CHAPTER 1
INTRODUCTION

1.1 **Background of Study**

Brakes are an energy-absorbing mechanism that converts vehicle movement into heat while stopping the rotation of wheels. All braking systems are designed to reduce the speed and stop a moving vehicle and to keep it from moving if the vehicle is stationary [1]. Sometimes when braking action stops the wheels of the vehicle, it is not necessarily stopping the vehicle itself but also for parking purpose. Hence the effective braking action has to study in this work.

Brake pads are an important part of braking systems for all types of vehicles that are equipped with drum or disc brakes. Brake pads are steel backing plates with friction material bound to the surface facing the brake disk or drum [2].

The brake pads are designed for high friction and when it is in contact with the disc, it wears evenly in the process. Although it is commonly thought that the pad material contacts with the metal of the disc to stop the car, the pads work with a very thin layer of their own material and generate a semi-liquid friction boundary that creates the actual braking force. Of course, depending on the properties of the material, disc wear rates may vary. The properties that determine material wear involve trade-offs between performance and longevity [3].

The tribological interactions of a solid surface's exposed face with interfacing materials and environment may result in loss of material from the surface. The process leading to loss of material is known as "wear". Major types of wear include abrasion, adhesion (friction), erosion, and corrosion [4].

1.2 Problem Statement

Under the normal working action the brake pad has to cope with wide range of disc rotating speed but it is still hoping to deliver a better braking action. Sometimes the brake pad fail to perform effectively and it may cause major traffic accidence. The manner in which the brake peddle is applied during driving is also reflected to the ability of the brake pad to bear the loading or applied pressure. This project is trying to investigate the relationship between various sliding speed and loading to the friction and wear properties of the selected automotive brake pad materials.

1.3 Objectives and Scope of Study

1.3.1 Objectives

i. To conduct a laboratory investigation on the effect of loadings and sliding speed to the tribological and physical properties of the automotive brake pad materials.
ii. To analyze the results obtained from this investigation; able to make recommendation, draw to a conclusion and future work.

1.3.2 Scope of Study

i. To select a Proton Wira brake pad as a testing specimen in this investigation.
ii. To study the effect of loading and sliding speed to the tribological properties of brake pad materials.
iii. To conduct a wear test using a Multi-Specimen Friction and Wear Tester. Able to use a tools or equipments such as SEM-EDAX, SEM-Micrograph (Using SE I, SE II and Backscatter Modes), Optical Microscope and Surface Profiler.

iv. To analyze results and able to made a recommendation, come to a conclusion and future work.

CHAPTER 2
LITERATURE REVIEW

2.1 Brake Pads

Disc-style brakes began in England in the 1890s; the first ever automobile disc brakes were patented by Frederick William Lanchester in his Birmingham factory in 1902, though it took another half century for his innovation to be widely adopted [2].

Brake linings are composed of a relatively soft but tough and heat-resistant material with a high coefficient of dynamic friction (and ideally an identical coefficient of static friction) typically mounted to a solid metal backing using high-temperature adhesives or rivets [5]. The complete assembly (including lining and backing) is then often called a *brake pad* or *brake shoe*. The dynamic friction coefficient "μ" for most standard brake pads is usually in the range of 0.35 to 0.42 [5].

There are numerous types of brake pads, depending on the intended use of the vehicle, from very soft and aggressive such as racing applications and harder, more durable and less aggressive compounds. Most vehicle manufacturers recommend a specific compound of brake pad for their vehicle, but compounds can be changed by either using a different make of pad or upgrading to a performance pad in a manufacturer's range according to personal tastes and driving styles. Care must always be taken when fitting non standard brake pads, as operating temperature ranges may vary, such as performance pads not braking efficiently when cold or standard pads fading under hard driving [2].

Most pad backings include mounting ears, clips, or projections; some have only mounting hole. The pads of a fixed-caliper brake and the inboard pad of a floating-caliper brake are normally designed to drop in place between two abutments with just enough clearance for application and release movement. Braking pressure is transferred to the abutments in the caliper or caliper mounting bracket. Most floating-caliper outboard pads are secured solidly to the caliper. Any motion between the outboard pad and the caliper might cause vibration and brake squeal [6].

2.1.1 Brake Pads Function

Brake pads convert kinetic energy of the car to thermal energy by friction. When a brake pad is heated up by coming into contact with either a drum or rotor, it starts to transfer small amounts of friction material to the disc or drum (that is the reason a brake disk has a dull grey). The brake rotor and disk (both now with friction material on), will then "stick" to each other to provide stopping power. The friction of the pad against the disk is however responsible for the majority of stopping power [2].

In disc brake applications, there are usually two brake pads per disc rotor, held in place and actuated by a caliper affixed to a wheel hub or suspension upright. In drum brake applications, the brake pads are affixed to the wheel hub or mounting plate, with the friction surfaces pushing out against the inside of the drum itself [2].

