The Tribological Study on Metallic Materials Which Had Undergone Surface Preparations Using Pin-on-Disc Testing Technique

by

Mohd Rahman bin Mohd Rosli

Dissertation submitted in partial fulfillment of

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CERTIFICATION OF APPROVAL

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Approved by,

………………………………

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TRONOH, PERAK

JUNE 2010

CERTIFICATION OF ORIGINALITY

This is to certify that I am responsible for the work submitted in this project, that the original work is my own except as specified in the references and acknowledgements, and that the original work contained herein have not been undertaken or done by unspecified sources or persons.

…………………………………………….

MOHD RAHMAN BIN MOHD ROSLI

ABSTRACT

The objective of this ‘Progress Report’ is to compile all the works and progress done by the student up to this point of the tribological study on metallic materials. It is to have a better understanding of the effect of wear and tear on metallic materials used either in the industries, automotives or even everyday use. Types of other materials or elements used as the rubbing surface, load and the time frame will be used considered as among the most important aspect that will affect the results of this project. The collection of technical details and data regarding the wear and tear of the metallic materials used will be done. At the end of this project, the results will give a better overview and understanding of the tribological study itself. A simple ‘Pin on Disc’ test will be carried out to determine the wear and tear rate of the metallic materials chosen for this project. Three materials will be chosen specifically and its surface will be prepared under three different categories. All three samples will be tested under these three different surface conditions.

ACKNOWLEDGEMENT

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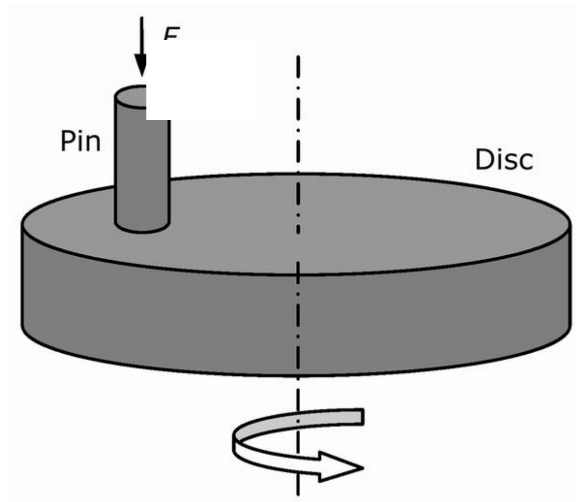


Figure 44: Sketch diagram of Pin-on-Disc test

Tribology is the science and technology of interacting surfaces in relative motion. It includes the study and application of the principles of friction, lubrication and wear. This technology is commonly applied in bearing designs and extends to most all other modern aspect of the technology. Any product where one material rubs against another is affected by the complex tribological interactions. Historically, Leonardo da Vinci (1452-1519) was the first to enunciate two laws of friction. According to da Vinci, the frictional resistance was the same for two different objects of the same weight but making contacts over different widths and lengths. He also observed that the force needed to overcome friction is doubled when the weight is doubled. The tribological interactions of a solid surface's exposed face with interfacing materials and environment may result in loss of material from the surface or known as 'wear'. Abrasion, adhesion (friction), erosion and corrosion are among the major types of wear. The wear rates can be determined using a few tests such as the Pin-on-Disc test.

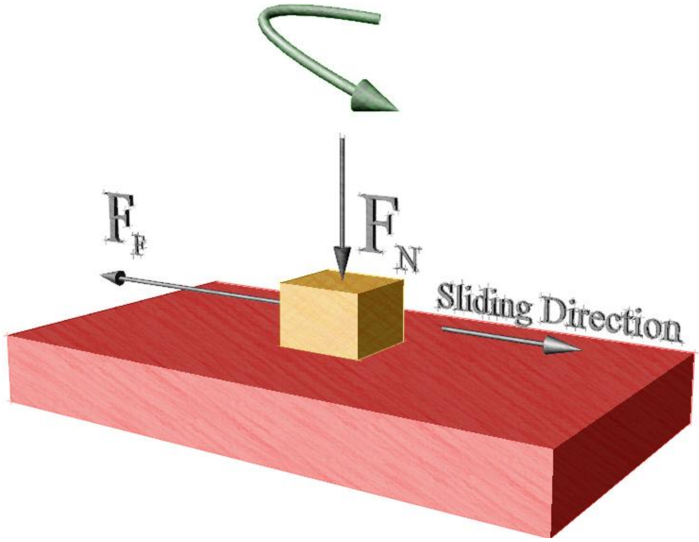


Figure 45: Tribology - Skin Friction

1.2 Problem Statement

Most moving equipment and parts especially in industries and automotive are metallic material based due to their high strength and wear resistance. Although it is highly known that these materials are widely used, it is unwise to consider that tribology won't have any effect on the metallic materials chosen. Each component used will be limited by the service life according to the manufacturer's research and documents. Other than that, surface finish of a moving material is very important if it is in contact with another material. Different surface profile could affect the service life of the moving component. In order to prevent any major losses or damage, the user must have full understanding of the material especially the friction and load being applied and the wear rate of the metallic materials. Without any basic understanding of tribology, it could cause major losses and plant shutdown.

1.3 Objective

1. To study the effect of surface roughness to wear properties on the selected test samples.
2. To measure the coefficient of friction and wear rate on the selected test samples.
3. To analyze results obtained and recommend.

1.4 Scope of Study

The scope of this study consists of:

i. To study the operation principle of Pin-on-Disc test.
ii. To study the principle of tribology.
iii. To study the effects of surface preparation and condition towards wear effect.
iv. To measure the friction and sliding wear properties of dry surface of various metallic materials.
v. To choose materials from conventional parts where metallic materials were used and exposed to friction and wear.
vi. To analyze results and recommend the best way or materials to be used for the parts chosen.

2.0 LITERATURE REVIEW

The literature review for this report would be more on the ASTM G99-04, which are the 'Pin-on-Disk' test and an introduction towards the material which shall be tested as samples for the testing.

2.1 Standard Test Method for Wear Testing with a Pin-on-Disk Apparatus (ASTM G99-04 Volume 03.02)

2.1.1 Scope

The lab procedure for this test is to determine the wear of materials. Materials used as sample will be tested in pairs under nominally non-abrasive conditions. In some cases, coefficient of friction may also be determined.

2.1.2 Summary of Test Method

For this test, two (2) specimens are required which are; the ‘pin’ and the ‘disk’. Usually for the pin, a ball rigidly held is used and acted as the pin. The machine will either cause the disk specimen or the pin specimen to revolve about the disk center. The plane of the disk is either oriented horizontally or vertically. The wear results may vary for different orientation.

The pin is pressed against the disk at a specific load by means of an arm or lever attached weights. Hydraulic and pneumatics might be used as well. The different kind of loading used might as well vary the results outcome.

The wear results would be the volume loss in cubic millimeters (mm^3) for the pin and disk separately. In order to get a more precise and detailed results, it is best for each material to be tested on the pin and disk position. The amount of wear can be measured by using the linear dimensions. It can also be measured by weighing both specimens before and after the test.

If the loss of mass technique is used, the mass loss value calculated must be converted to volume loss in cubic millimeters (mm^3) using the appropriate value for the specimen density.

For the linear dimensions, the length change or shape change of the pin and the depth or shape change of the disk wear track in millimeters (mm) are determined by any suitable metrological technique. Electronic distance gaging or stylus profiling are among the techniques can be used. Linear measures of wear are converted to wear volume in cubic millimeters (mm^3) by using appropriate geometric relations. Linear measures of wear are used frequently in practice since mass loss is often too small to measure precisely. The results obtained through test for a selected sliding distance and for selected values of load and speed.

2.1.3 Significance and Use

The amount of wear of the materials depends on the applied load, machine, characteristics, sliding speed, sliding distance, the environment, and the material properties. The value of any wear test methods lies in predicting the relative ranking of material combinations. Pin-on-disk doesn't duplicate all the conditions that may be experienced in service. There's no insurance that the test will predict the wear rate of a given material under conditions differing from those in the test.

2.2 Sample Material

2.2.1 Tool Steel H14

Figure 46: Tool Steel

Tool steel refers to a variety of carbon and alloy steels that are particularly well-suited to be made into tools. Their suitability comes from their distinctive hardness, resistance to abrasion, their ability to hold a cutting edge, and/or their resistance to deformation at elevated temperatures (red-hardness). Tool steel is generally used in a heat-treated state.

With carbon content between 0.7% and 1.4%, tool steels are manufactured under carefully controlled conditions to produce the required quality. The manganese content is often kept low to minimize the possibility of cracking during water quenching.

However, proper heat treating of these steels is important for adequate performance, and there are many suppliers who provide tooling blanks intended for oil quenching.

Tool steels are made to a number of grades for different applications. Choice of grade depends on, among other things, whether a keen cutting edge is necessary, as in stamping dies, or whether the tool has to withstand impact loading and service conditions encountered with such hand tools as axes, pickaxes, and quarrying implements. In general, the edge temperature under expected use is an important determinant of both composition and required heat treatment. The higher carbon grades are typically used for such applications as stamping dies, metal cutting tools, etc. Tool steels are also used for special applications like injection molding because the resistance to abrasion is an important criterion for a mold that will be used to produce hundreds of thousands of parts.

Table 18: AISI-SAE Tool Steel Grades

AISI-SAE tool steel grades		
Defining property	**AISI-SAE grade**	**Significant characteristics**
Water-hardening	W	
Cold-working	O	Oil-hardening
	A	Air-hardening; medium alloy
	D	High carbon; high chromium
Shock resisting	S	
High speed	T	Tungsten base

	M	Molybdenum base
Hot-working	H	H1–H19: chromium base H20–H39: tungsten base H40–H59: molybdenum base
Plastic mold	P	
Special purpose	L	Low alloy
	F	Carbon tungsten

Table 19: Tool Steel 14 Chemical Composition

Element	H14 %Present
C	0.35-0.45
Mn	0.20-0.50
Si	0.80-1.20
Cr	4.75-5.50
Ni	0.3
W	4.00-5.25

Cu	0.25
P	0.03
S	0.03

Table 20: Tool Steel H14 Mechanical Properties

Properties	
Density (×1000 kg/m3)	7.89
Poisson's Ratio	0.27-0.30
Elastic Modulus (GPa)	190-210
Thermal Expansion (10-6/ºC)	11

2.2.2 Aluminum 6063

Figure 47: Aluminum 6063

Aluminum is a silvery white and ductile member of the boron group of chemical elements. It has the symbol Al; its atomic number is 13. It is not soluble in water under normal circumstances. Aluminum is the most abundant metal in the Earth's crust, and the third most abundant element therein, after oxygen and silicon. It makes up about 8% by weight of the Earth’s solid surface. Aluminum is too reactive chemically to occur in nature as a free metal. Instead, it is found combined in over 270 different minerals.[4] The chief source of Aluminum is bauxite ore.

Aluminum is remarkable for its ability to resist corrosion due to the phenomenon of passivation and for the metal's low density. Structural components made from Aluminum and its alloys are vital to the aerospace industry and very important in other areas of transportation and building. Its reactive nature makes it useful as a catalyst or additive in chemical mixtures, including being used in ammonium nitrate explosives to enhance blast power.

Aluminum is a soft, durable, lightweight, malleable metal with appearance ranging from silvery to dull grey, depending on the surface roughness. Aluminum is nonmagnetic and nonsparking. It is also insoluble in alcohol, though it can be soluble in water in certain forms. The yield strength of pure Aluminum is 7–11 MPa, while Aluminum alloys have yield strengths ranging from 200 MPa to 600 MPa.[5] Aluminum has about one-third the density and stiffness of steel. It is ductile, and easily machined, cast, and extruded.

Corrosion resistance can be excellent due to a thin surface layer of Aluminum oxide that forms when the metal is exposed to air, effectively preventing further oxidation. The strongest Aluminum alloys are less corrosion resistant due to galvanic reactions with alloyed copper.[5] This corrosion resistance is also often greatly reduced when many aqueous salts are present however, particularly in the presence of dissimilar metals.

Aluminum atoms are arranged in a face-centred cubic (fcc) structure. Aluminum has stacking-fault energy of approximately 200 mJ/m^2.[6]

Aluminum is one of the few metals that retain full silvery reflectance in finely powdered form, making it an important component of silver paints. Aluminum mirror finish has the highest reflectance of any metal in the 200–400 nm (UV) and the 3000–10000 nm (far IR) regions, while in the 400–700 nm visible range it is slightly outdone by tin and silver and in the 700–3000 (near IR) by silver, gold, and copper.[7]

Aluminum is a good thermal and electrical conductor, by weight better than copper. Aluminum is capable of being a superconductor, with a superconducting critical temperature of 1.2 Kelvin and a critical magnetic field of about 100 gauss.[8]

Table 21: Aluminum 6063 Chemical Composition

Element	6063 % Present
Si	0.2 to 0.6
Fe	0.35 max
Cu	0.1 max
Mn	0.1 max
Mg	0.45 to 0.9
Zn	0.1 max
Ti	0.1 max
Cr	0.1 max
Al	Balance

Table 22: Aluminum 6063 Mechanical Properties

Mechanical Properties	
Density (×1000 kg/m3)	2.7
Poisson's Ratio	0.33
Elastic Modulus (GPa)	70-80
Tensile Strength (MPa)	90
Yield Strength (MPa)	48
Hardness (HB500)	25
Shear Strength (MPa)	69
Fatigue Strength (MPa)	55

2.2.3 Mild Carbon Steel AISI 1018

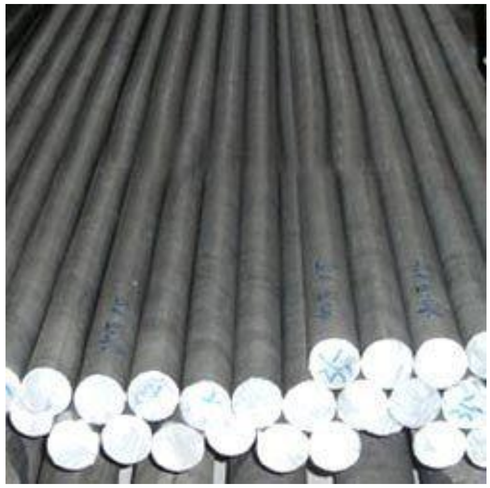


Figure 48: Mild Carbon Steel

Carbon steel, also called plain carbon steel, is steel where the main alloying constituent is carbon. The AISI defines carbon steel as: "Steel is considered to be carbon steel when no minimum content is specified or required for chromium, cobalt, columbium [niobium], molybdenum, nickel, titanium, tungsten, vanadium or zirconium, or any other element to be added to obtain a desired alloying effect; when the specified minimum for copper does not exceed 0.40 percent; or when the maximum content specified for any of the following elements does not exceed the percentages noted: manganese 1.65, silicon 0.60, copper 0.60."[1]

The term "carbon steel" may also be used in reference to steel which is not stainless steel; in this use carbon steel may include alloy steels.

Steel with low carbon content has properties similar to iron. As the carbon content rises, the metal becomes harder and stronger but less ductile and more difficult to weld. In general, higher carbon content lowers the melting point and its temperature resistance. Carbon content influences the yield strength of steel because carbon atoms fit into the interstitial crystal lattice sites of the body-centered cubic (BCC) arrangement of the iron atoms. The interstitial carbon reduces the mobility of dislocations, which in turn has a hardening effect on the iron. To get dislocations to move, a high enough stress level must be applied in order for the dislocations to "break away". This is because the interstitial carbon atoms cause some of the iron BCC lattice cells to distort.

