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Selection of Suitable Material for Journal Bearing by Tribology

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***Abstract:** Wear is an influencing parameter which reduces the overall life of a machine and its parts. The wear rate and coefficient of friction under the same conditions of speed, load, lubrication and time were calculated for a set of materials used as journal bearings. Since journal bearings are important in a variety of applications, a wise selection of material with a constant low wear rate and low coefficient of friction is essential. The four materials tested for this purpose include Molybdenum Disulphide (MoS_2), Stainless Steel (SS 304), Nylon 66, INCONEL 625. The basic methodology for determining wear and friction of these materials involves the use of a pin-on-disc test apparatus. The materials taken for testing are made into a pin of diameter and length 8 mm and 25 mm respectively. Scanning Electron Microscope (SEM) analysis and surface roughness measurements were carried out to study the properties. Hence, INCONEL 625 was found to be the ideal material for journal bearing applications due to its low wear rate, no fluctuation in wear rate, lower coefficient of friction and better mechanical properties compared to others.*

***Keywords:** Disulphide (MoS_2), Stainless Steel (SS 304), Nylon 66, INCONEL 625.*

I. INTRODUCTION

Tribology is vital to modern-day machinery which involves the use of rolling and sliding surfaces in contact. It comprises the study of principles of friction, lubrication and wear of surfaces with a perspective of comprehending surface interactions in detail and then analyzing the modifications in the respective fields. The tribology study involves directly depends on the force of friction as per the requirement, either minimum or maximum.

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Friction and wear are the most important factors that affect the life of machines and tools. Journal bearings find their application in high speed and heavy load applications where low wear rate and low coefficient of friction are desirable. Lubrication is done to reduce the friction and undue wear in Journal bearings where there is a direct contact between two metals of moving parts which are in relative motion in a wide range of applications.

The properties of journal bearings were calculated by measuring the temperature of lubrication oil and the coefficient of friction when a normal load is applied according to tribology. The wear rate and coefficient of friction were measured from the Pin-On-Disc experimental setup for all the materials under study.

Sanjay Kumar et al.[1] experimented five different materials for journal bearing applications namely Nylon, PTFE, Nickel, Nickel Chrome, Molybdenum Disulphide and concluded that Molybdenum disulphide is the best suitable material because of its minimal rate of wear, lower coefficient of friction and preferred properties. Voong M et al.[2] tested the crankshaft bearings of IC engines with low wear rate which are made of Al-Si alloys with the same viscosity and it was inferred that materials which have high ferrous based content are influential in reducing wear and friction. Gwidon W Stachowiak et al.[3] explains the impact of wear on metallic materials i.e. polymers and ceramics. In case of ceramics, which offers high temperature resistance and wear resistance but has poor coefficient of friction when it is not lubricated, whereas in the case of polymers, has low wear and coefficient of friction but is vulnerable to high temperatures, high speeds and loads and both of them are affected by wear when corrosive reagents are present. E. Feyzullahoglu et al.[4] examined the brass and tin-based alloys which are subjected to oil lubrication and was inferred that brass proved to be a wise selection as its performance in oil-lubricated conditions was superior to tin-based alloys because of its hardness and moreover its wear rate is also low at same loading conditions. Boncheol Ku et al.[5] discussed tribological properties of PTFE and aluminium alloys used in journal bearings and inferred that aluminium alloy journal bearings are effective in reducing the coefficient of friction by 28%.T Miyajima et al.[6] examined the wear properties of Al-Sn-Si alloy coated with MoS_2 layer subjected to lubrication and observed that the coating of MoS_2 layer lowered the friction by 70% than Al-Sn-Si alloy without coating. Bekir Sadik Unlu et al.[7] devised a new approach to examine the friction coefficient of bronze radial bearings and observed that high coefficient of friction and wear rate in dry conditions and less friction coefficient and wear rate in lubricated conditions.

Shiv Kumar et al.[8] observed a lower wear rate at lower loads (30N and 40N) on hardened and tempered steel when compared to forced air-cooled steel. The rate of wear increases for hardened and tempered steel at high loads (40N),because of its poor work hardening characteristics than the forced air-cooled steel and a shorter duration of oxidative wear with the abrasive wear being predominant.

