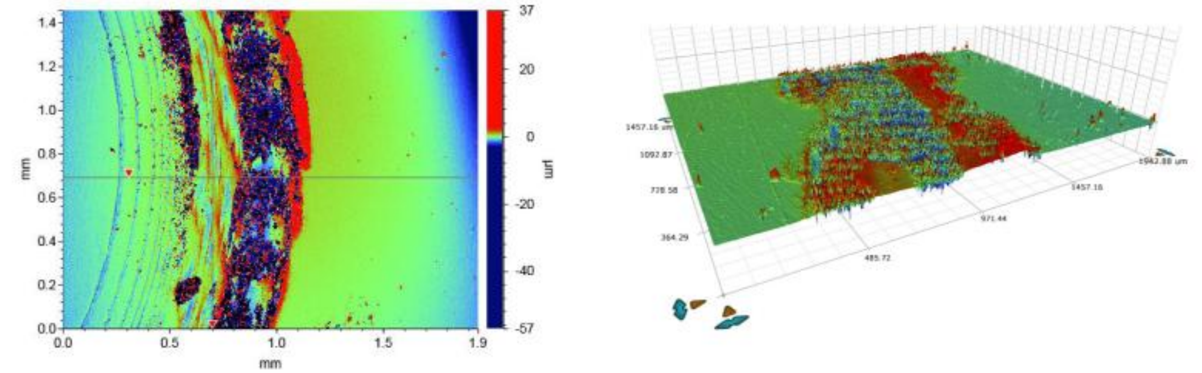


Figure 13: 2D (left) and 3D(right) images of wear track on HS304 SS disk under 3N load obtained from optical profilometer.

Experimental Results Continued….

Figure 14: Cross sectional view of wear track at three locations for HS304 SS disk under 3N load obtained from optical profilometer.

Calculated Specific Wear Rate: $W_s \approx 0.664 \times 10^{-3}$ mm³/mN

Experimental Results Continues SS304 at 5N Load

Cross Section No.	Wear Depth (µm)	Wear Width (mm)	Cross-Sectional Area ($\times 10^{-3} mm^2$)
1	-30.8013	0.6156	29.6979
2	-33.3664	0.5511	27.7286
3	-35.6645	0.5296	27.6172

Table 7: Wear track measurements from optical profilometer for HS304 Stainless steel disk under 5N normal load.

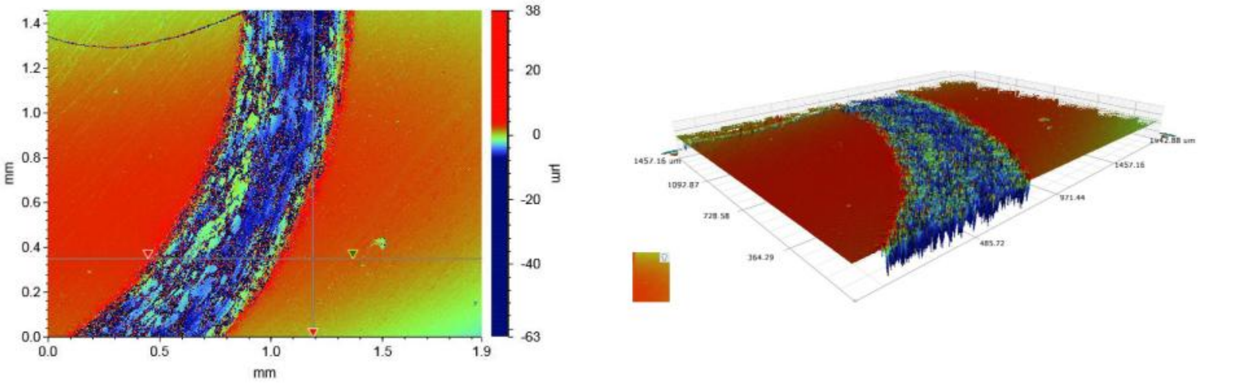


Figure 15: 2D (left) and 3D(right) images of wear track on HS304 SS disk under 5N load obtained from optical profilometer.

Experimental Results Continued….