2.1.2 Brake Design Requirements

All braking forces must provide for the following [1]:-

i. Equal forces must be applied to both the left and right sides of the vehicle to ensure straight stops.
ii. The hydraulic system must use a fluid that will not evaporate or freeze. The fluid has to withstand extreme temperatures without boiling and must not damage rubber or metal parts of braking system.
iii. The friction material (braking lining or brake pads) must be designed to provide adequate friction between the stationary axles and the rotating drum or rotor.
iv. The design of the braking system should secure the brake lining solidly to prevent the movement of the friction material during braking.

2.2 Composition of Friction Materials and Their Roles

Materials		Function
Resin	Phenolic, Epoxy etc.	Binder
Fiber	Asbestos, Steel, Aramid etc.	Friction Material Reinforcement
Metal Powder	Cu, Cu-Zn, Fe, Al, Zn etc.	Increase Friction Coefficient
Solid Lubricant	Graphite, MoS_2, Mica etc.	Prevent Micro Stick to the Rotor
Abrasive	Al_2O_3, SiO_2, MgO, Fe_2O_3 etc.	Cleaning Surface of Rotor
Organic Filler	Cashew Dust, Rubber etc.	Reduce Wear at Low Temperature
Inorganic Filler	$BaSO_4$, $CaCO_3$, $Ca(OH)_2$ etc.	Reduce Wear at High Temperature

Table 1: Materials used for brake pads [7]

- Fiber - The fiber weaves through the matrix and overlaps on itself to provide the necessary rigidity, strength and integrity to the brake lining.
- Filler - Low cost materials that are added to extend the brake lining occupy space and minimize cost.
- Binder - Material that holds the brake lining together.
- Friction modifier - The most diverse type of material in brake lining.
- Lubricants - To assist in part removal from molds.

2.3 Friction

Friction is the force that opposes the relative motion or tendency toward such motion of two surfaces in contact. When contacting surfaces move relative to each other, the friction between the two objects converts kinetic energy into thermal energy, or heat [8].
The coefficient of friction (also known as the frictional coefficient) is a dimensionless scalar value which describes the ratio of the force of friction between two bodies and the force pressing them together. The coefficient of friction depends on the materials used –

for example, ice on steel has a low coefficient of friction (the two materials slide past each other easily), while rubber on pavement has a high coefficient of friction (the materials do not slide past each other easily) [8].

When the surfaces are adhesive, Coulomb friction becomes a very poor approximation (for example, Scotch tape resists sliding even when there is no normal force, or a negative normal force). In this case, the frictional force may depend strongly on the area of contact. Some drag racing tires are adhesive in this way [8].

The force of friction is always exerted in a direction that opposes movement (for kinetic friction) or potential movement (for static friction) between the two surfaces. For an example of potential movement, the drive wheels of an accelerating car experience a frictional force pointing forward; if they did not, the wheels would spin, and the rubber would slide backwards along the pavement. The coefficient of friction is an empirical measurement – it has to be measured experimentally, and cannot be found through calculations [9].

2.3.1 Types of Friction

There are three types of friction which are static friction, rolling friction and kinetic friction (dynamic friction).

2.3.1.1 Static Friction

Static friction is the force between two objects that are not moving relative to each other. For example, static friction can prevent an object from sliding down a sloped surface. The *coefficient of static friction* is typically denoted as μ_s. It is usually higher than the coefficient of kinetic friction. The initial force to get an object moving is often dominated by static friction [9].

2.3.1.2 Rolling Friction

Rolling friction is the frictional force associated with the rotational movement of a disc or other circular objects along a surface. Generally the frictional force of rolling friction is less than that associated with kinetic friction. Typical values for the coefficient of rolling friction are 0.001 [9].

2.3.1.3 Kinetic Friction

Kinetic (or dynamic) friction occurs when two objects are moving relative to each other and rub together (like a sled on the ground). The *coefficient of kinetic friction* is typically denoted as μ_k, and is usually less than the coefficient of static friction [9].

Since friction is exerted in a direction that opposes movement, kinetic friction usually does negative work, typically slowing something down [9].

These are the examples of kinetic friction:-

- Sliding friction is when two objects are rubbing against each other. Putting a book flat on a desk and moving it around is an example of sliding friction [9].
- Fluid friction is the friction between a solid object as it moves through a liquid or a gas. The drags of air on an airplane or of water on a swimmer are two examples of fluid friction [9].

2.3.2 Energy of Friction

According to the law of conservation of energy, no energy is destroyed due to friction, though it may be lost to the system of concern. Energy is transformed from other forms into heat. A sliding hockey puck comes to rest due to friction as its kinetic energy changes into heat. Since heat quickly dissipates, many early philosophers, including Aristotle, wrongly concluded that moving objects lose energy without a driving force [8].