Jens Wahlstorm et al.[9] observed that coefficient of friction and disc temperatures are similar for all contact pairs after the run and indicated that particle emissions are reduced by 50% when the disc is coated with WC/CoCr coating. Matteo Federici et al.[10] inferred that in coating materials having low hardness, constant coefficient of friction is reached sooner. Moreover at elevated temperatures (300°C) due to thermal softening there is a formation of broad and thick friction layer which contributes to the constant coefficient of friction from the beginning of the experiment. R Venkatesh et al.[11] experimented a comparative study of silicon carbide coated and uncoated high-speed steel and observed less volume loss, wear rate and compressive stress in coated material when compared to the latter. Moreover, temperature rise in coated material was lesser thereby resulting in lesser thermal stress. Jiang et al.[12] tested the behaviour of bearing materials coated with plasma-spray TiO_2 and concluded that copper-lead alloy which is paired with TiO_2 coating which is subjected to oil lubrication showed superior tribological performance. Banker et al.[15] analysed the wear behaviour of Inconel 600 when subjected to friction. During the application of friction, the wear increased as the load increased but eventually, the rate of wear started to decrease because of work hardening happening at the point of contact.

II. MATERIALS

Molybdenum disulphide (MoS2) is the most widely used solid lubricant material which is used in various bearing applications [14]. It consists of a three-layered structure in which the single layer of molybdenum atoms are present in between two layers of sulphide atoms which altogether forms a single monolayer of MoS2 which are held together by weak van der Waals forces thereby resulting in a low coefficient of friction. It is suitable for lubrication and bearing applications on account of its layered structure and a lower coefficient of friction. A pure MoS2 has yield strength of 821 Mpa. Nylon 66, a condensation polymer formed from two monomers containing six carbon atoms each has good fatigue and abrasion resistance. It has a tensile strength of 93 Mpa and Rockwell hardness of 88 HRC at 23°C. Stainless Steel 304 is an alloy made up of Chromium (18-20%) and Nickel (8-10.5%) which are the main non-ferrous constituents, with 50-70% of Fe which contributes to low wear rate. It has excellent corrosion and wear resistance which has a tensile strength of 515 Mpa and hardness value of 92 HRB and 201 HB thus making it suitable for journal bearing applications. INCONEL 625 is a superalloy that exhibits high strength properties and can withstand elevated temperatures. It mainly contains Nickel, Chromium and Molybdenum. There is a precipitation formation at a particular temperature i.e. 923-1148K which contributes to higher strength at a higher temperature which has a direct influence in reducing the wear rate. It has a tensile strength of 796 MPa[13]. The properties of the materials are shown in Table 1.

Table 1

Properties of materials

Materials	Melting Point(°C)	Hardness(HRC)	Colour
MoS_2	1185	22	Black
Nylon 66	269	18	White
SS 304	1450	32	Grey Silver
INCONEL625	1350	43	Grey Silver

Figure 1. Pin samples of (a) MoS_2 (b) Nylon 66 (c) SS304 (d) INCONEL 625

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III. EXPERIMENTAL SETUP

The basic methodology for determining wear and friction of these materials involves the use of Pin-On-Disc test apparatus. The pin-on-disc tribometer, which is of MAGNUM make, works on the principle of testing the wear and friction characteristics of either lubricated or dry sliding contact of a wide range of materials including metals, polymers, lubricants, composites, a slurry of abrasives, coating materials, and heat-treated specimens. Wear and friction were examined using Tribo DATA, which is the supplied Windows-based Data Acquisition Software. The materials tested for this purpose include Molybdenum Disulphide (MoS2), Stainless Steel (SS 304), Nylon 66, INCONEL 625 which finds their application in journal bearings. These materials are made into a pin of diameter and length 8 mm and 25 mm respectively, which is then mounted on a holder.To obtain similar surface conditions, each pin is finished with a abrasive paper. The disc material of EN 31 is rotated at a speed ranging from 500 to 1000 rpm. The parameters such as friction coefficient, values of temperature and rate of wear of the bearing coating material samples are recorded for a span of 60 minutes. The test is carried out for all materials using the same lubricant which in this case is 20W40 oil.