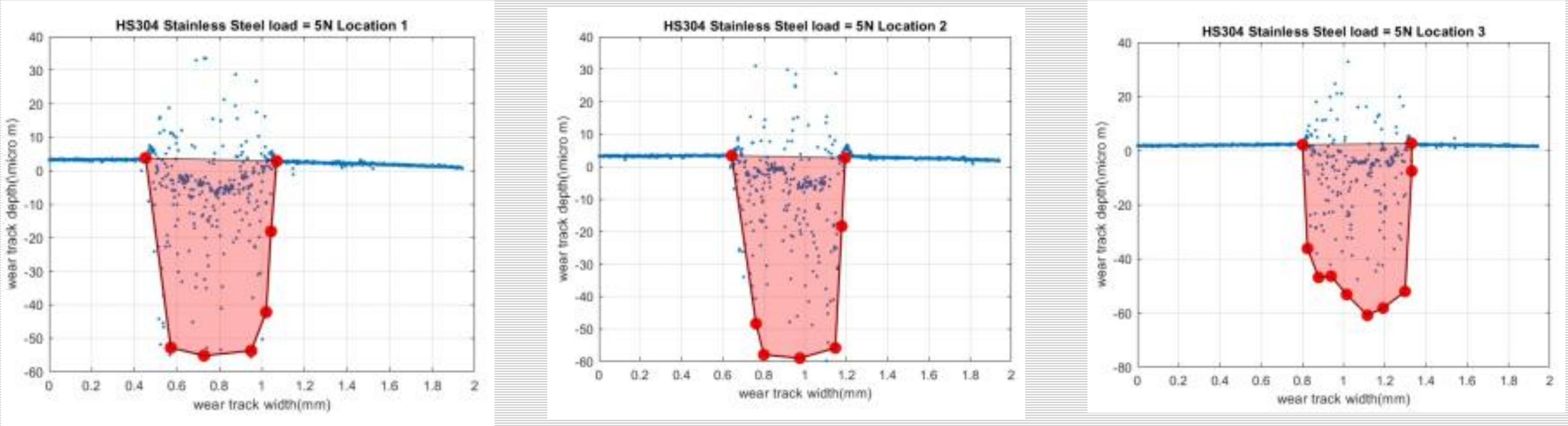


Figure 16: Cross sectional view of wear track at three locations for HS304 SS disk under 5N

Calculated Specific Wear Rate: $W_S \approx 1.01 \times 10^{-3}$ **mm³/mN**

Comparative wear rate summary of LM6 and SS304 SS

Load (N)	Specific Wear Rate – LM6 ($mm^3/N \cdot m$)	Specific Wear Rate - HS304 SS ($mm^3/N \cdot m$)	Dominant Wear Mechanism – LM6	Dominant Wear Mechanism - SS304 SS
1 N	3.2998×10^{-3}	0.0444×10^{-3}	Adhesive & Abrasive Wear	Mild Abrasive Wear
3 N	2.1938×10^{-3}	0.6639×10^{-3}	Transition To Tribolayer Formation	Increase In Abrasive Wear
5 N	1.5219×10^{-3}	1.0079×10^{-3}	Stable Tribolayer Formation	Micro-plastic Deformation