When an object is pushed along a surface, the energy converted to heat is given by [7]:

$$E = \mu_k \int N(x)dx$$

Where;

N = the normal force.

μ_k = coefficient of kinetic friction,

x = coordinate along which the object transverses.

2.4 Wear

In materials science, wear is the erosion of material from a solid surface by the action of another solid. The study of the processes of wear is part of the discipline of tribology. There are four principal wear processes [10]:

2.4.1 Adhesive Wear

Adhesive wear is also known as scoring, galling, or seizing. It occurs when two solid surfaces slide over one another under pressure. Surface projections, or asperities, are plastically deformed and eventually welded together by the high local pressure. As sliding continues, these bonds are broken, producing cavities on the surface, projections on the second surface, and frequently tiny, abrasive particles, all of which contribute to future wear of surfaces [10].

2.4.2 Abrasive Wear

When material is removed by contact with hard particles, abrasive wear occurs. The particles either may be present at the surface of a second material or may exist as loose particles between two surfaces. Abrasive wear can be measured as loss of mass by the Taber Abrasion Test according to ISO 9352 or ASTM D 1044 [10].

2.4.3 Corrosive Wear

Often referred to simply as "corrosion", corrosive wear is deterioration of useful properties in a material due to reactions with its environment. One form of high temperature corrosive (oxidative) wear can lead to the formation of compacted oxide layer glazes, which under certain circumstances reduces wear [10].

2.4.4 Surface Fatigue

Surface fatigue is a process by which the surface of a material is weakened by cyclic loading, which is one type of general material fatigue [10].

2.5 Pin on Disc

The standard equipment used to determine the sliding friction coefficient and wear resistance of surfaces is the pin on disc tester. The pin on disc tester consists of a stationary "pin" under an applied load in contact with a rotating disc. Either the pin or the disc can be wear and friction tested using the pin on disc tester. The pin is usually a sphere however it may be any geometry that simulates the actual application counter surface. A load cell attached to the pin on disc tester is used to measure the evolution of the friction coefficient with sliding distance. Sliding wear of the disc can be measured after the pin on disc test using a simple piece of equipment called a Calo tester [11].

One of the commonest and simplest methods to test for wear resistance is by using a pin-on-disk wear tester. A pin of one material is loaded against a sliding flat surface or rotating cylinder. The weight loss from either the pin or the counterface is measured. Wear is usually expressed as worn volume per unit load per unit sliding distance. This is sometimes non-dimensionalised by dividing by the hardness of the softer surface [12].

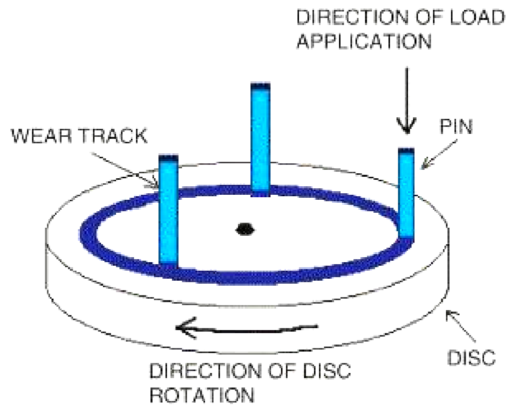


Figure 1: Typical 3 pins-on-disc set up

The normal load, rotational speed, and the wear track diameter are all is set by the user prior to the pin on disc test [13].

2.6 Scanning Electron Microscope (SEM)

The scanning electron microscope (SEM) is a type of electron microscope capable of producing high-resolution images of a sample surface. Due to the manner in which the image is created, SEM images have a characteristic three-dimensional appearance and are useful for judging the surface structure of the sample [14].

The electron beam, which typically has an energy ranging from a few hundred eV to 100 keV, is focused by one or two condenser lenses into a beam with a very fine focal spot sized 0.4 nm to 5 nm. The beam passes through pairs of scanning coils or pairs of deflector plates in the electron optical column, typically in the objective lens, which deflect the beam horizontally and vertically so that it scans in a raster fashion over a rectangular area of the sample surface. When the primary electron beam interacts with the sample, the electrons lose energy by repeated scattering and absorption within a teardrop-shaped volume of the specimen known as the interaction volume, which extends from less than 100 nm to around 5 µm into the surface [14].

The size of the interaction volume depends on the electrons' landing energy, the atomic number of the specimen and the specimen's density. The spatial resolution of the SEM depends on the size of the electron spot, which in turn depends on both the wavelength of the electrons and the magnetic electron-optical system which produces the scanning beam. The resolution is also limited by the size of the interaction volume, or the extent to which the material interacts with the electron beam [14].