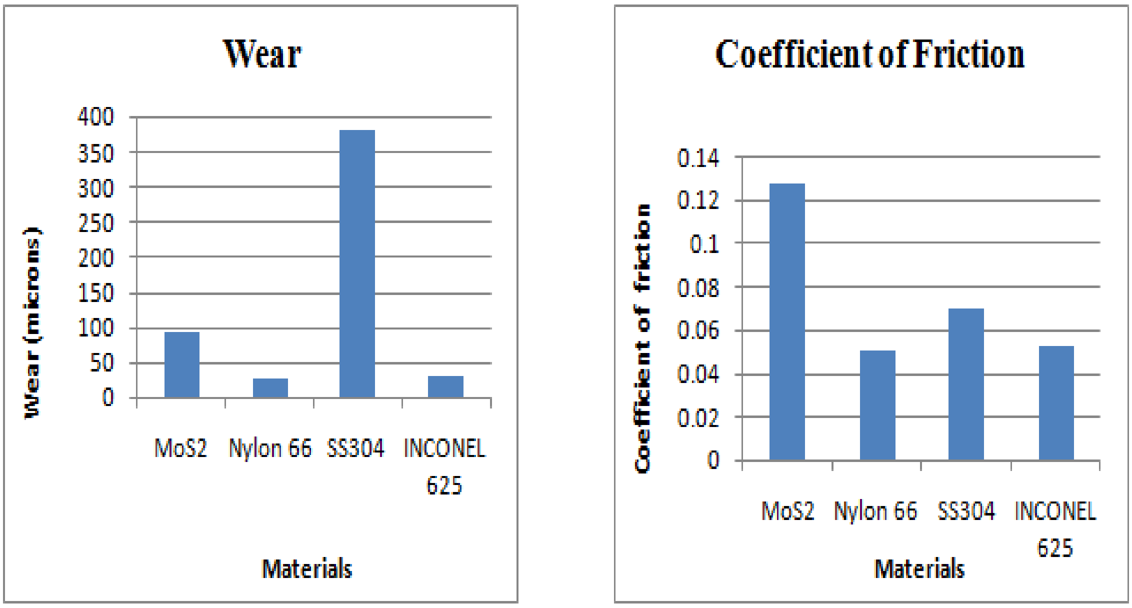
Table 2

Test parameters

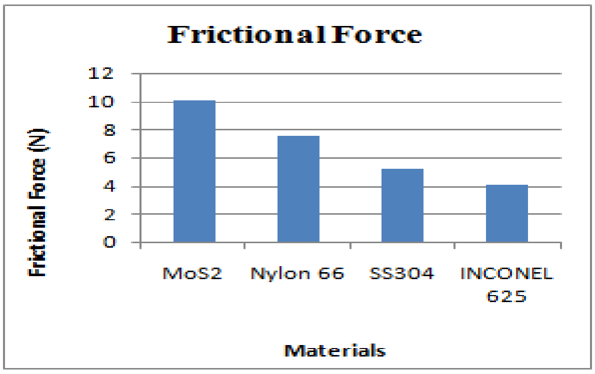
Pin Size	8 to 10 mm
Length of pin	25 mm
Disc Rotation Speed	500 to 1000 rpm
Normal Load	0 N to 200 N.
Wear Measurement Range	0 to 4microns.
Disc Material	EN34
Hardness of disc material	58 to 62 HRC
Lubricant	20W40 (HP)
Testing duration	15 mins
Speed	800 rpm
Velocity	1.07 m/s
Load	80 N
Wear track radius	65 mm

IV. RESULTS AND DISCUSSIONS

After the experiment has been carried out for the given duration of time, the results for all the test materials obtained are shown below in the figures 2,3 and 4.