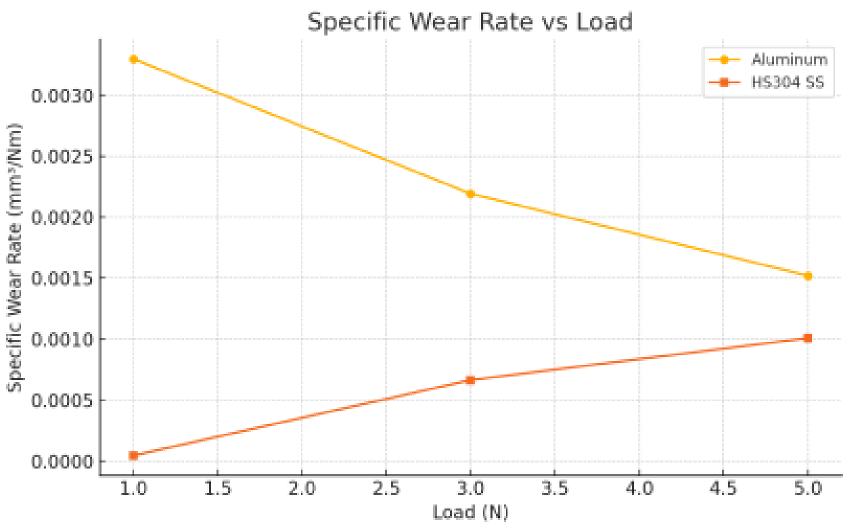
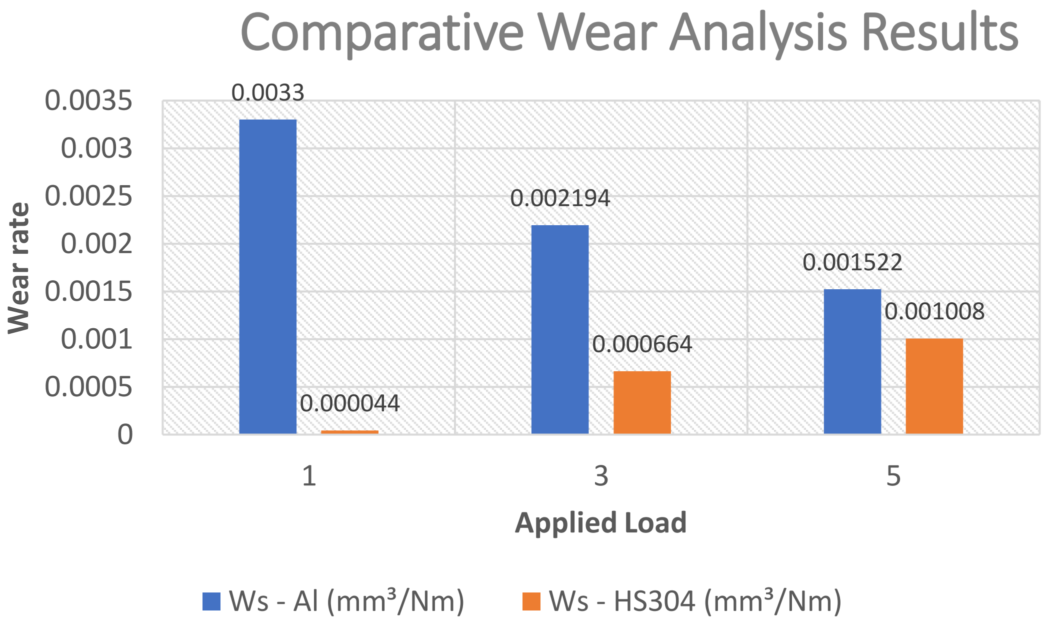


Figure 17: Comparison of specific wear rates of Aluminum and HS304 stainless steel under different loads.



Summary and **Conclusion**

- This study evaluated the wear behavior of aluminum and SS304 stainless steel against AISI 52100 bearing steel.
- Tests were performed under 1N, 3N, and 5N normal loads using a ball-on-disk tribometer.
- Optical profilometry provided precise analysis of wear track depth, width, and cross-sectional area.
- Specific wear rates and wear mechanisms were compared across materials and load levels.

Conclusion Continued…..

LM6

- Decreasing trend attributed to formation of tribolayer under higher loads
- High coefficient of friction (~**0.93**) due to:
  - Soft material nature
  - Strong adhesion with counter face
  - Significant plowing action

SS304 Stainless Steel

- Coefficient of friction is lower than aluminum (~0.58–0.67)
- Wear features indicate more controlled surface degradation

Tribological Insights: Load-Dependent Wear Behavior

LM6 Wear Behavior:

- Higher wear under low load
- Improved resistance at higher loads
- Likely due to load-induced protective layers

SS304 Stainless Steel Wear Behavior:

- Superior wear resistance at low loads
- Gradual deterioration as load increases

General Outlook and Future Scope

- Perform **long-duration wear tests** to evaluate the stability of the **tribo layer** at high loads.
- Study **wear behavior under high temperatures and corrosive environments** for real-world relevance.
- Extend the load range beyond 5N to examine extreme wear scenarios.
- Test different sliding speeds to understand how velocity influences wear mechanisms.
- Use SEM to characterize the tribolayer’s composition, thickness, and structure.
- Create a computational model to simulate tribolayer formation and predict wear behavior.

Acknowledgement

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THANK YOU

Q&A?