85% of all steel used in the U.S. is carbon steel.[1]

Mild steel is the most common form of steel as its price is relatively low while it provides material properties that are acceptable for many applications. Low carbon steel contains approximately 0.05–0.15% carbon [1] and mild steel contains 0.16–0.29% [1] carbon, therefore it is neither brittle nor ductile. Mild steel has a relatively low tensile strength, but it is cheap and malleable; surface hardness can be increased through carburizing.[2]

It is often used when large amounts of steel are needed, for example as structural steel. The density of mild steel is approximately 7.85 g/cm^3 (0.284 lb/in^3)[3] and the Young's modulus is 210,000 MPa (30,000,000 psi).[4]

Low carbon steels suffer from *yield-point runout* where the materials have two yield points. The first yield point (or upper yield point) is higher than the second and the yield drops dramatically after the upper yield point. If low carbon steel is only stressed to some point between the upper and lower yield point then the surface may develop Lüder bands.[5]

Table 23: Mild Steel AISI1018 Chemical Composition

Element	Weight %
C	0.15 – 0.20
Mn	0.60 – 0.90
P	0.04 (max)
S	0.05 (max)

Table 24: Mild Steel AISI1018 Mechanical Properties

Properties	
Density (×1000 kg/m3)	7.7 – 8.03
Poisson's Ratio	0.27 – 0.30
Elastic Modulus (GPa)	190 – 210
Tensile Strength (MPa)	634
Yield Strength (MPa)	386
Elongation (%)	27
Reduction in Area (%)	48
Hardness (HB)	197

2.3 Sample Preparation

2.3.1 Pin Sample Preparation

Figure 49: Pin Sample

The pin samples were made of the same material as the disc samples. All of the three (3) materials were used to make the pin sample for experimental purposes. The samples bought from engineering shops and industrial company came in a cylindrical bar shaped. The bar is far larger than specification required for the pin. The bars are required to undergo diameter reducing process which can be done by the lathe machine. The diameter is reduced to 5mm in order to meet the specification requirement. Once the diameter of the bar had been reduced, the sample will be cut into desired length which is approximately 10mm @ 1cm by using a saw. The surfaces of the pins which will be used in the Pin-on-Disc test are required to be smooth and flat. Silicone Carbide (SiC) paper with

2.3.2 Disc Sample Preparation

The samples which were bought from industrial company and engineering shops came in a cylindrical bar shaped. The samples had to be cut according to desired thickness and diameter before can be loaded into the Multi Specimen Machine. Lathe machine and Band Saw Machine were used to ensure the samples are in correct dimension and thickness. This is for the disk and pin specimen.

Figure 50: Band Saw Machine

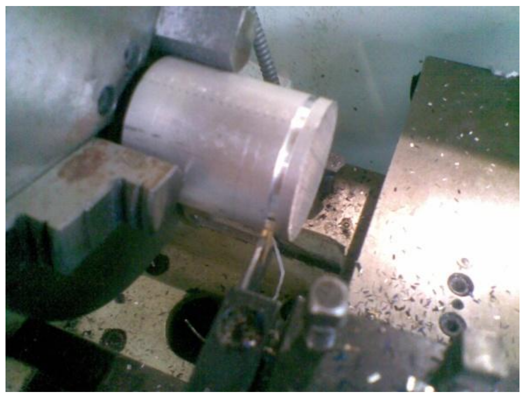


Figure 51: Lathe Machine

2.4 Surface Preparation

Surface preparation is where the surface of the disk is prepared for the test according to the desired categories. The three categories are rough, medium and fine. In order to achieve the three states of surface, sandpaper, grinding and polishing machine were used. For rough surface, normal sandpaper with low grit (Grit60/ P60) is being used using the grinding machine for faster and more accurate surface result. A higher and more fine sandpaper is being used for the medium surface (Grit600/P1200). While for the fine surface, a polishing machine is being used along with diamond suspension (3micron natural). The three surface were then tested using the Perthometer Concept in order to get the roughness readings.

2.4.1 Grinding

The main aim of grinding is to remove material deformed during cutting (rough, plance grinding). It is also to remove the superficial layer of the specimen that covers the material destined for examination. Other than that, grinding also prepares a flat surface while introducing only some residual or superficial deformation that can be eliminated during polishing (fine grinding).

Figure 52: Disc Prepared Through Grinding

Figure 53: Grinding Machine

Above is the grinding machine used in Block 17 to grind the sample's surface from any defect or deformation. It is also used with different grade sandpaper for surface preparation.

2.4.2 Polishing

Polishing and **buffing** are finishing processes for smoothing a workpiece's surface using an abrasive and a work wheel. Technically *polishing* refers to processes that use an abrasive that is glued to the work wheel, while *buffing* uses a loose abrasive applied to the work wheel. Polishing is a more aggressive process while buffing is less harsh, which leads to a smoother, brighter finish.[1] A common misconception is that a polished surface has a mirror bright finish, however most mirror bright finishes are actually buffed.[2] Polishing is often used to enhance the looks of an item, prevent contamination of medical instruments, remove oxidation, create a reflective surface, or prevent corrosion in pipes.[3]

The removal of oxidization (tarnish) from metal objects is accomplished using a metal polish or tarnish remover; this is also called polishing. To prevent further unwanted oxidization, polished metal surfaces may be coated with a wax, oil or lacquer. This is of particular concern for copper alloy products such as brass and bronze. [4]

The procedures for polishing are as follows:

Table 25: Polishing Step

Step	Cloth	Gradation	Abrasive	Rotational Speed (rev/min)	Time, min
1	Napless	3 micron	DP (Paste)	200	1

Figure 54: Polishing Machine

Figure 55: Polished Disc Sample

Figure 56: Diamond Suspension 3micron

2.4.3 Sandpaper

Sandpaper is a form of paper where an abrasive material has been fixed to its surface. Sandpaper is part of the "coated abrasives" family of abrasive products. It is used to remove small amounts of material from surfaces, either to make them smoother (painting and wood finishing), to remove a layer of material (e.g. old paint), or sometimes to make the surface rougher (e.g. as a preparation to gluing). Materials used for the abrading particles are:

- Flint: no longer commonly used
- Garnet: commonly used in woodworking
- Emery: commonly used to abrade or polish metal
- Aluminum Oxide: perhaps most common in widest variety of grits; can be used on metal (i.e. body shops) or wood
- Silicon Carbide: available in very coarse grits all the way through to microgrits, common in wet applications
- alumina-zirconia: (an Aluminum oxide–zirconium oxide alloy), used for machine grinding applications
- Chromium Oxide: used in extremely fine micron grit (micrometer level) papers
- Ceramic Aluminum Oxide: used in high pressure applications, used in both coated abrasives, as well as in bonded abrasives.

2.5 Roughness Test

Figure 57: Perthometer Concept

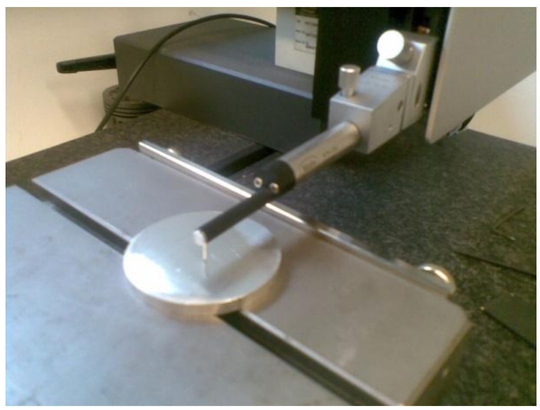


Figure 58: Disc Sample on Perthometer Concept

After surface preparation had been done on each samples, we had to determine the surface roughness for each preparation done. The Perthometer Concept is used in order to determine the contour, roughness and topography in combinations or independently. Below is the working procedure of the Perthometer Concept:

1. Check whether the dongle is connected to parallel port.
2. Check whether the printer is connected to the parallel via dongle.
3. Check whether the drive unit or the perthometer is connected to the computer.
4. If any of these connections has not been made switch off the computer, make the connections and switch the computer back on.
5. Start windows.

6. Double click the CONCEPT icon on the desktop.
7. Select ‘configuration of measure station’ dialog box will popup.
8. Click ‘OK’ at the ‘configuration of measure station’ dialog box.
9. Go to FILE then OPEN FORM. Choose UTPFORM2.
10. To change the measurement setting, go to SETTING then ‘MEASURING CONDITION’
11. Set the measuring conditions.
12. Check the ‘Measurement Station View’.
13. Place your sample on the stage. Make sure the sample is under the sensor.
14. Click the initialize icon.
15. Choose single or multiple measurements.
16. Click ‘Start Measurement’ icon then click Close.
17. The measurement will begin.
18. After the first measurement, move the ample a bit so that the new surface can be measured.
19. Click the ‘Measurement Station View’ again and repeat the procedures.
20. When all measurements completed, click OFF the multiple measurement icon.
21. Double click on the Profile Info, go to Edit, Roughness Parameter confirmed with OK.
22. Click on the form to delete any extra form.
23. Save your measurement under the Roughness Folder and print.

2.6 Multi Specimen Tester

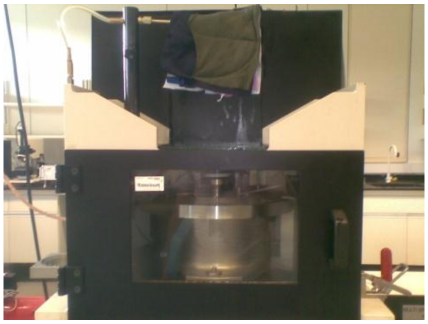


Figure 59: Multi Specimen Tester

The Multi Specimen Tester is a machine used for the Pin-on-Disk Test. The machine is compatible of imitating the function and purpose of the Pin-on-Disk machine. These are the procedures for running the Multi Specimen Tester:

1. Run “WINDUCOM 2006” software.
2. Click ‘run continuously’ icon under the toolbar at the left corner of the screen.
3. Click the ‘Power’ icon switch on the machine.
4. Set desired testing time.
5. Set desired speed and speed type.
6. Set desired temperature.
7. Set desired trip value for safety.
8. Enter file name, sample id, etc.
9. Click ‘Acquire’ icon.
10. Set all parameter to zero.
11. Apply balancing load the levers by past 5kg weighting mass to balancing mechanical load.
12. Check whether the wear sensor has touched the disc holder or not.
13. Apply the load by putting the dead weight.
14. Adjust the load icons into desired value by sliding the weighting mass slowly.
15. Click ‘Run’ icon to start the test.
16. It is advisable to perform the running in test for 10 minutes.
17. Rerun the test to the required setting.
18. Click the ‘Power’ icon to switch off the machine.
19. Remove the sample from the holder.

3.0 METHODOLOGY

3.1 Overview

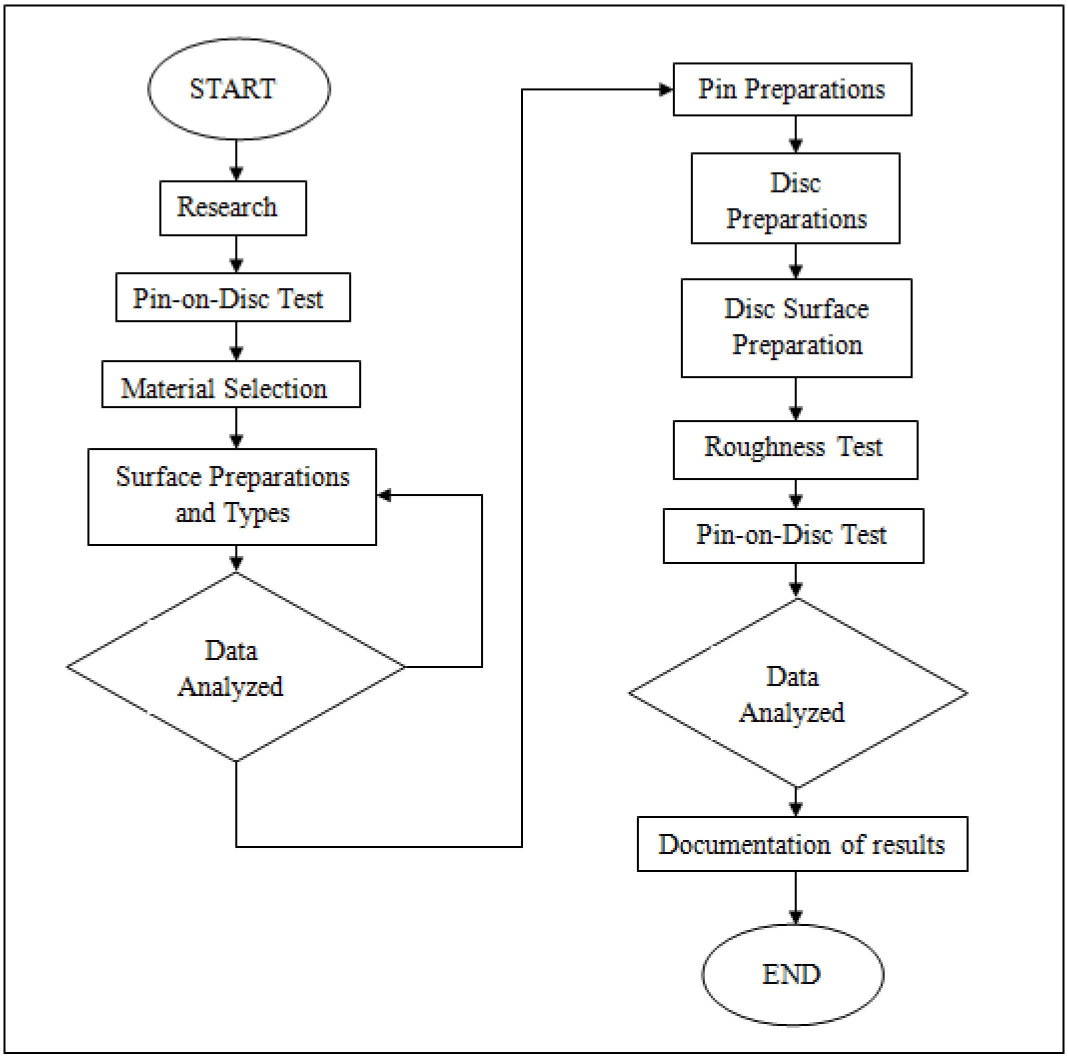


Figure 60: Project Methodology Diagram

3.2 Research

This step involves the determination and specification of the objectives and scope of the study, in addition to develop a detailed understanding of the project title. Research on the topic is collected from various sources such as internet, journal and book to help better understanding on concept of Pin-on-Disc testing and surface preparations. A few samples of different material will be made for experimental purposes. Material selection is determined by the difference in the materials specification. A total of three (3) types of materials were required for this research and experimental purposes. The types of surface preparations were chosen by different type of surface roughness.

3.3 Test Specimen and Sample Preparation

Materials – Specimens having the required dimensions. Materials tested are described by dimensions, surface finish, material type, form, composition, microstructure and processing treatments.

Test specimen – Pin is cylindrical (d = 5mm). Disk (d = 50mm and t = 5mm)

3.4 Test Parameters

The experiment requires a few parameters in order for it to run smoothly and ensuring precision in all of the results obtained. Below are the test parameters that requires consideration.

Load – Force in Newton at the wearing contact.

Speed – Relative sliding speed (ms^{-1})

Time – The time period each specimen being tested (min)

Temperature – Temperature of both specimens at locations near the wearing contact.