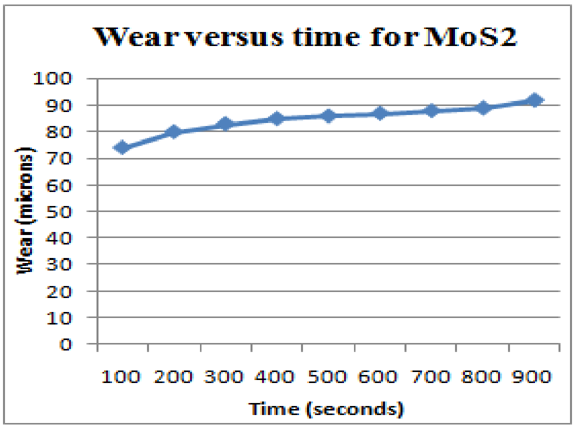
(a) (b)



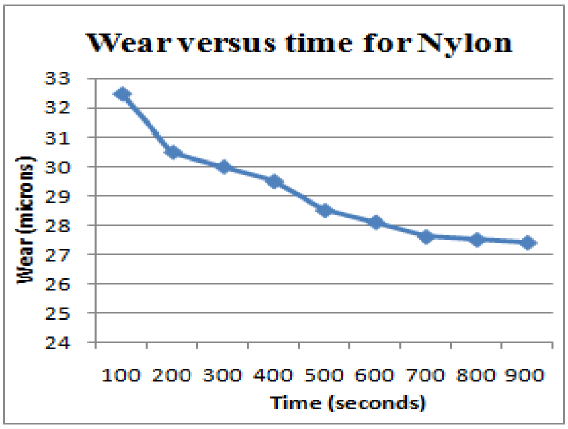
(c)

Figure 2. (a) Wear (b) Coefficient of friction (c) Frictional Force for all the materials

The above charts show the wear (microns), Coefficient of friction and Frictional Force (N) values for the tested materials. Once the experimental results were obtained the wear versus time plots and coefficient of friction versus time plots were plotted and are shown below in Figures 3 and 4. From the plots shown below, the material with a low wear rate and low coefficient of friction is selected for journal bearing applications.



(a)



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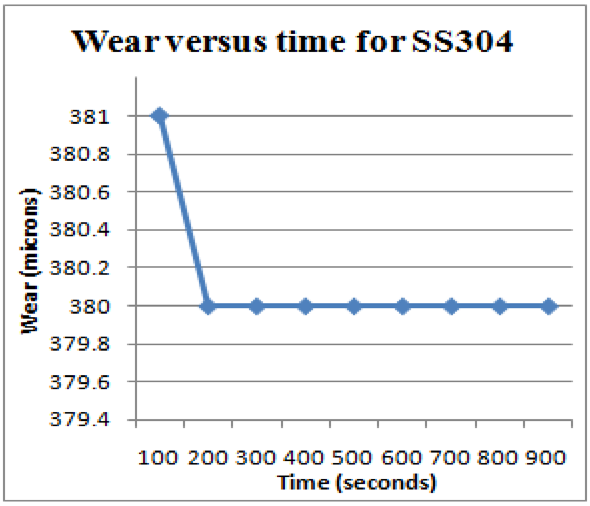

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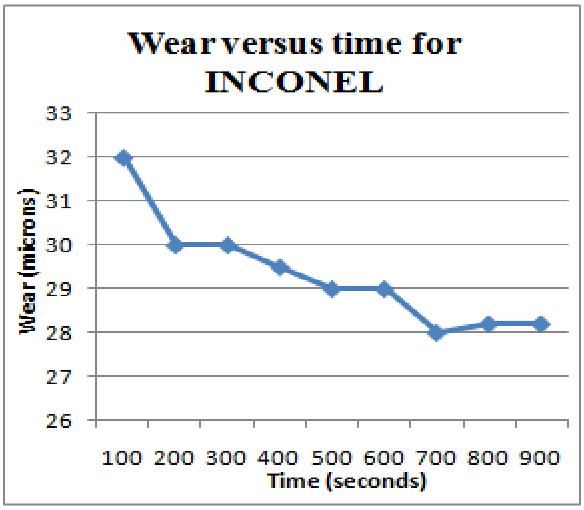