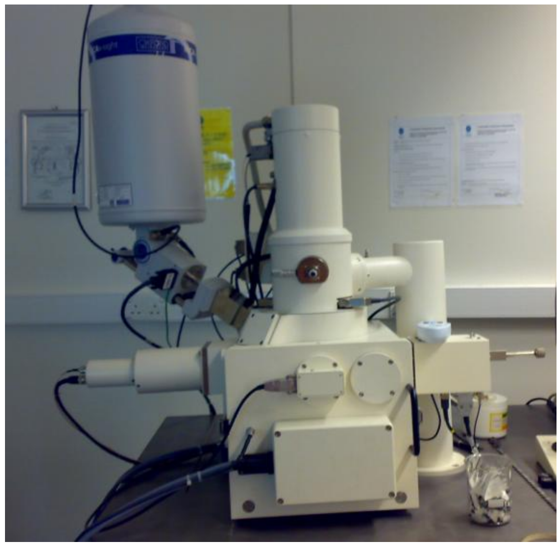


Figure 2: Front view of SEM – EDAX machine

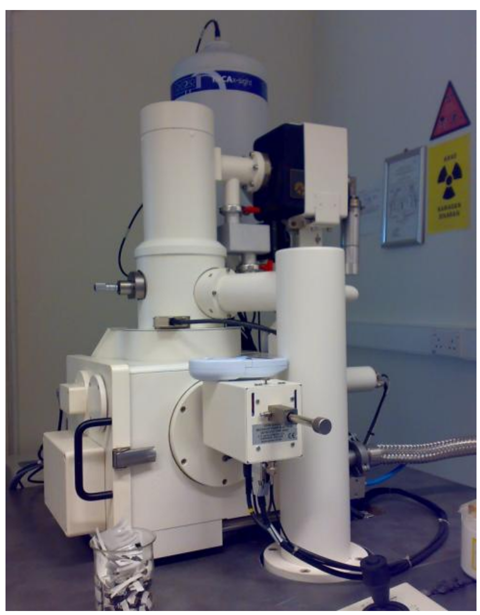
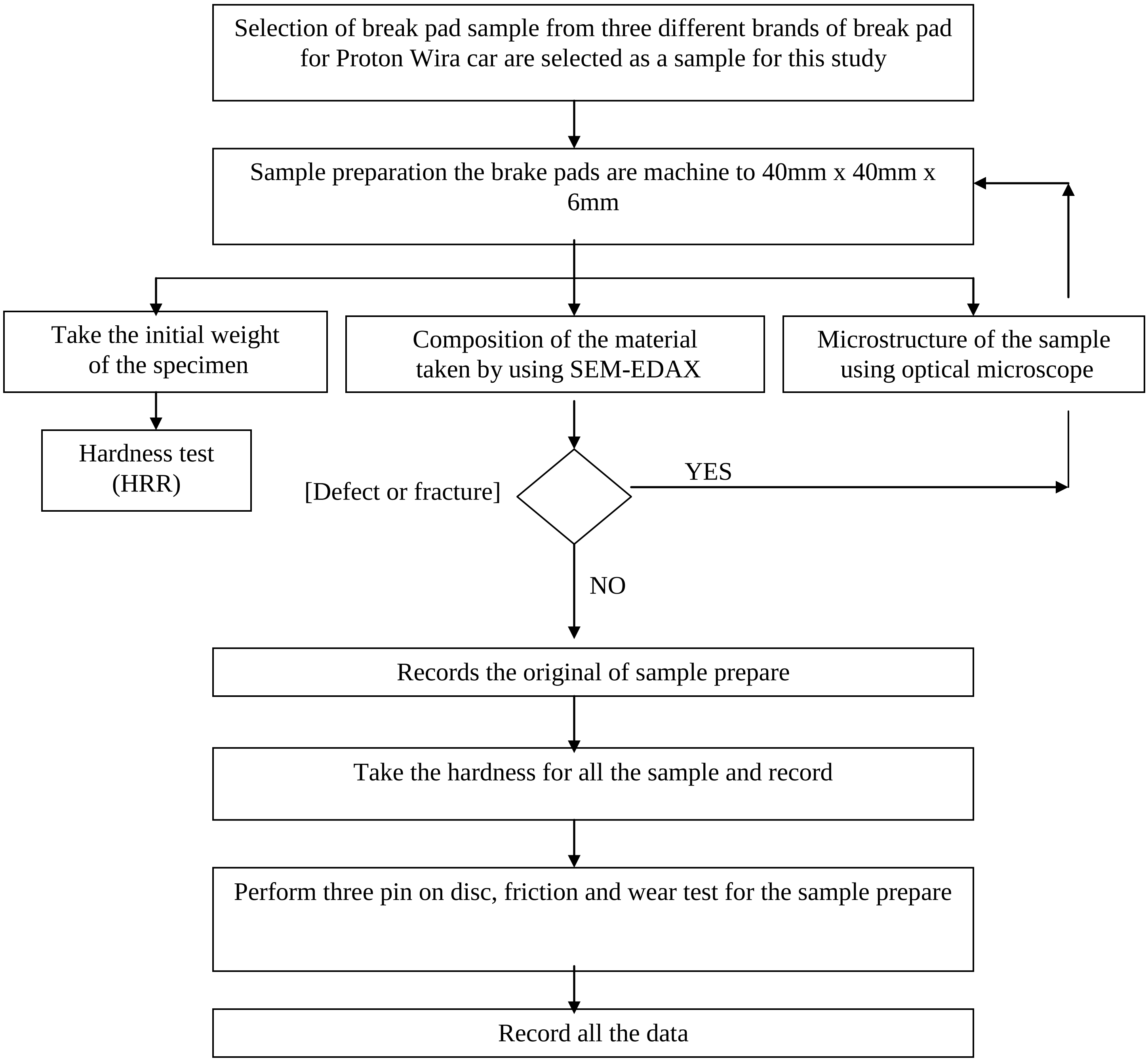