Table 26: Test Parameters

Test Parameters	
Load (N)	+/-50
Speed (RPM)	100
Total Revolution (per sample)	600
Temperature (^{o}C)	27 (Lab/Air Temperature)

*There will be an interval of 200 revolutions for each sample tested for data collecting purposes.

4.0 RESULTS & DISCUSSION

The Methodology in Chapter 3 has led to the final result of this project which is the results of the Pin-on-Disc testing on the samples which the surface had been prepared into three different groups. This chapter will show the effect and results of the surface prepared on the three different materials.

4.1 Perthometer Concept Readings

The Perthometer Concept Readings were taken 3 times for each disc samples which had undergone surface preparations. The samples were divided into two major groups; Group A and B. Each group is divided by the type of pin sample being used in the Pin-on-Disc test. In order to obtain a precise result, the reading on each sample had to be taken at least three times.

4.1.1 Disc Sample Group A

For disc sample Group A, all of the disc samples will be tested against the Mild Steel AISI 1018 pins. The disc will be divided into each material category; Al6063, H14 and Mild Steel. Each of the material categories, three different surface preparations were made; ‘rough’, ‘medium’ and ‘fine’. In order to identify the surface profile of each disc, the Roughness Test is being conducted using the Perthometer Concept.

- This is the reading for ‘rough’ surface on Al6063:

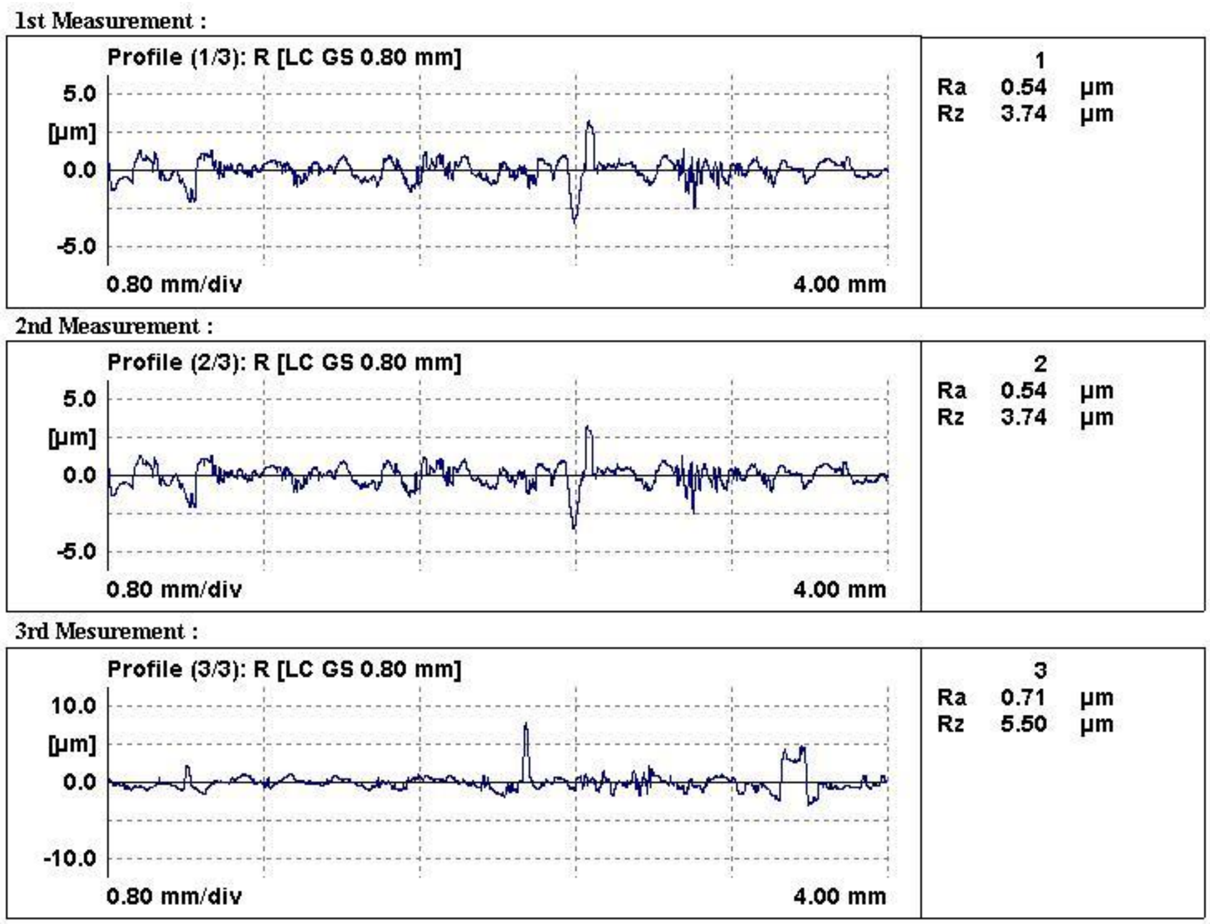


Figure 61: Al6063 'Rough' Surface

- This is the reading for ‘medium’ surface on Al6063:

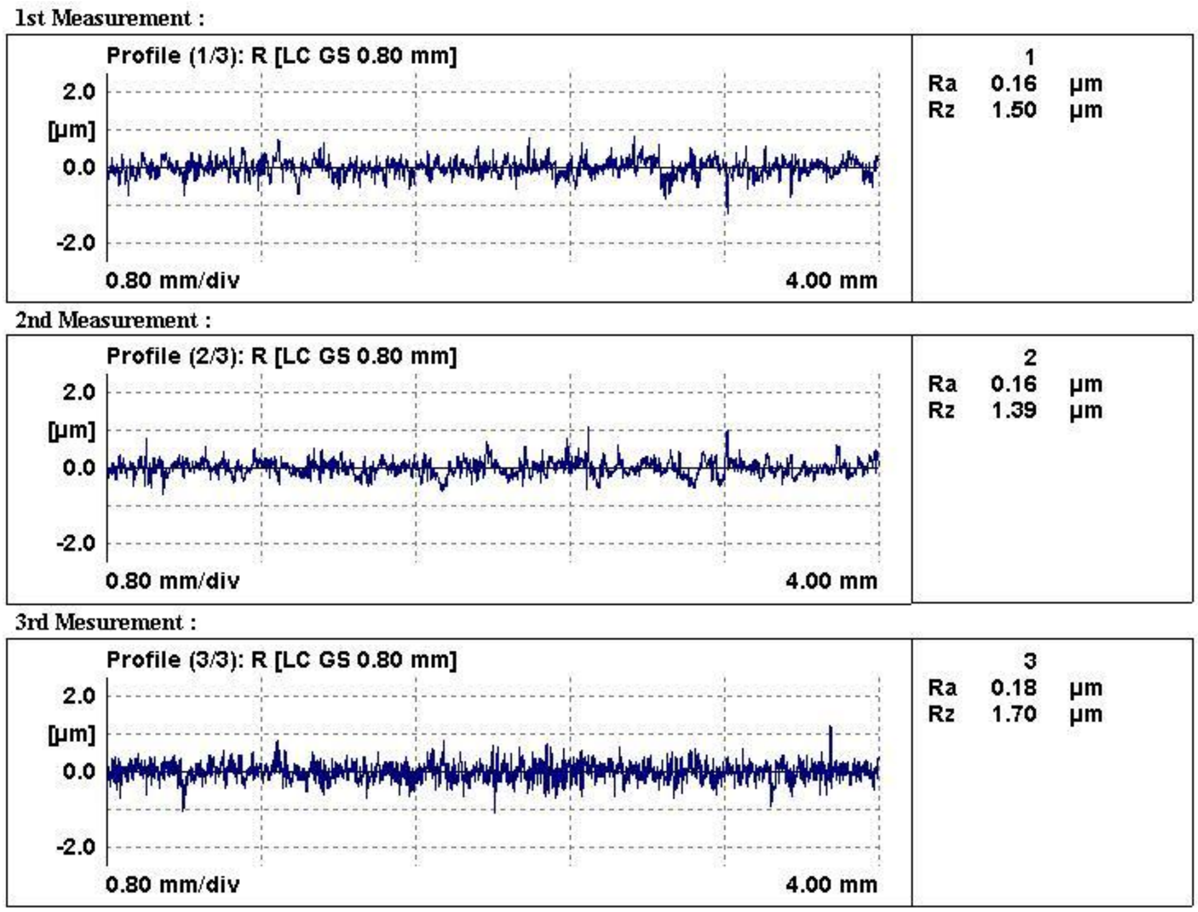


Figure 62: Al6063 'Medium' Surface

- This is the reading for ‘fine’ surface on Al6063:

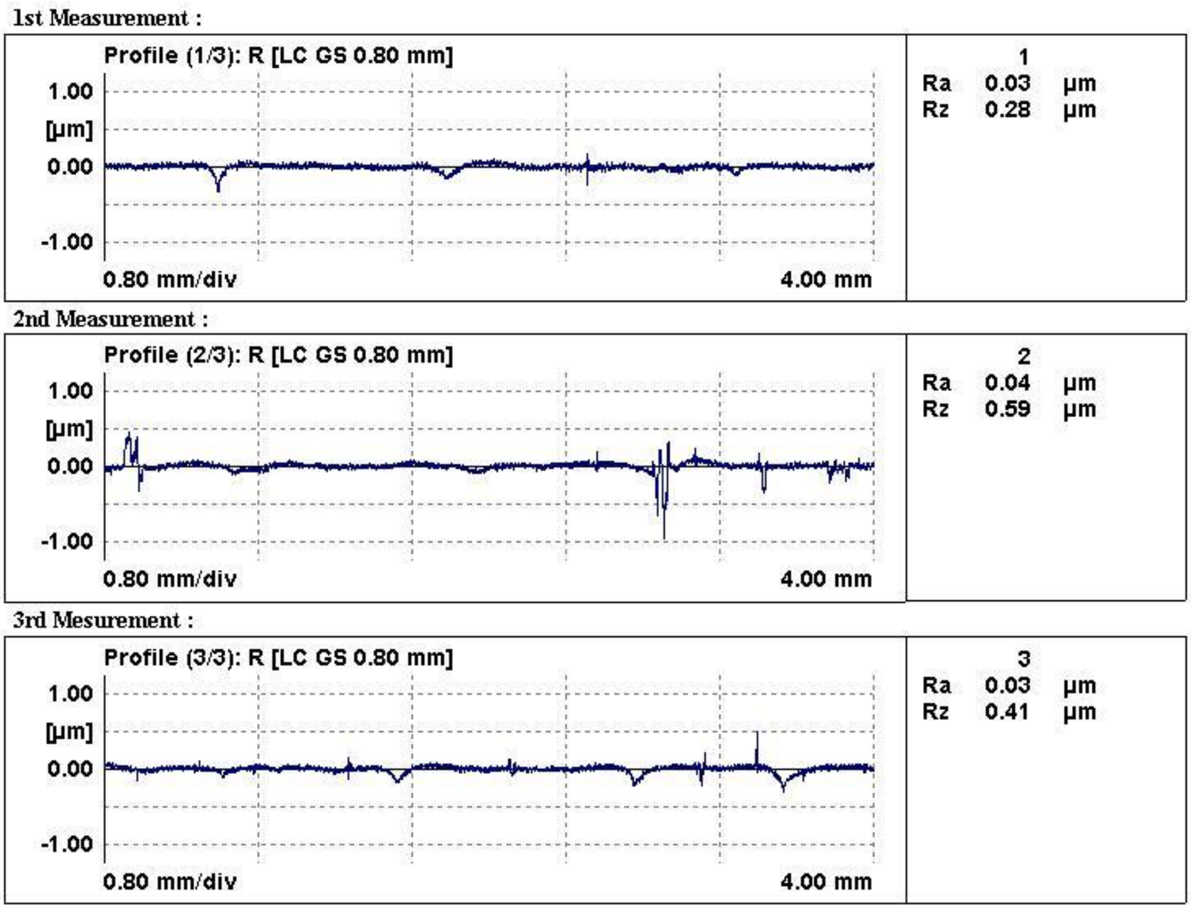


Figure 63: Al6063 'Fine' Surface

- This is the reading for ‘rough’ surface on H14:

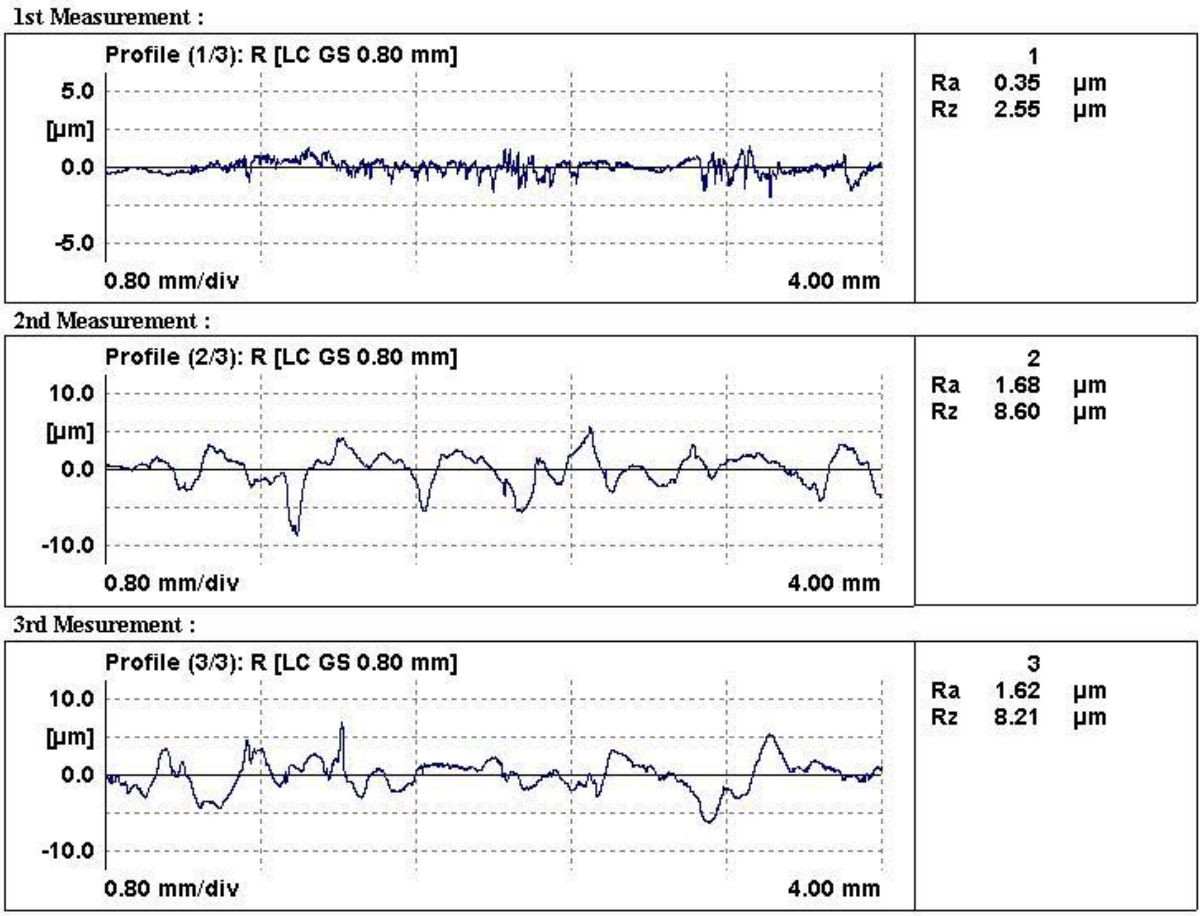


Figure 64: H14 'Rough' Surface

- This is the reading for ‘medium’ surface on H14:

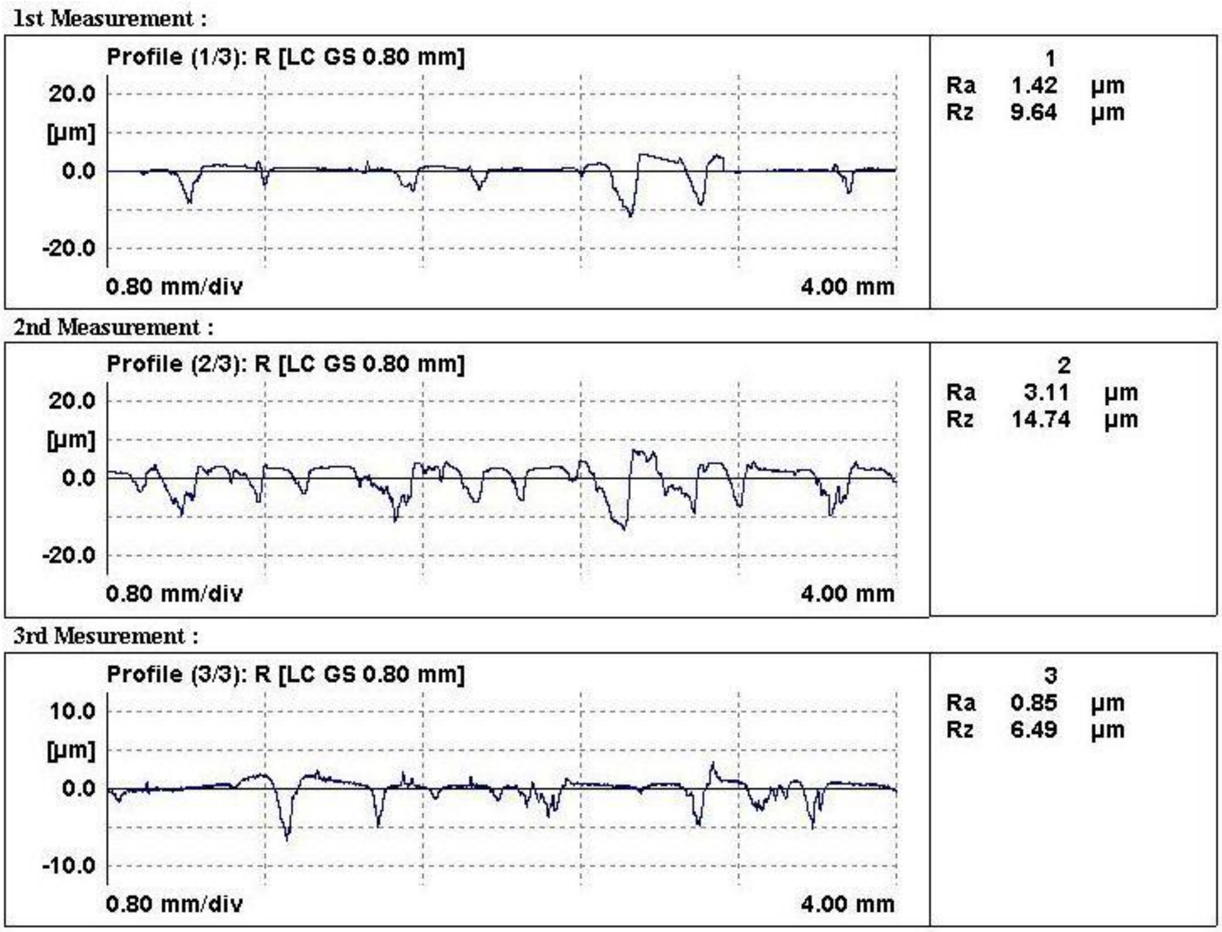


Figure 65: H14 'Medium' Surface

- This is the reading for ‘fine’ surface on H14:

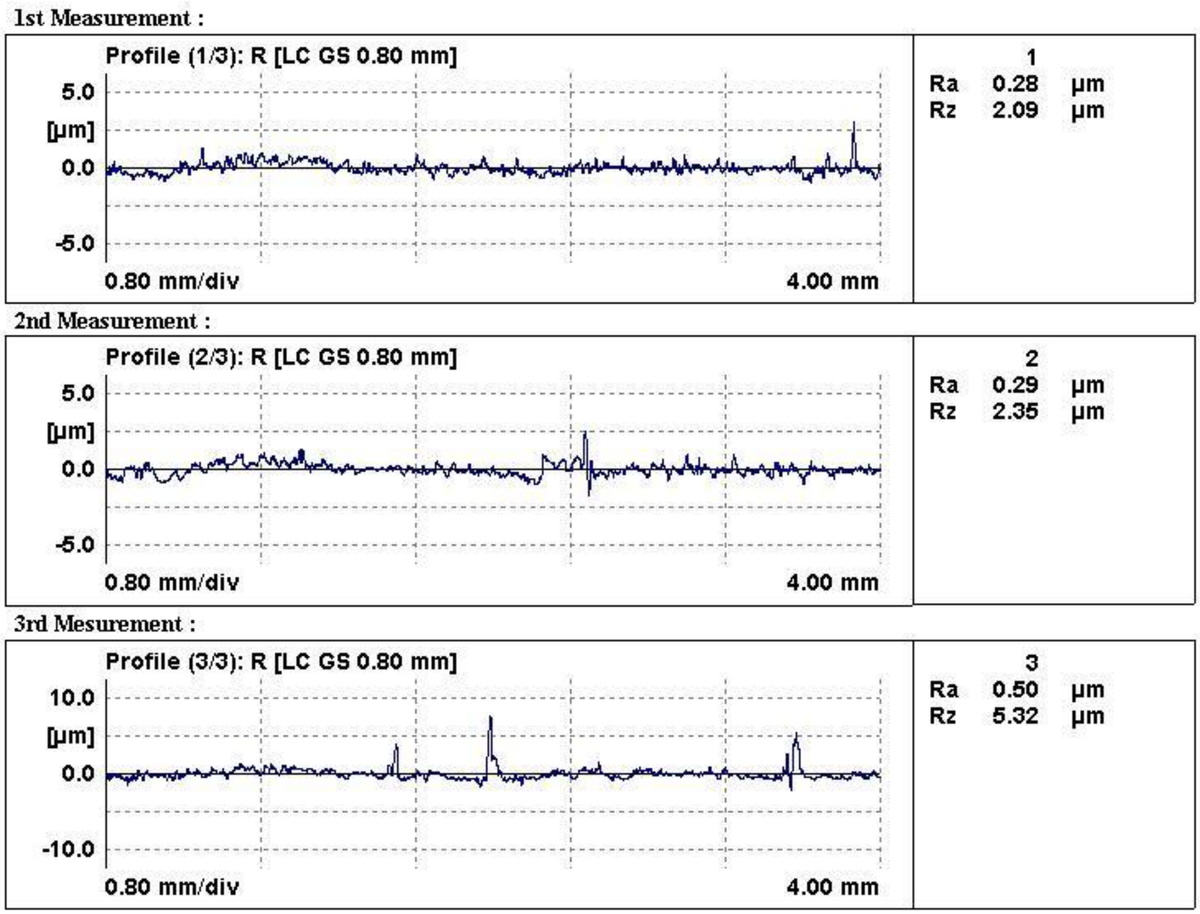


Figure 66: H14 'Fine' Surface

- This is the reading for ‘rough’ surface on Mild Steel:

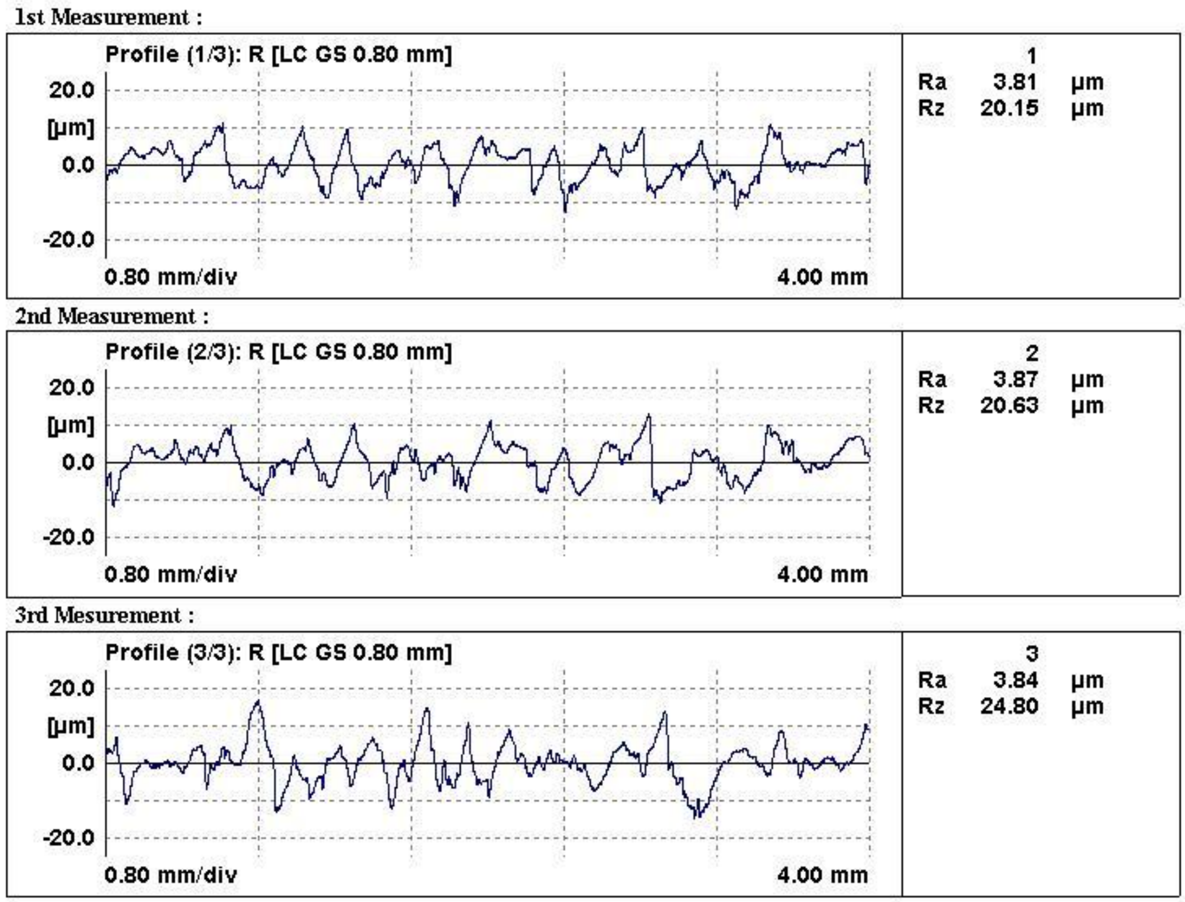


Figure 67: Mild Steel 'Rough' Surface

- This is the reading for 'medium' surface on Mild Steel:

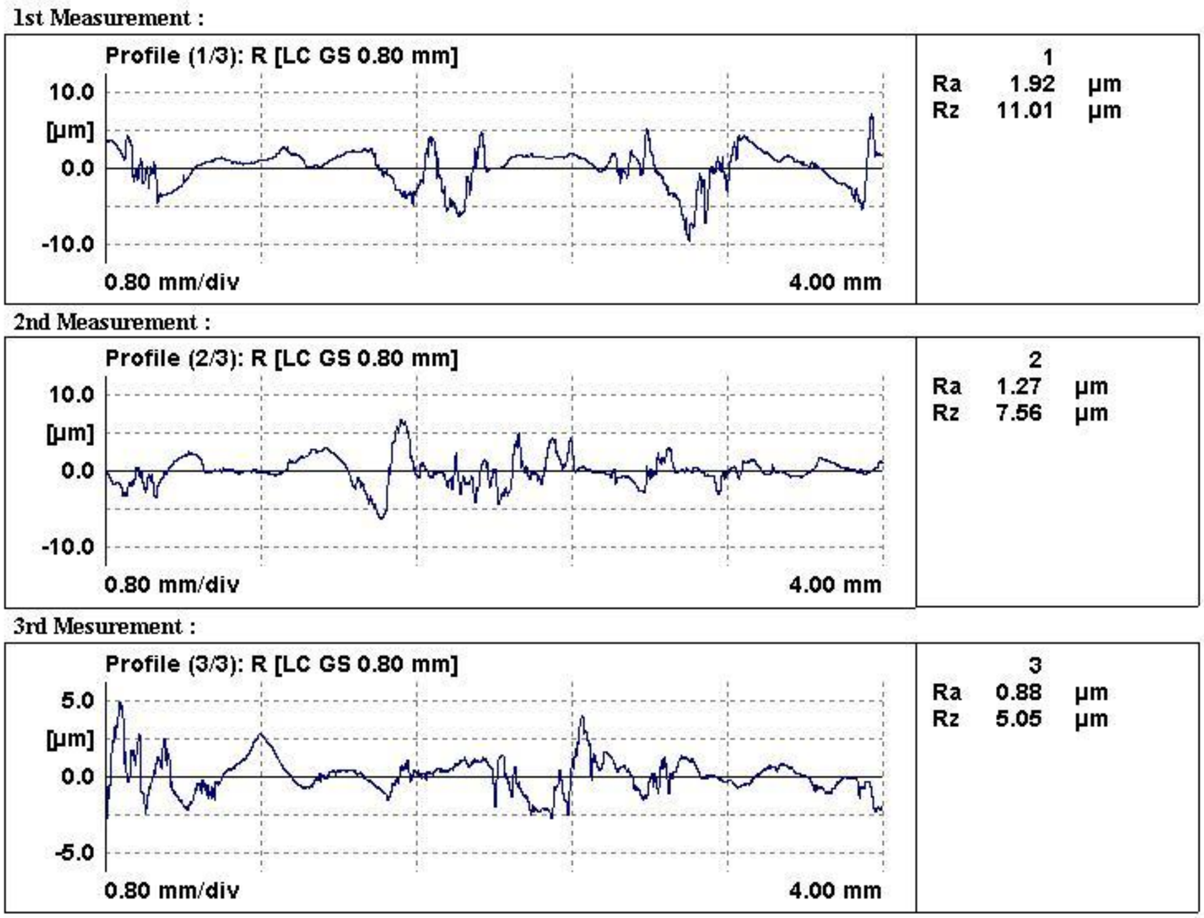


Figure 68: Mild Steel 'Medium' Surface

- This is the reading for ‘fine’ surface on Mild Steel:

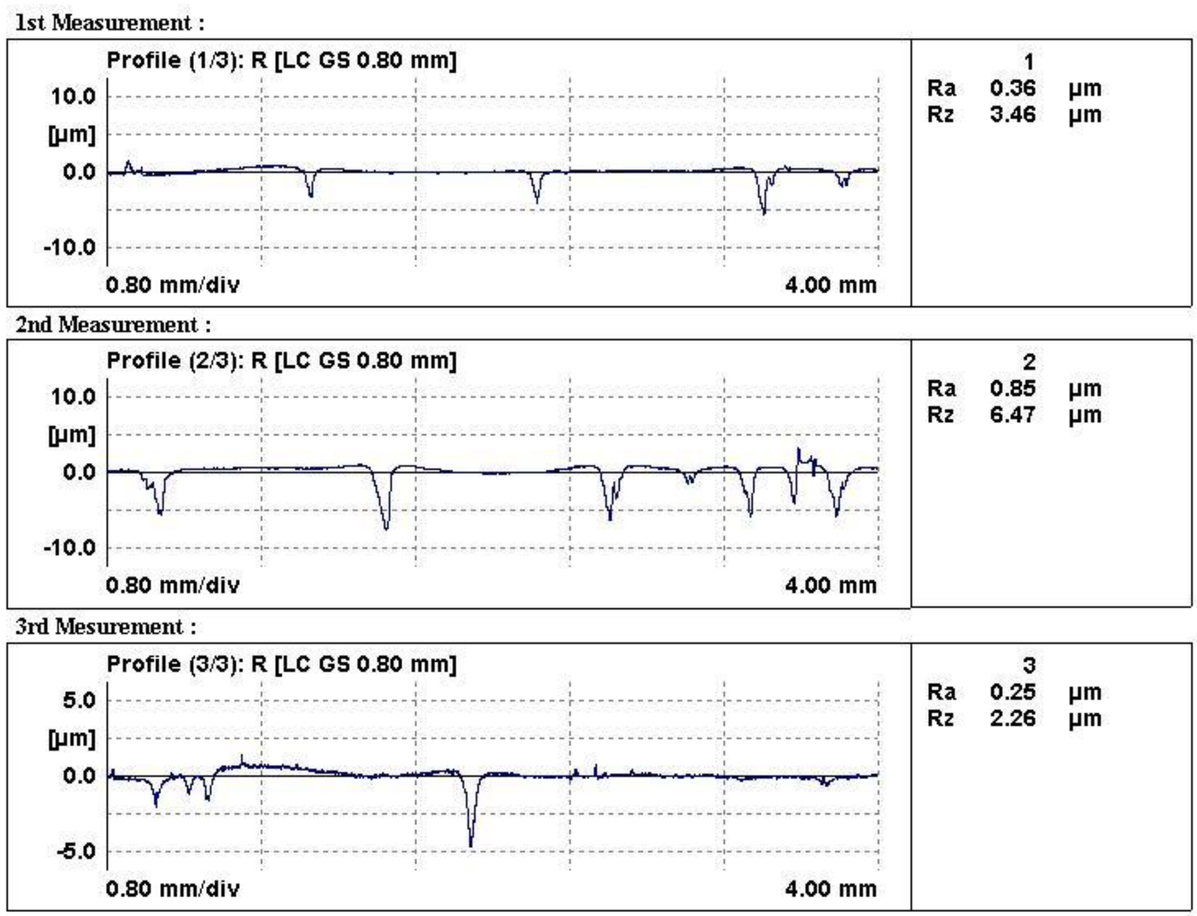


Figure 69: Mild Steel 'Fine' Surface

4.1.2 Disc Sampel Group B

For disc sample Group B, all of the disc samples will be tested against the Tool Steel H14 pins. The disc will be divided into each material category; Al6063, H14 and Mild Steel. Each of the material categories, three different surface preparations were made; ‘rough’, ‘medium’ and ‘fine’. In order to identify the surface profile of each disc, the Roughness Test is being conducted using the Perthometer Concept.

- This is the reading for ‘rough’ surface on Al6063:

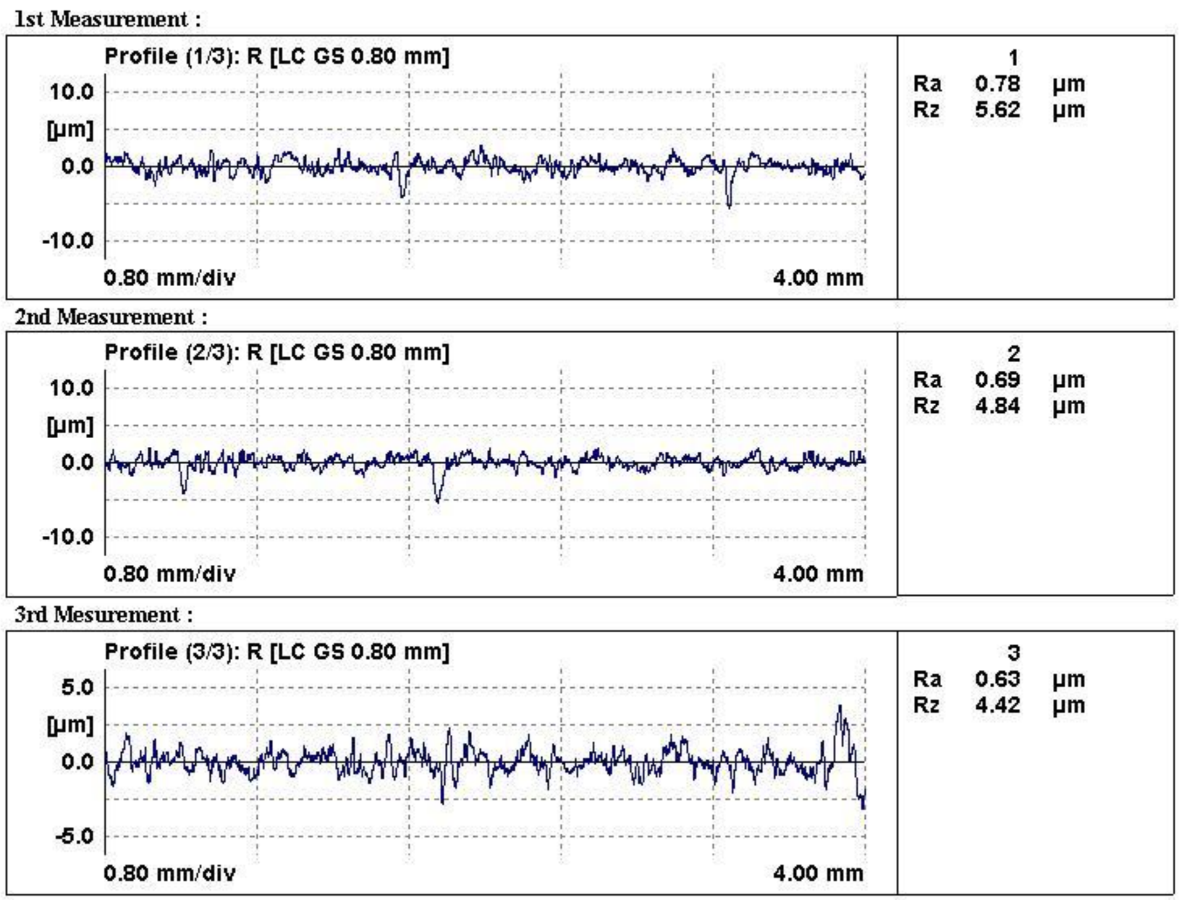


Figure 70: Al6063 'Rough' Surface

- This is the reading for ‘medium’ surface on Al6063:

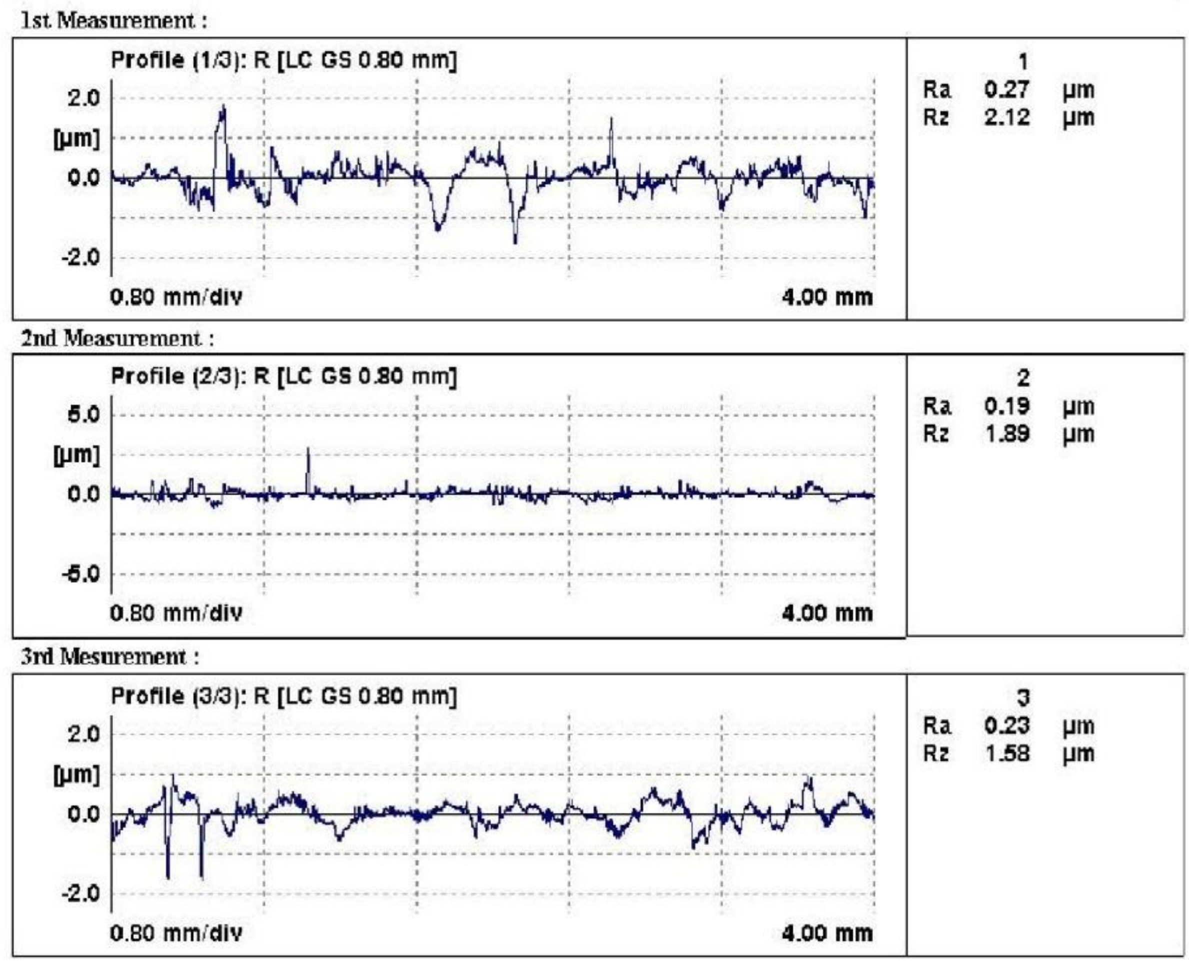


Figure 71: Al6063 'Medium' Surface

- This is the reading for 'fine' surface on Al6063:

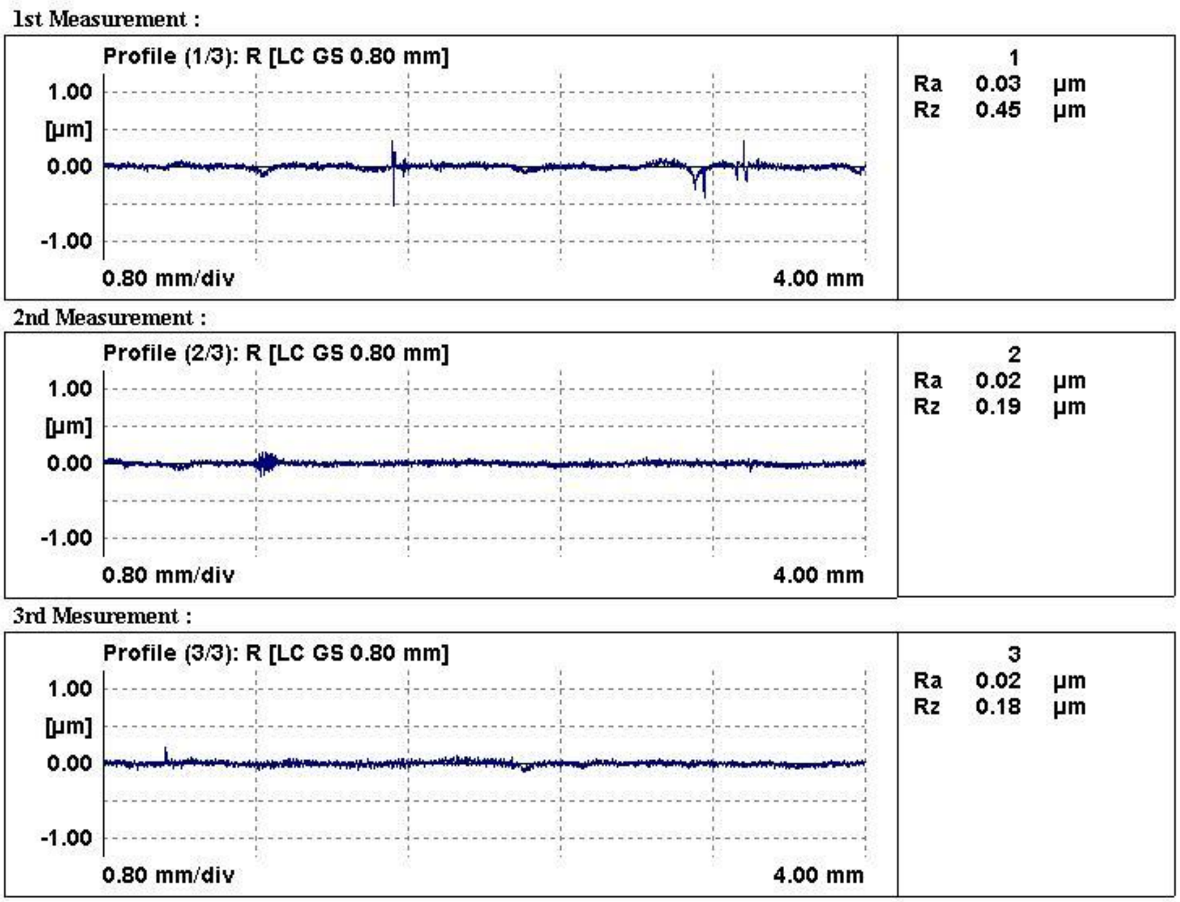
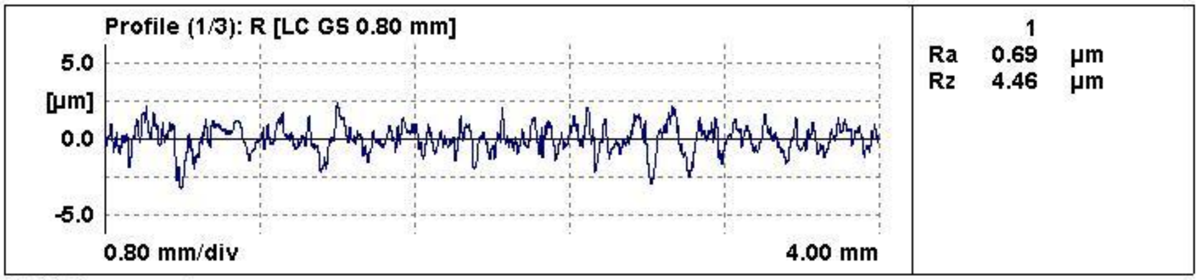