(d)

Figure 3. Wear versus time for (a) MoS_2 (b)Nylon 66 (c) SS304 (d) INCONEL 625

Figure 3 shows the wear versus time plot for the four test materials. From Figure 3 (a) we can observe that the wear rate is increasing for MoS_2. From Figure 3 (b) we can observe that the wear is decreasing with respect to time for Nylon 66. From Figure 3(c) we can observe that the wear is constant but the wear rate is high for SS304 when compared to other materials. From Figure 3 (d) we can observe that the wear is reducing and the wear rate is less for INCONEL 625. Wear, being a phenomenon of plastic deformation is comparatively lower in INCONEL 625 than the others because of its high tensile strength which enables it to undergo plastic deformation at a much higher value. Wear rate decreases on account of precipitation hardening which occurs with time.

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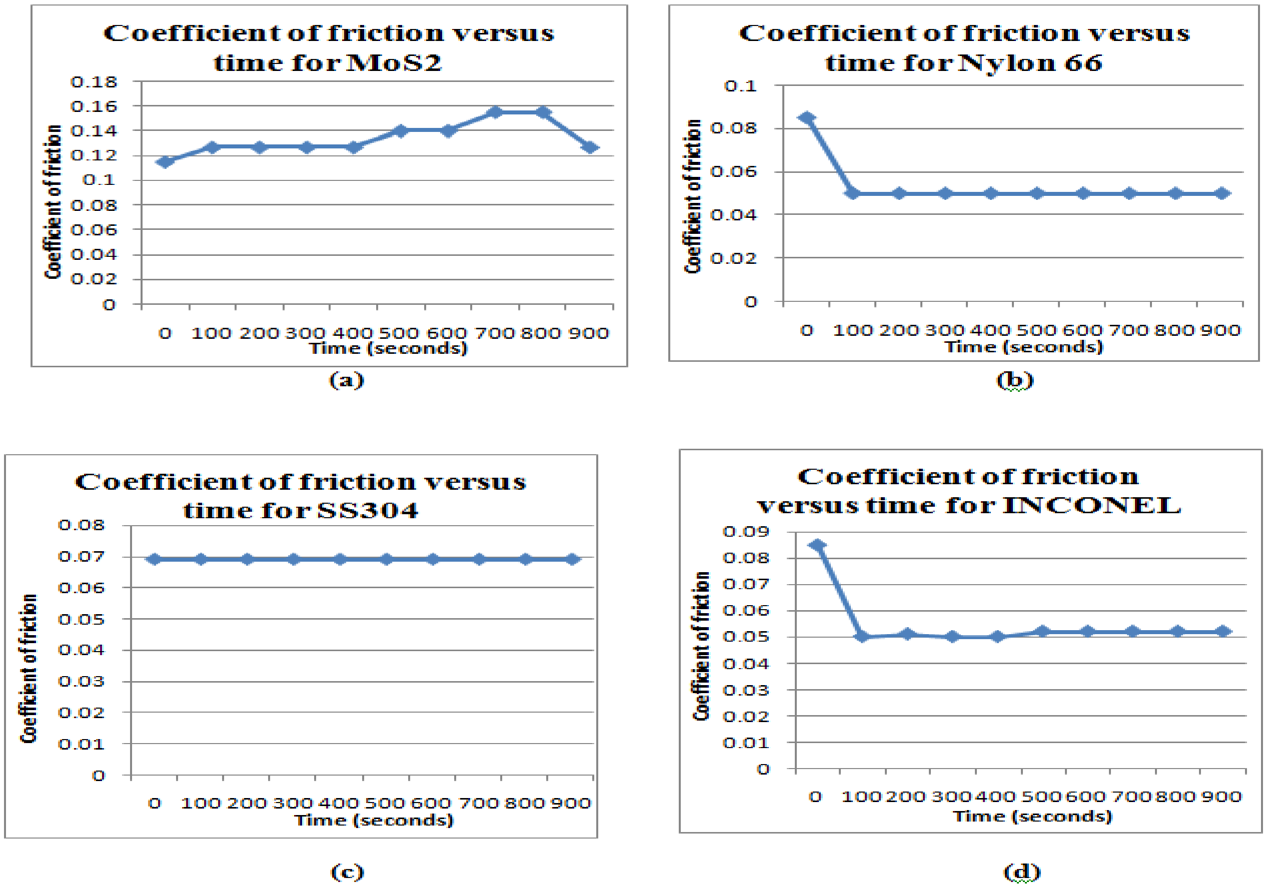