Figure 3: Side view of SEM – EDAX machine

CHAPTER 3

METHODOLOGY

3.1 Research Methodology



- Three different brands or manufacturer for Proton Wira Model brake pads as a testing specimen in this investigation were selected:-
  - MINTYE
  - Metallic
  - Deluxe (Trestor)
- To machine the brake pads into a dimension needed for this experiment, Linear Hack Saw machine was used.

Figure 4: Side view of Linear Hack Saw Machine

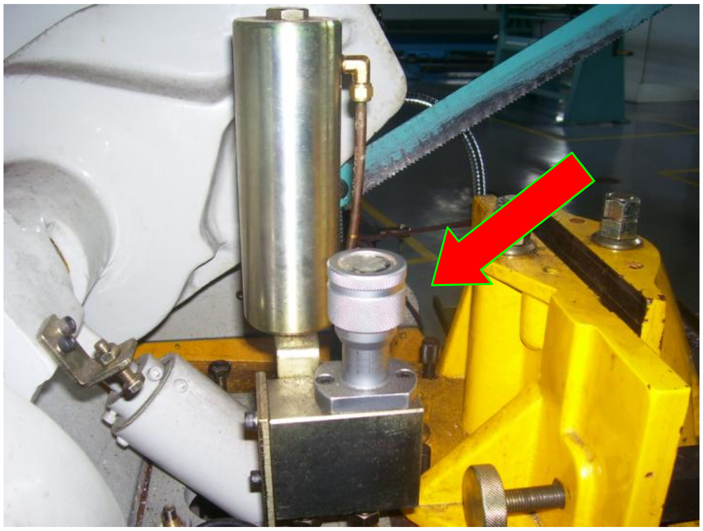


Figure 5: Speed control of Linear Hack Saw Machine

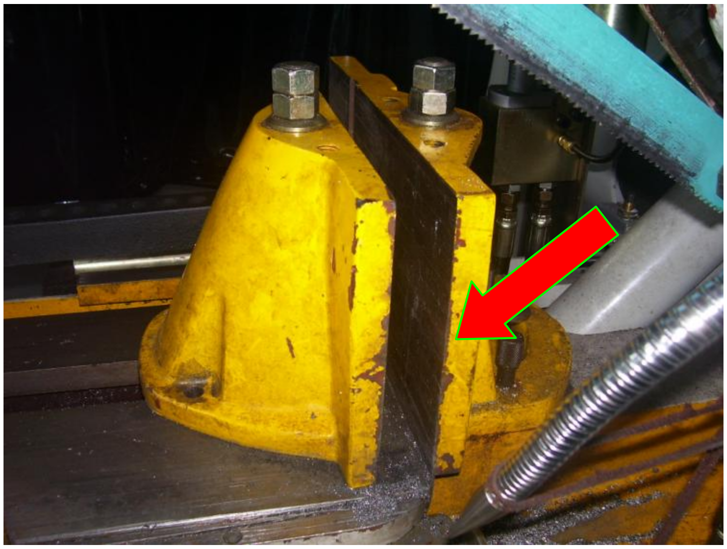


Figure 6: Clamp of Linear Hack Saw Machine

- Speed control: to control the saw's speed while cutting the specimen.
- Clamp : to hold tight the specimen during cutting process.

3.2 Surface profiler

To get surface roughness of these samples, surface roughness tester was used. For each sample, three reading was taken to get an average reading.

- Surface roughness tester operating procedure:-

  How to operate surface roughness machine

  i. Switch on computer.
  ii. Switch on machine.
  iii. Open roughness software in computer.
  iv. Locate specimen to the position.
  v. Select the testing parameter.
  vi. Press start button.
  vii. Start taking measurement.