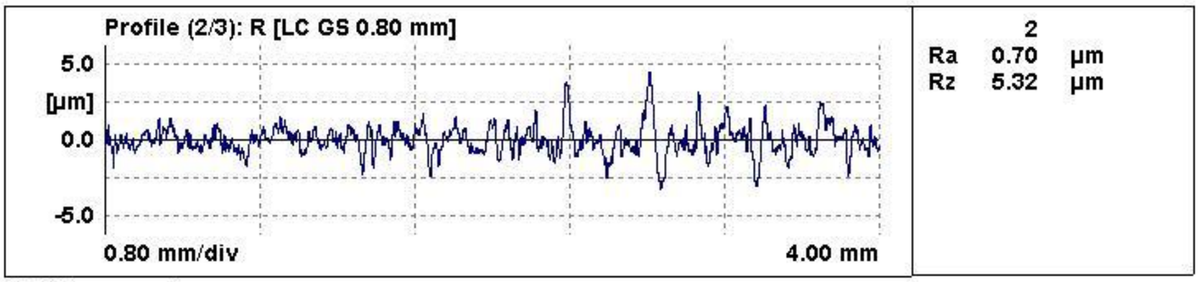
Figure 72: Al6063 'Fine' Surface

- This is the reading for ‘rough’ surface on H14:

1st Measurement :



2nd Measurement :



3rd Mesurement :

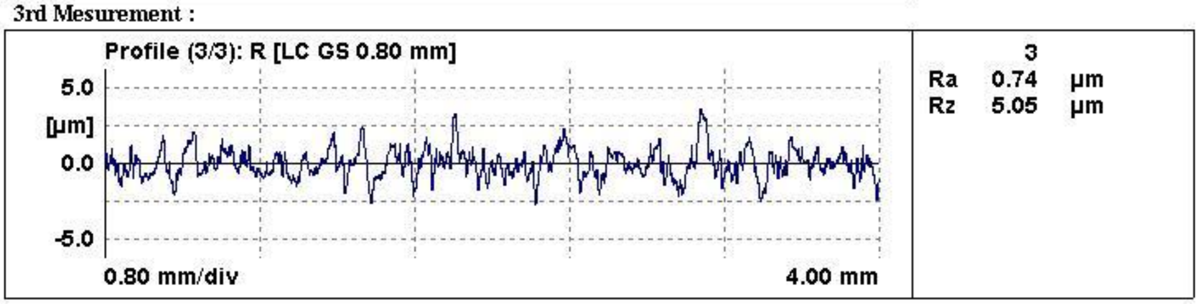


Figure 73: H14 'Rough' Surface

- This is the reading for 'medium' surface on H14:

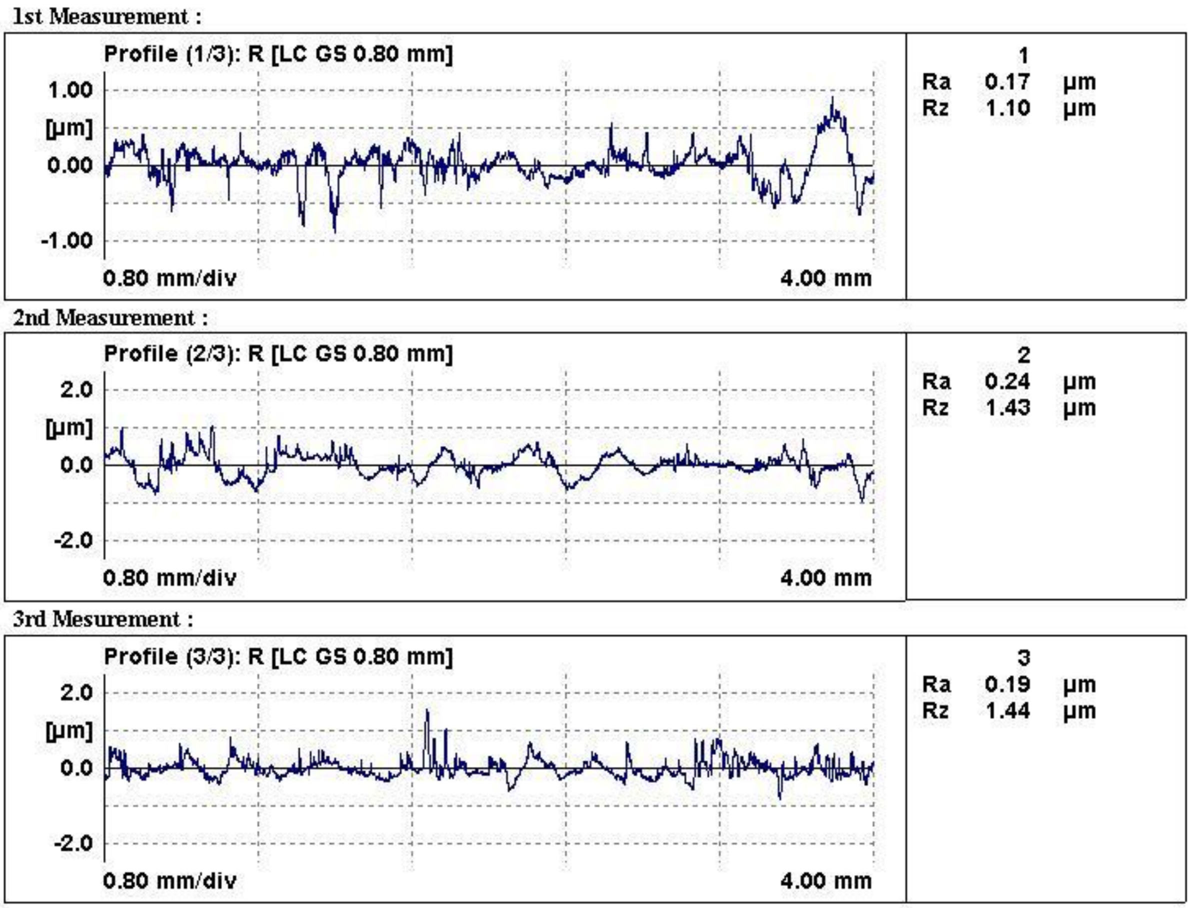


Figure 74: H14 'Medium' Surface

- This is the reading for ‘fine’ surface on H14:

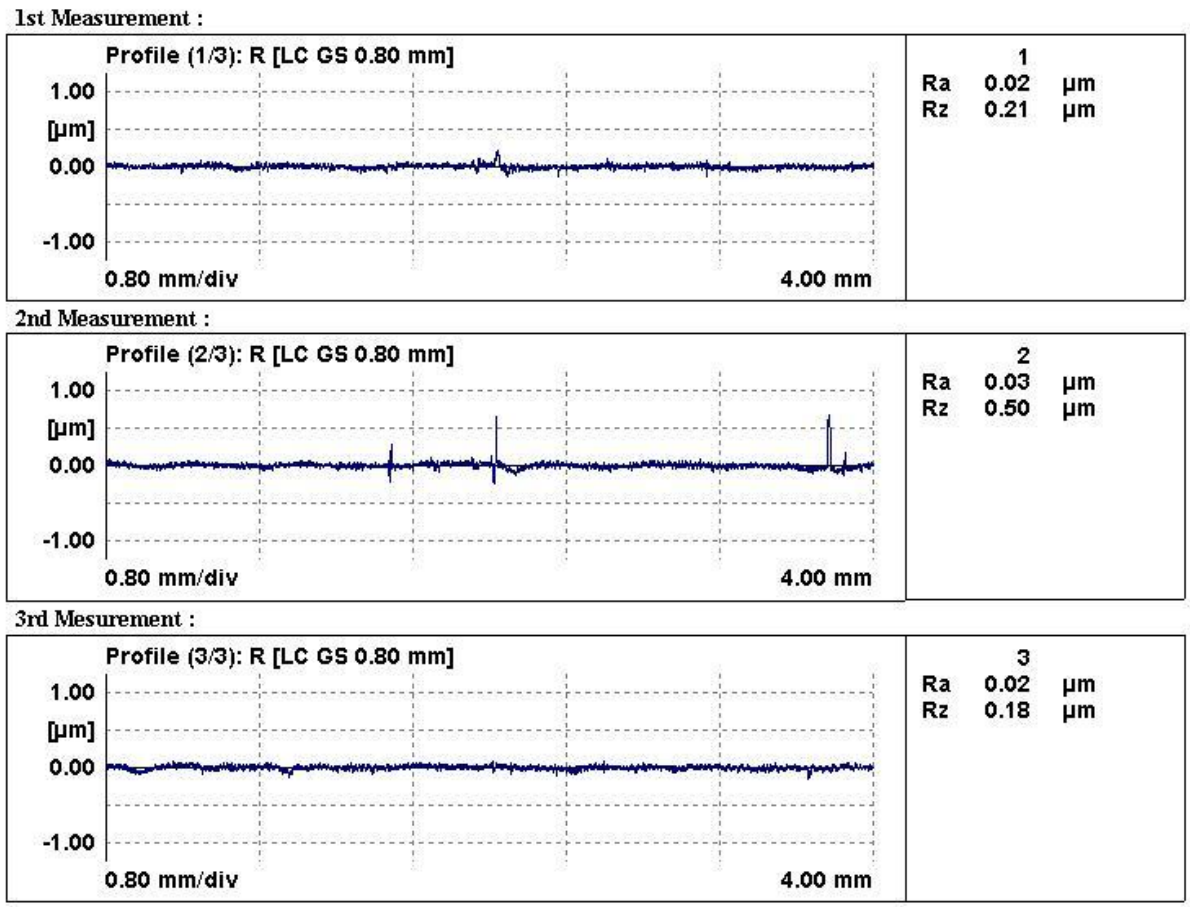


Figure 75: H14 'Fine' Surface

- This is the reading for 'rough' surface on Mild Steel:

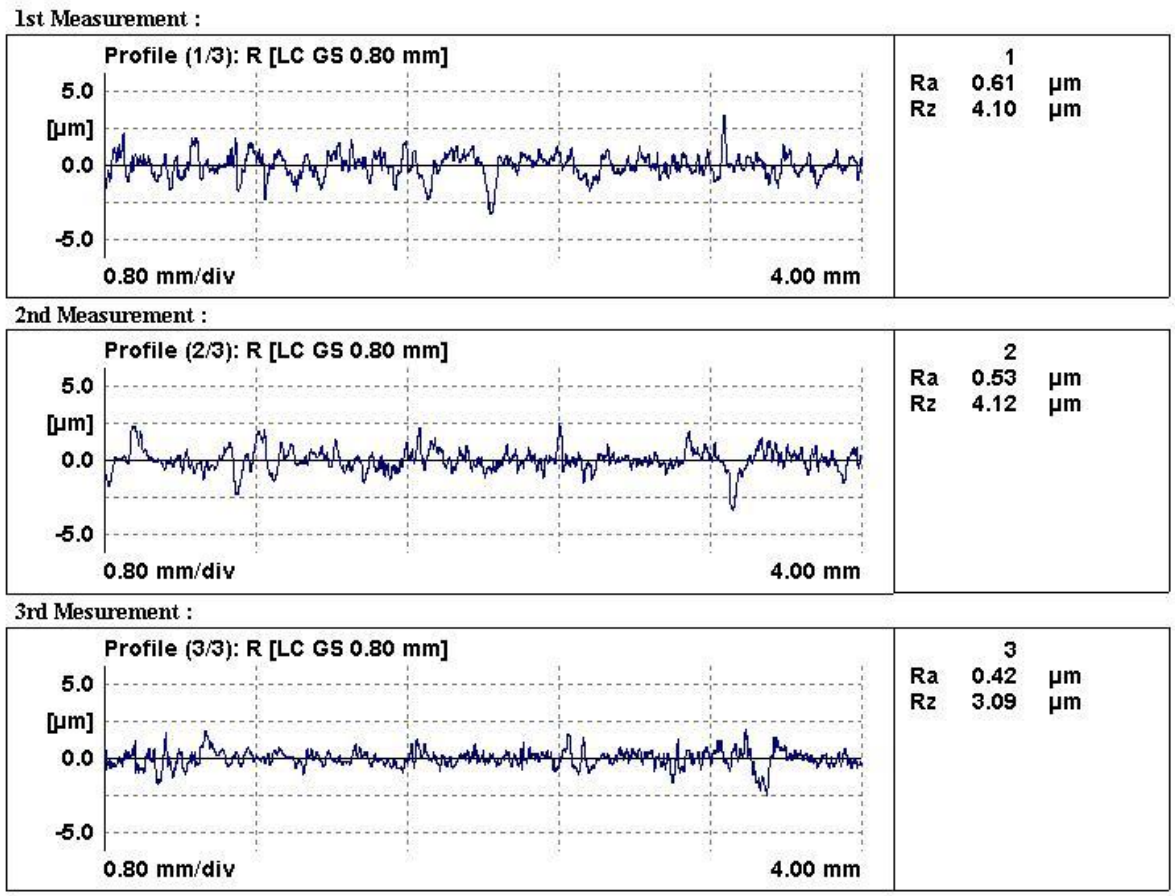


Figure 76: Mild Steel 'Rough' Surface

- This is the reading for ‘medium’ surface on Mild Steel:

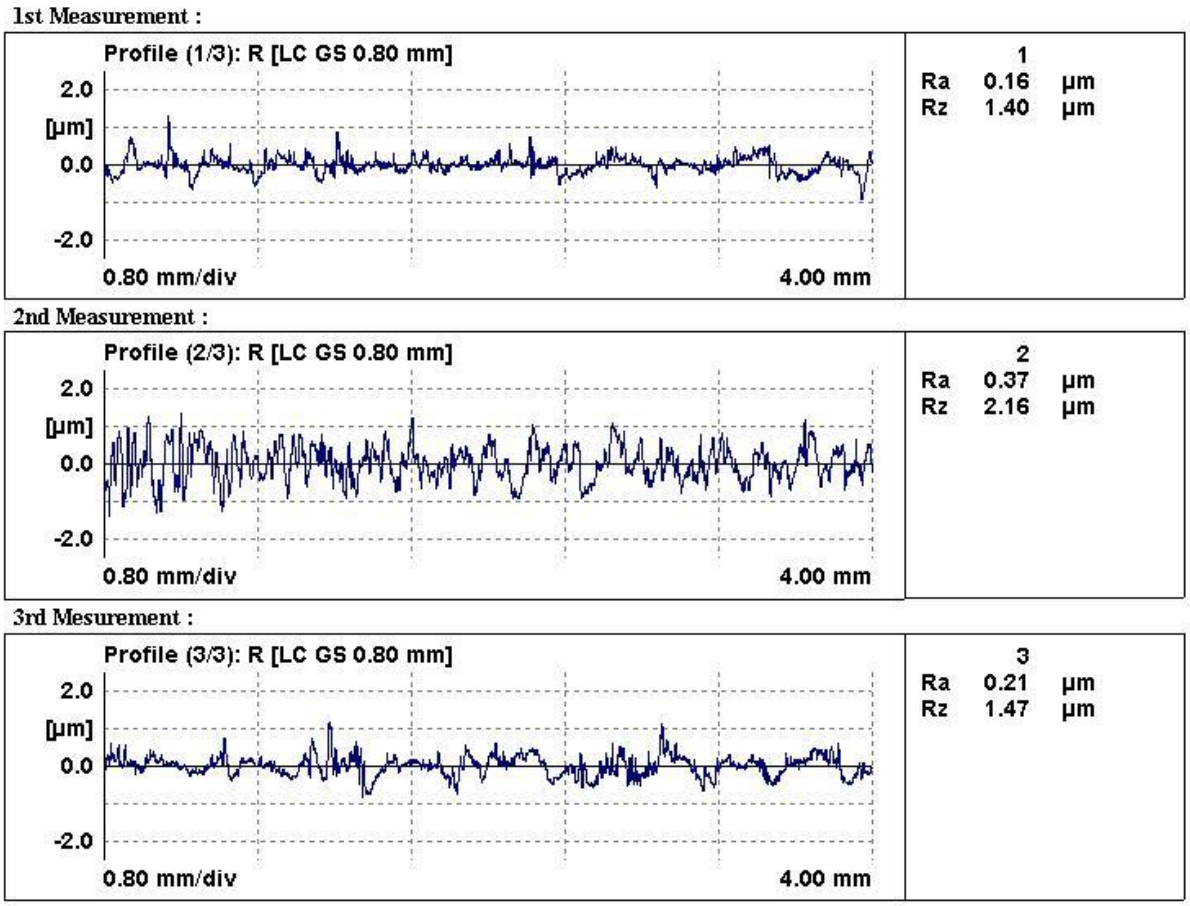


Figure 77: Mild Steel 'Medium' Surface

- This is the reading for ‘fine’ surface on Mild Steel:

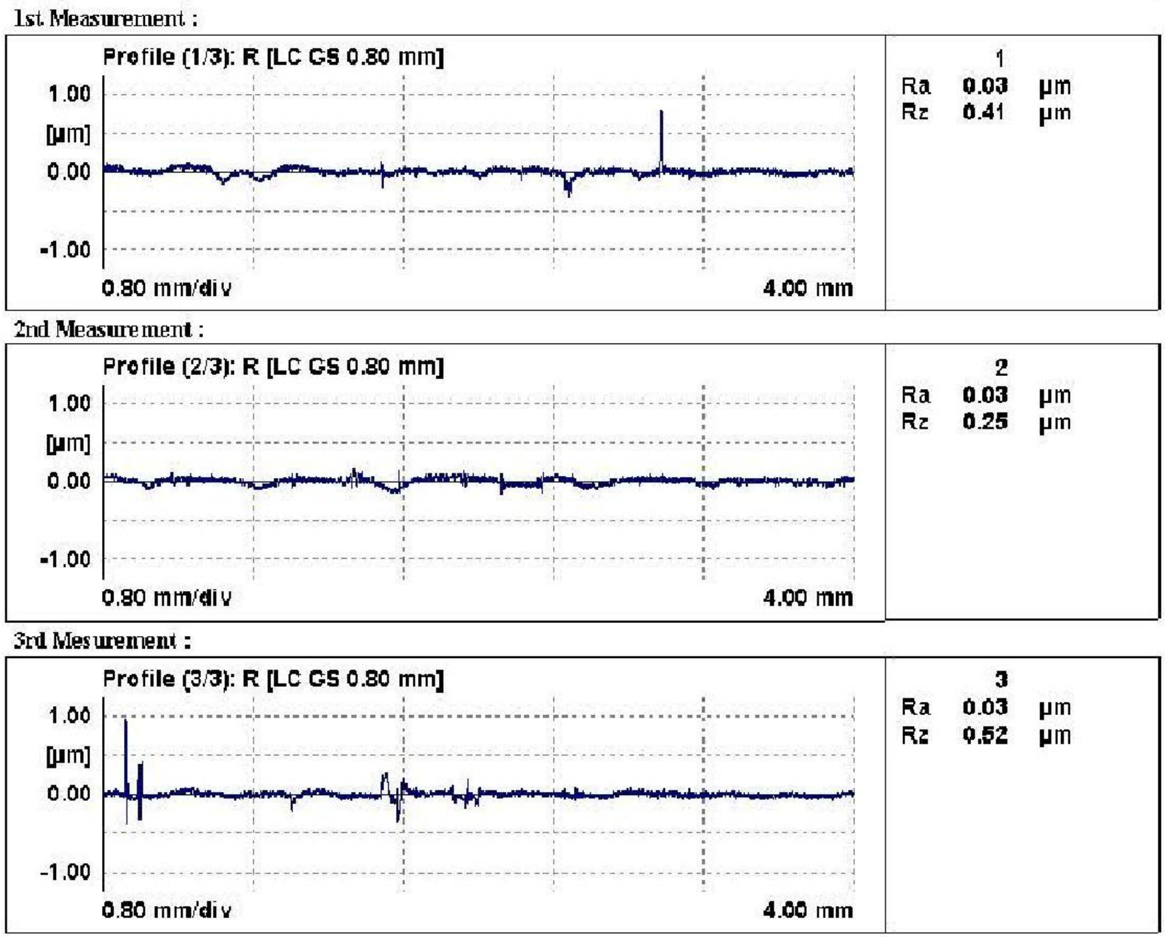


Figure 78: Mild Steel 'Fine' Surface

4.2 Pin-on-Disc Test Results

The results obtained from the Pin-on-Disc test are accumulated in this part. This is where the effect of the surface preparation on the disc can be observed and discussed. Both Group A and B disc samples were tested on the Mild Steel AISI 1018 and Tool Steel H14 pins. Both of the group disc samples shows the effect of the surface preparation which had been done earlier throughout the research. Most of the materials used shows that the volume loss of a 'fine' surface prepared discs are much smaller compared to the 'rough' surface prepared ones.

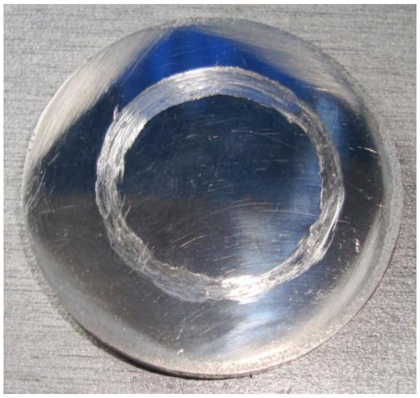


Figure 79: Disc Sample after Pin-on-Disc Test

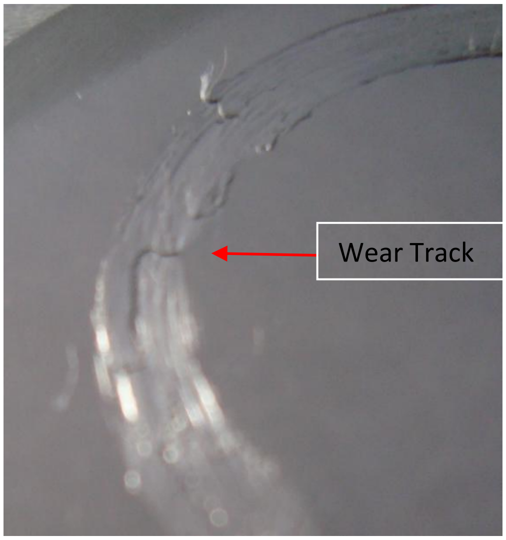


Figure 80: Wear Track

4.2.1 Group A Samples

For this group, all three types of material (Al6063, Mild Steel and H14) with the three types of surface preparations were being tested with the Mild Steel AISI 1018 pins.

Table 27: Experimental Results for Group A

Material	Surface Type	Mass Loss (g)	Volume Loss (mm^3)	Wear Rate (mm^{3}/mm)	Friction Coefficient	Roughness (Ra) and (Rz) (µm)
Aluminum (Al6063)	Rough	0.0942	34.8889	6.17×10^{-4}	0.47	0.68 4.90
	Medium	0.0616	22.8148	4.03×10^{-4}	0.41	0.22 1.79
	Fine	0.0425	15.7407	2.78×10^{-4}	0.36	0.02 0.33
Mild Steel (AISI1018)	Rough	0.0857	11.1299	1.97×10^{-4}	0.57	0.68 3.91
	Medium	0.0573	7.4416	1.32×10^{-4}	0.52	0.29 1.49
	Fine	0.0338	4.3896	7.76×10^{-4}	0.45	0.03 0.31
Tool Steel (H14)	Rough	0.0724	9.1762	1.62×10^{-4}	0.50	0.78 4.87
	Medium	0.0476	6.0329	1.07×10^{-4}	0.46	0.21 1.76
	Fine	0.0127	1.6096	2.85×10^{-5}	0.41	0.03 0.29

From the Table 10, we can see the results of mass loss (g), volume loss (mm^3), wear rate (mm^{3}/mm), and the friction coefficient of each material with the three different surface preparation types.

Table 28: Al6063 Interval Data Collection

Surface Type	Mass Loss (g)		
	200 rev	400 rev	600 rev
Rough	0.0308	0.0547	0.0942
Medium	0.0231	0.0311	0.0616
Fine	0.0162	0.0297	0.0425

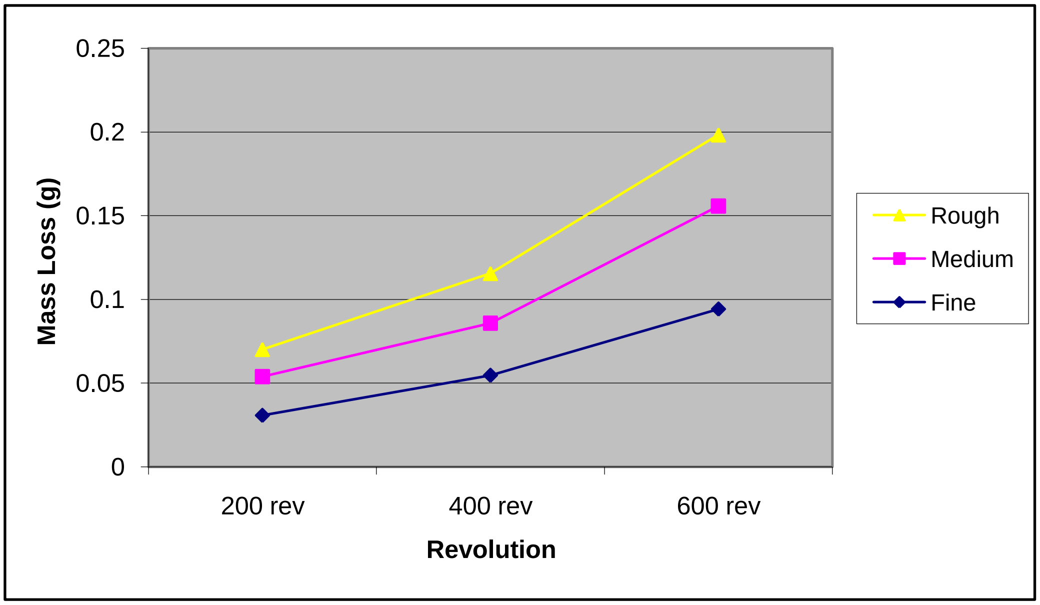


Figure 81: Al6063 Interval Data Collection

Table 29: Mild Steel Interval Data Collection

Surface Type	Mass Loss (g)		
	200 rev	400 rev	600 rev
Rough	0.0307	0.0629	0.0857
Medium	0.0225	0.0397	0.0573
Fine	0.0092	0.0165	0.0338

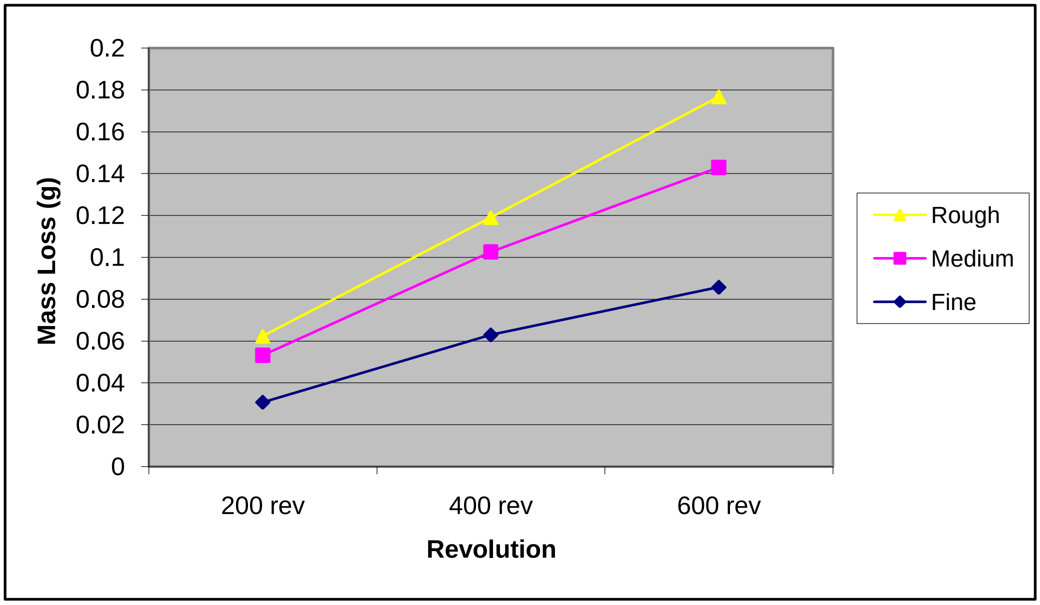


Figure 82: Mild Steel Interval Data Collection

Table 30: H14 Interval Data Collection

Surface Type	Mass Loss (g)		
	200 rev	400 rev	600 rev
Rough	0.0226	0.0473	0.0724
Medium	0.0184	0.0298	0.0476
Fine	0.0042	0.0075	0.0127

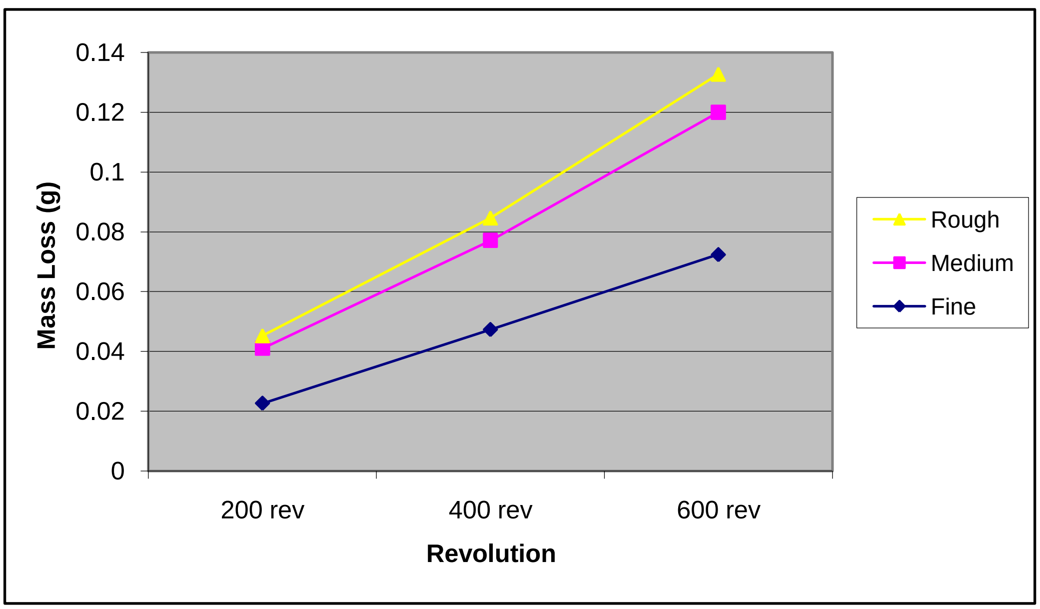


Figure 83: H14 Interval Data Collection

4.2.2 Group B Samples

For this group, all three types of material (Al6063, Mild Steel and H14) with the three types of surface preparations were being tested with the Tool Steel H14 pins.