Figure 4. Friction coefficient versus time for (a) MoS_2 (b) Nylon 66 (c) SS304 (d) INCONEL 625

Figure 4 shows the Friction Coefficient versus time plot for the four test materials. From Figure 4 (a) we can observe that the coefficient of friction is not stable for MoS_2. From Figure 4 (b) we can observe that the coefficient of friction is low and stable for Nylon 66. From Figure 4 (c) we can observe that the coefficient of friction is constant for SS304. From Figure 4 (d) we can observe that the coefficient of friction is low and stable for INCONEL 625 when compared to the other materials.

Surface Roughness

	Table 3	
	Surface Roughness	
Sl no.	Materials	R_a(µm)
1	MoS_2(unmachined)	6.8490
2	MoS_2(machined)	3.0134
3	Nylon(unmachined)	0.8548
4	Nylon(machined)	0.2974
5	SS304(unmachined)	0.4960
6	SS304(machined)	0.6113
7	INCONEL 625(unmachined)	0.9995
8	INCONEL 625(machined)	1.0228

Sem imaging

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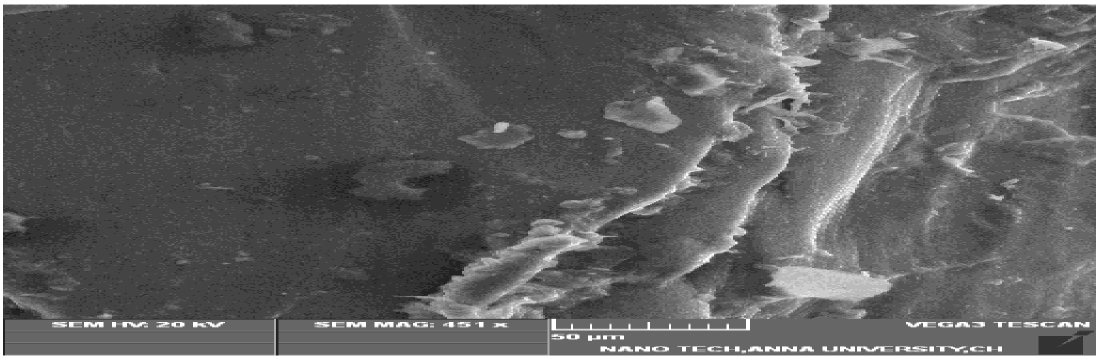