  After operation,

  i. Close roughness software.
  ii. Switch off machine.
  iii. Shutdown computer.

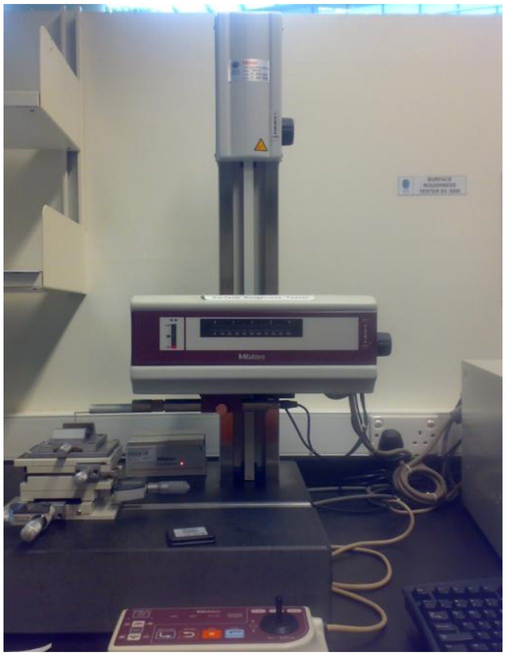


Figure 7: Surface Roughness Tester SV 3000 MITUTOYO

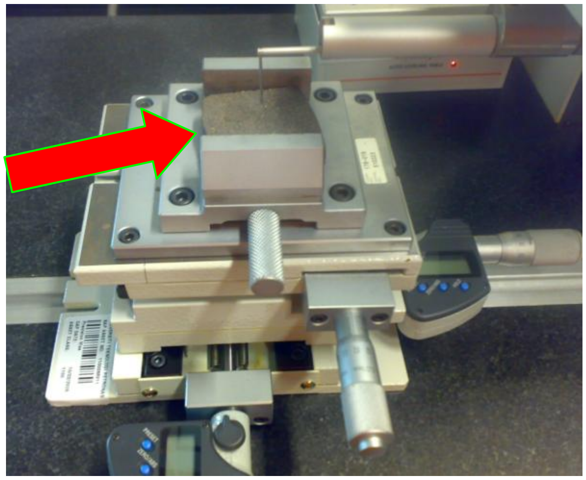


Figure 8: Brake pad sample with surface roughness tester

3.3 Grinder and polisher

To get a flat and smooth surface of specimen after cutting, we use a grinder machine. All of the specimens were ground to 120grit number SiC paper to ensure them to have same surface roughness. When the specimens' surface is flat, no vibration will occur during we using a multi-specimen friction and wear tester. So we can minimize an error when we take the reading after the test.

Figure 9: Grinder and polisher machine

3.4 Rockwell Hardness Test

The Rockwell hardness number is calculated from the permanent depth of penetration, resulting from the application and removal of the additional major load. The test constitute the most common method used to measure hardness because they are simple and require no special skills.

In this case, the Rockwell hardness method consists of indenting the specimen with a hardened steel ball indenter. Ten samples from each type of brake pads were used in this experiment. The test method is done with accordance to the Rockwell R scale procedures. A ½ inch hardened steel ball indenter was used with minor and major loads of 10 kgf and 150 kgf respectively.

3.4 Tools/equipments required

- Linear Hack Saw Machine.
- Multi-Specimen Friction and wear Tester.
- SEM-EDAX, SEM-Micrograph (Using SE I, SE II and Backscatter Modes)
- Optical Microscope
- Surface Profiler
- Rockwell Hardness Test

CHAPTER 4

RESULT

4.1 Discussion

During this project, there are a few test have been done such as three pin on disc test, SEM-EDAX test, SEM-Micrograph, Optical Microscope and surface profiler. The objectives of these tests are to collect a data of the brake pad that have been purchased. These are the purchased brake pads:

i. Deluxe (Trestor).
ii. MINTYE.
iii. Metallic.

For each brands, the brake pads will be machine into a dimension of 40mm x 40mm x 6 mm. After cut the brake pads, it will test with a three different rotation per minute (rpm), three different loads (N) and times (hour).

For the pin on disc test, three different sliding speeds and loading pressures were chosen. They are:-

- Sliding speeds:
  - 110 km/h [15].
  - 80 km/h.
  - 40 km/h.
- Loading pressures:
  - 0.5 MPa
  - 1.0 MPa
  - 1.5 MPa

4.1.1 Calculation of sliding speeds

Assume that mean diameter of disc or rotor equal to 0.2m and using this equation:-

$$v = \pi D_o N$$

Where:-

V = speed in m/s

Do = mean diameter of disc or rotor in m.