Table 31: Experimental Results for Group B

Material	Surface Type	Mass Loss (g)	Volume Loss (mm^3)	Wear Rate (mm^{3}/mm)	Friction Coefficient	Roughness (Ra) and (Rz) (μm)
Aluminum (Al6063)	Rough	0.1157	42.8519	7.58×10^{-4}	0.49	0.70 4.96
	Medium	0.0831	30.7778	5.44×10^{-4}	0.40	0.23 1.86
	Fine	0.0592	21.9259	2.88×10^{-4}	0.35	0.02 0.27
Mild Steel (AISI1018)	Rough	0.0937	12.1688	2.15×10^{-4}	0.51	0.52 3.77
	Medium	0.0711	9.2338	1.63×10^{-4}	0.44	0.25 1.68
	Fine	0.0468	6.0779	1.08×10^{-4}	0.39	0.03 0.39
Tool Steel (H14)	Rough	0.0791	10.0253	1.77×10^{-4}	0.45	0.72 4.92
	Medium	0.0516	6.5399	1.15×10^{-4}	0.41	0.20 1.32
	Fine	0.0208	2.6362	4.55×10^{-5}	0.37	0.02 0.30

From the Table 11, we can see the results of mass loss (g), volume loss (mm^3), wear rate (mm^{3}/mm), and the friction coefficient of each material with the three different surface preparation types.

Table 32: Al6063 Interval Data Collection

Surface Type	Mass Loss (g)		
	200 rev	400 rev	600 rev
Rough	0.0427	0.0729	0.1157
Medium	0.0374	0.0520	0.0831
Fine	0.0162	0.0297	0.0592

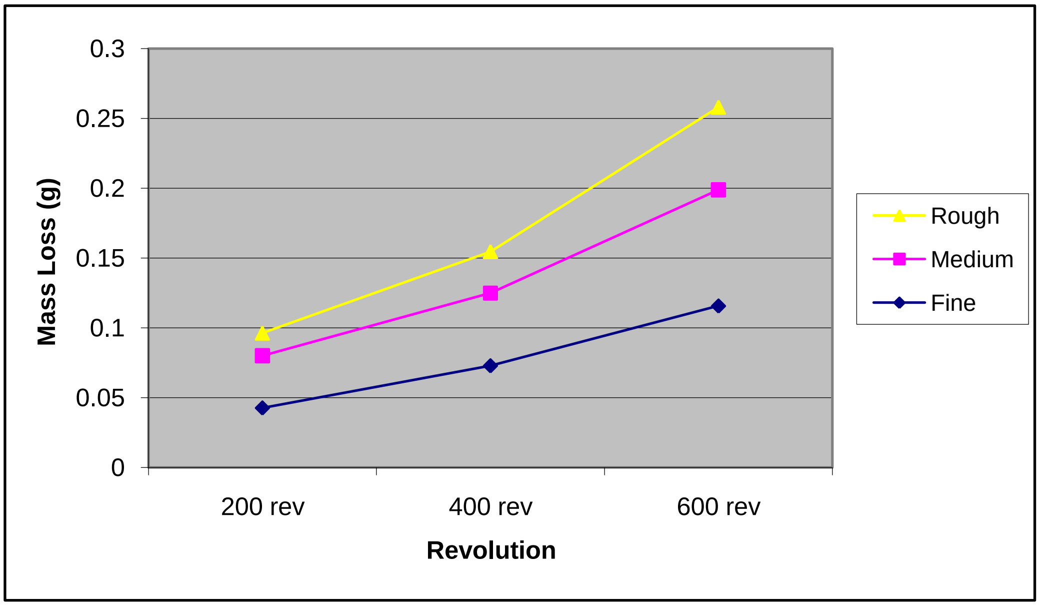


Figure 84: Al6063 Interval Data Collection

Table 33: Mild Steel Interval Data Collection

Surface Type	Mass Loss (g)		
	200 rev	400 rev	600 rev
Rough	0.0352	0.0598	0.0937
Medium	0.0193	0.0305	0.0711
Fine	0.0096	0.0203	0.0468

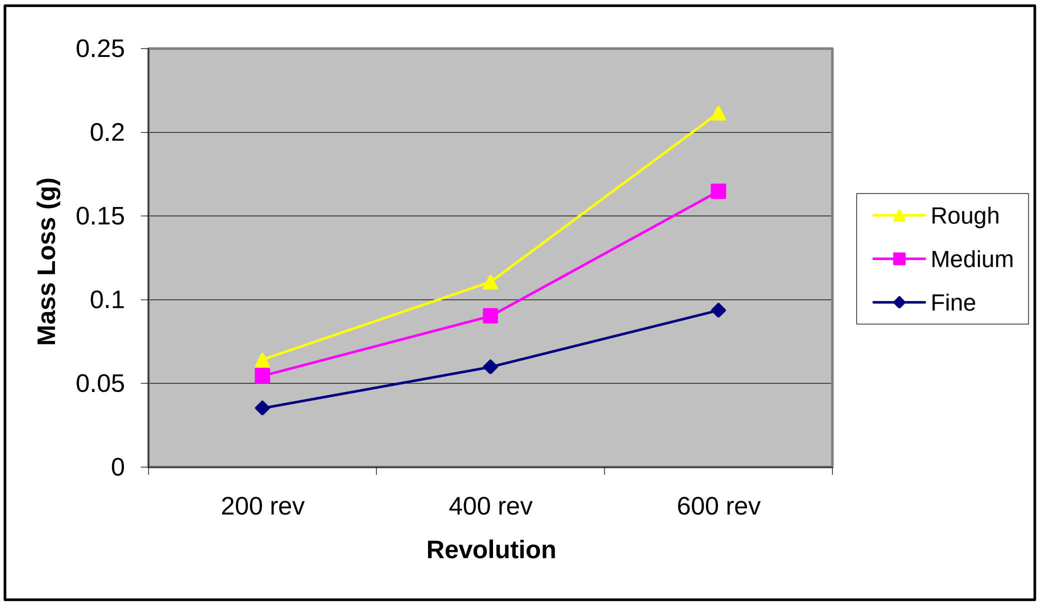


Figure 85: Mild Steel Interval Data Collection

Table 34: H14 Interval Data Collection

Surface Type	Mass Loss (g)		
	200 rev	400 rev	600 rev
Rough	0.0258	0.0455	0.0791
Medium	0.0162	0.0248	0.0516
Fine	0.0072	0.0094	0.0208

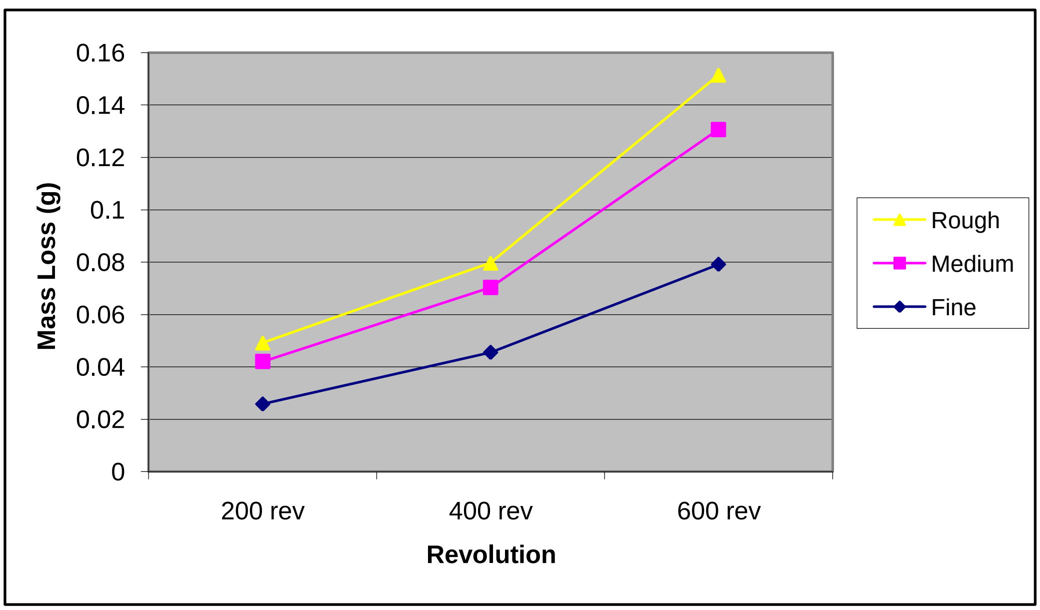


Figure 86: H14 Interval Data Collection

4.3 Discussion

From Group A and B, we can observe that each type of surface preparation done had different mass and volume loss. It can also be observed that the finer the surface is being prepared, the less mass is loss. This is due to the smaller friction between the surface of the pin and the disc which allows the sliding of both surfaces to be much smoother. Although all of the surfaces had been well prepared, wear will still occur since the pin and disc are in contact and rubs against each other. Both the wear and the roughness of the surface of the material are related; where the increment of the surface roughness will cause the wear to increase as well.

This is only applicable for the initial part of the Pin-on-Disc test. Once the surface of the material tested had been damaged by wear, the type of surface preparation being done won't be taken into account anymore. The wear rate for the three different types of surface preparations for one type of material will be the same once the surface had been damaged. Of course, the damaging process of the surface will be different for each surface preparation. 'Fine' surface will require more time in order for it to be damaged by the same amount of load, speed and material compared to 'medium' surface. The same principle applies for 'medium' surface, where it will take more time to be damaged compared to 'rough' surface. Since the experiment running time is constant, we can see the effect through different material mass loss or volume loss.

From Figure 38 and Figure 39, it can be observed that the wear of the same material with two different surface preparations. Both figures are comparing two different surface preparations of the same material; 'medium' and 'rough' surface of Tool Steel H14. Wear starts to occur much later for 'medium' surface compared to the 'rough' surface. Once the surface preparations had been damaged, the graph increment trends for both samples are almost identical.

Since there are Group A and Group B, the samples and surface preparations used in both groups are the same. The difference is, Group A are paired with Mild Steel AISI 1018 pins while Group B are paired with Tool Steel H14. Group B has an overall higher mass and volume loss compared to Group A for all disc samples. This shows that a harder material will cause the paired material to lose more mass if wear occurs between the two different materials.

5.0 CONCLUSION AND RECOMMENDATION

5.1 Conclusion

As a conclusion for this report, it can be concluded that rougher surface finish gives larger wear rate compared to finer surface finish. This principle applies to the entire three test samples experimented in this project. For example, for Al6063 with rough surface finish where the measured Ra = 0.7 µm, has a wear rate of 7.58 x 10^{-4} mm^3/mm. The same material but with a fine surface finish has a measured Ra = 0.02 µm, has a wear rate of 2.88 x 10^{-4} mm^3/mm. This proves that rougher surface finish has larger wear rate compared to finer surface finish.

Surface finish gives effect towards the wear rate and wear resistant. Finer surface finish gives lower wear rate of the materials. Same goes for the rougher surface finish which gives off higher wear rate. Higher wear rate indicates the material has lower wear resistant, while lower wear rate indicates higher wear resistant of the material. Thus, we can relate that finer surface finish has higher wear resistant since it has lower wear rate, while rougher surface finish has lower wear resistant due to the high amount of wear rate.

Different surface finish will affects the life of moving metallic materials in contact with another surface. Although the wear rate of the material with different surface preparations once it had been damaged are the same, the time for the surface to be damaged are totally different and dependant on the types of surface profile the material has. Finer surface profile allows longer service time of the material or machine. Other than that, finer surface profile allows energy saving in order to overcome the friction between two contacting surface that are rubbing against each other. It will also greatly reduce unwanted sound pollution made by the grinding of the two surfaces. By having flaws on the surface of a contacting material which is rubbing against each other will cause the lifespan of the material or machine to be reduced greatly. By having different types of material with different hardness on two contacting surface which are rubbing against each other allows lesser wear effect on the harder material. By having the least expensive parts as the softer material allows cost savings in the long run.

5.2 Recommendation

Through the project which had been carried out for two semesters, there are some recommendations that might be applicable for future improvement such as:

- To have further study on effect of surface preparations on other types of non-metallic materials.
- To have further study on the application of lubricant for metallic materials with the same surface preparations.

Reference(s)

1. [a] ***b c d e*** Oberg, p. 1439.
2. *How Polishing, Buffing & Burnishing Work*, retrieved 2009-01-11.
3. ***a b c*** *Metal polishing*, retrieved 2009-01-05.
4. Deck, Clara, *The care and preservation of historical brass and bronze*, retrieved 2009-01-06.
5. E.A. Almond and M.G. Gee , Results from a U.K. inter-laboratory project on dry sliding wear. *Wear* **120** (1987), pp. 101–116.

6. E.A. Almond and M.G. Gee , Effects of test variables in wear testing of ceramics. *Mater. Sci. Technol.* **4** (1988), pp. 877–884.

7. H. Czichos, Design of friction and wear experiments, ASM Handbook 18 Friction, Lubrication and Wear Technology, The Materials Information Society, USA, 1992, pp. 480–488.

8. Statistica, 99 Edition, Kernel release 5.5, Statsoft Inc., Tulsa, USA.

9. J. Mandel, The statistical analysis of experimental data, Dover, New York, USA, 1984.

10. Robert H. Thurston, Friction and lubrication - Determination of the laws and co-ëfficients of friction by new methods and with new apparatus, Trübner and Co., Ludgate Hill, London, 1879

11. Robert H. Thurston, A treatise on friction and lost work in machinery and millwork, John Wiley&Sons, New York, 1894, fifth edition

12. H. Czichos, K.-H. Habig, Tribologie-Handbuch (Tribology handbook, Vieweg Verlag, Wiesbaden, 2nd edition, 2003, ISBN 3-528-16354-2

13. R. Stribeck, Die wesentlichen Eigenschaften der Gleit- und Rollenlager (The basic properties of sliding and rolling bearings), Zeitschrift des Vereins Deutscher Ingenieure, 2002, Nr. 36, Band 46, p. 1341-1348, p. 1432-1438 and 1463-1470

14. R. Stribeck, Kugellager für beliebige Belastungen Zeitschrift des Vereins Deutscher Ingenieure, 1901, Nr. 3, Band 45, p. 73-79

15. N.N. (R. Stribeck), Kugellager (ball bearings), Glasers Annalen für Gewerbe und Bauwesen, 1901, No. 577, p. 2-9, Published 01. July 1901

16. Martens, Schmieröluntersuchungen (Investigations on oils) Part I: Mitteilungen aus den Königlichen technischen Versuchsanstalten zu Berlin, Ergänzungsheft III 1888, p. 1-37, Verlag von Julius Springer, Berlin and Part II: Mitteilungen aus den Königlichen technischen Versuchsanstalten zu Berlin, Ergänzungsheft V, 1889, p. 1-57, Verlag von Julius Springer, Berlin

17. ASTM G99-04 Volume 03.02

18. Degarmo, E. Paul; Black, J T.; Kohser, Ronald A. (2003), *Materials and Processes in Manufacturing* (9th ed.), Wiley

19. Oberg, Erik; Jones, Franklin D.; Horton, Holbrook L.; Ryffel, Henry H. (2000), *Machinery's Handbook* (26th ed.), New York: Industrial Press, Inc., pp. 444–475

20. Oberg, p. 452.

21. http://en.wikipedia.org/wiki/Tool_steel

22. Polmear, I. J. (1995). *Light Alloys: Metallurgy of the Light Metals*. Arnold.

23. Dieter G. E. (1988). *Mechanical Metallurgy*

24. Guilbert, John M. and Carles F. Park (1986). *The Geology of Ore Deposits*. Freeman. pp. 774-795.

25. Christoph Schmitz, Josef Domagala, Petra Haag (2006). *Handbook of Aluminum recycling: fundamentals, mechanical preparation, metallurgical processing, plant design*. Vulkan-Verlag GmbH. p. 27.

26. *Modulus of Elasticity, Strength Properties of Metals - Iron and Steel*

27. Engineering fundamentals page on medium-carbon steel