Figure 5. SEM image of a machined MoS_2 at 451 x magnification

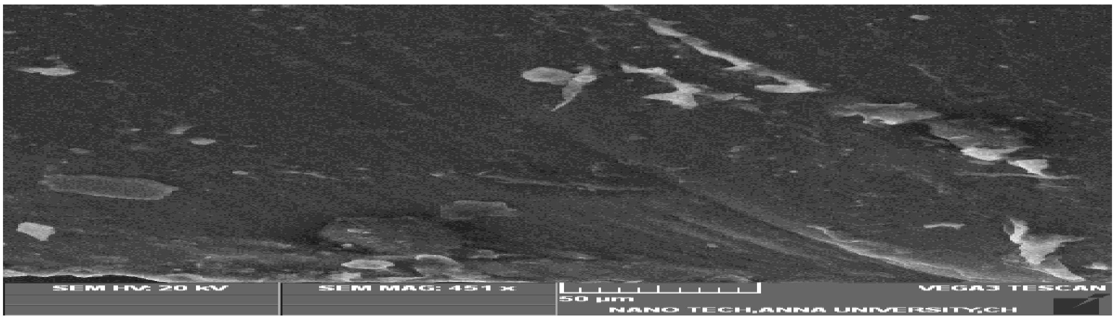

Figure 6. SEM image of a machined Nylon 66 at 451 x magnification

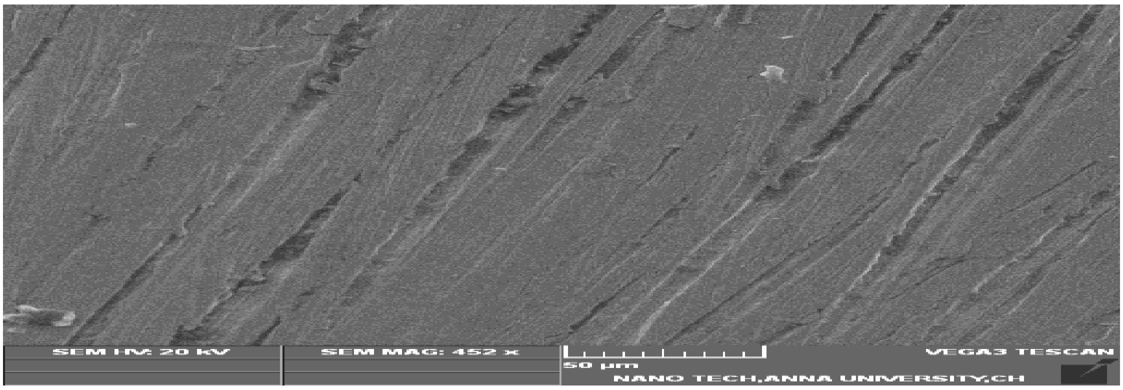

Figure 7. SEM image of a machined SS304 at 452 x magnification

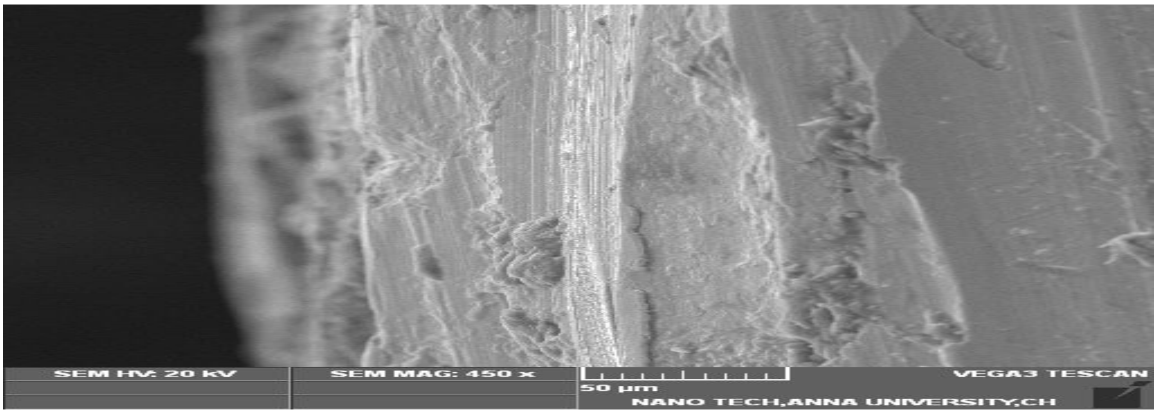

Figure 8. SEM image of a machined INCONEL 625 at 450 x magnification

V. CONCLUSION

INCONEL 625 has very good thermal and mechanical characteristics in comparison to other materials. It is appropriate for heavy load, elevated temperature and medium speed applications. It is more durable and resistant to high heat and pressure during journal bearing applications. The hardness and tensile strength of the material give supreme protection thereby counteracting power, friction and wear. Moreover, it helps components to withstand heat, have a longer life span and use less fuel to power the engines. Wear decreases in INCONEL 625 due to its high tensile strength and the wear rate also decreases on account of precipitation hardening.

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Hence, INCONEL 625 was found to be the ideal material for journal bearing applications due to its negligible variations on already low wear rate, lower friction coefficient and superior mechanical properties than other materials that were taken for examination.

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