N = rotation per minute (rpm).

- 100 km/h to rpm

  = 100 km/h X 1000m/km X 1/60 h/min

  = 100000/60 m/min

  = 1666.666667 m/min

  ≈ 1666.67 m/min

Using equation $v = \pi D_o N$

Rearrange, $N = \dfrac{v}{\pi D_o}$

N = 1666.67/ (0.2π)

N = 2652.582385 rpm

N ≈ 2652.58 rpm

- 80 km/h to rpm

  = 80 km/h X 1000m/km X 1/60 h/min

  = 80000/60 m/min

  = 1333.333333 m/min

  ≈ 1333.33 m/min

Using equation $v = \pi D_o N$

Rearrange, $N = \dfrac{v}{\pi D_o}$

N = 1333.33/ (0.2π)

N = 2122.065908 rpm

N ≈ 2122.07 rpm

- 40 km/h to rpm

  = 40 km/h X 1000m/km X 1/60 h/min

  = 40000/60 m/min

  = 666.6666667 m/min

  ≈ 666.67 m/s

Using equation $v = \pi D_o N$

Rearrange, $N = \dfrac{v}{\pi D_o}$

N = 666.67/ (0.2π)

N = 1061.032954 rpm

N ≈ 1061.03 rpm

4.1.2 Calculation of loading pressures

Assume that the area of brake pad is 85mm² and using this equation;

$$P=F/A$$

Where;

P = pressure (MPa)

F = force (N)

A = area (mm²)

- 0.5 MPa to Newton

  0.5MPa = N/85mm²

  Load = 0.5MPa X 85mm²

  Load = 0.5 (10^6) Pa X 85 (10^{-6}) m

  Load = 42.5 N

  Load ≈ 43 N

- 1.0 MPa to Newton

  1.0MPa = N/85mm²

  Load = 1.0MPa X 85mm²

  Load = 1.0 (10^6) Pa X 85 (10^{-6}) m

  Load = 85 N

- 1.5MPa to Newton

  1.5MPa = N/85mm²

  Load = 1.5MPa X 85mm²

  Load = 1.5 (10^6) Pa X 85 (10^{-6}) m

  Load = 127.5 N

  Load ≈ 128 N

4.1.3 SEM-EDAX

- Deluxe (Trestor) - Sample 1

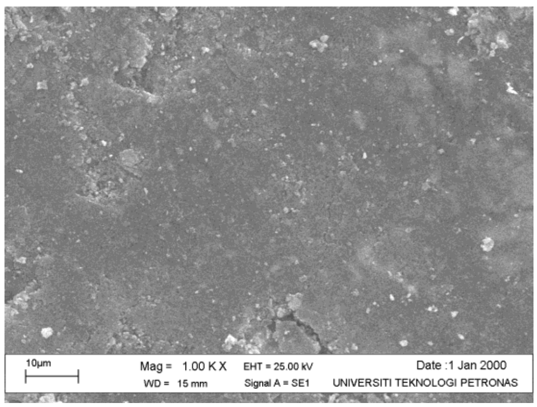


Figure 10: sample 1 taken by SEM

Element	Weight %	Atomic %
C	39.62	58.05
O	27.98	30.77
Mg	0.94	0.68
Si	5.81	3.64
S	2.58	1.42
Ca	6.85	3.01
Fe	1.91	0.60
Ba	14.30	1.83
Totals	100.00	

Table 2: Composition of brake pad sample 1

- MINTYE - Sample 2

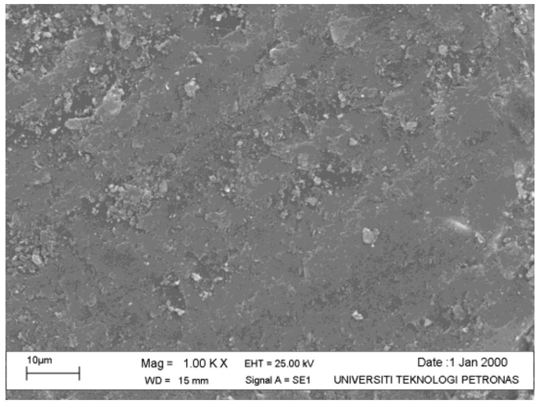


Figure 11: sample 2 taken by SEM

Element	Weight %	Atomic %
C	57.78	75.20
O	17.86	17.45
Mg	0.65	0.42
Al	0.83	0.48
Si	2.09	1.17
S	1.20	0.58
Ca	0.87	0.34
Fe	13.44	3.76
Ba	5.28	0.60
Totals	100.00	

Table 3: Composition of brake pad sample 2

- Metallic - Sample 3

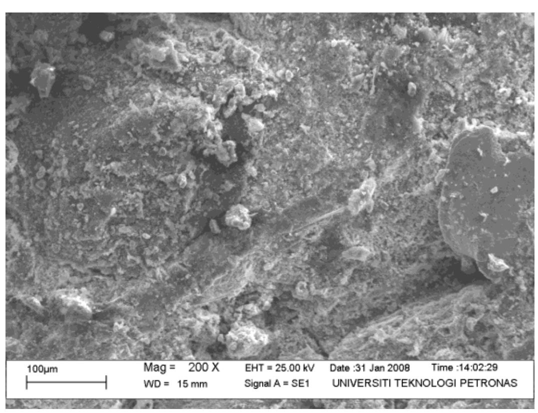


Figure 12: sample 3 taken by SEM

Element	Weight %	Atomic %
C	43.81	63.57
O	25.50	27.78
Mg	2.23	1.60
Si	1.88	1.17
S	3.10	1.68
Fe	6.58	2.06
Ba	16.90	2.15
Totals	100.00	

Table 4: Composition of brake pad sample 3

4.1.3 Surface Profiler

We used the surface profiler to get the roughness average which is ‘Ra’. ‘Ra’ is arithmetical mean deviation. It is the arithmetical mean of the absolute values of the profile deviations (Yi) from the mean line.

- Deluxe (Trestor) - Sample 1

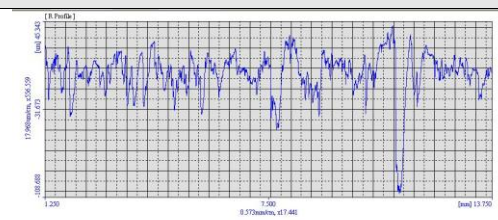
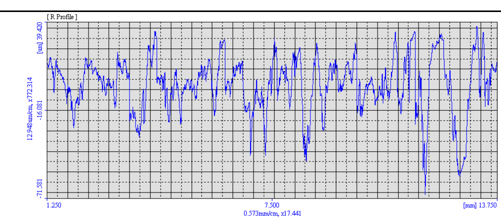
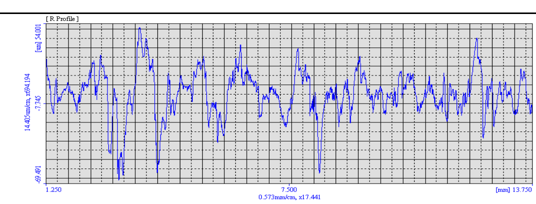
Sample	Ra (μm)	Ra average (μm)	Graph
Sample ‘a’	10.990	12.648	
	14.435		
	12.520		
Sample ‘b’	13.449	12.952	
	13.116		
	12.292		
Sample ‘c’	11.413	12.489	
	13.250		
	12.805		

Table 5: Arithmetical mean deviation ‘Ra’

- MINTYE - sample 2

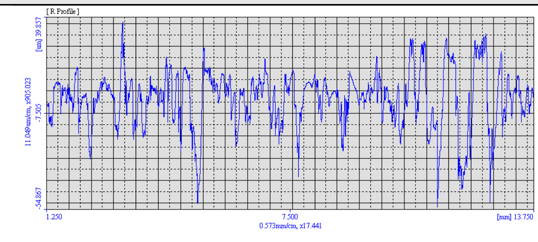
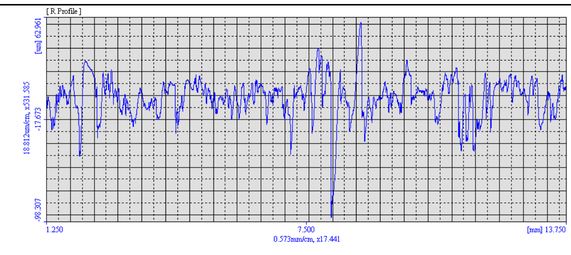
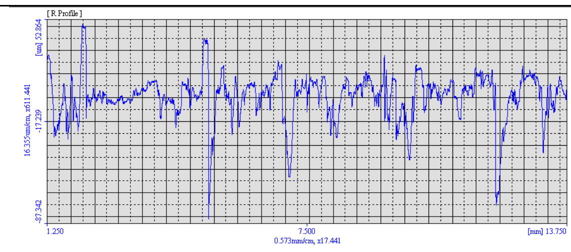
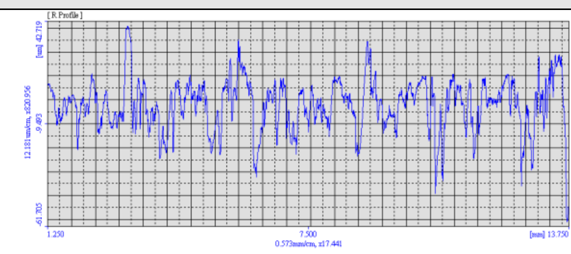
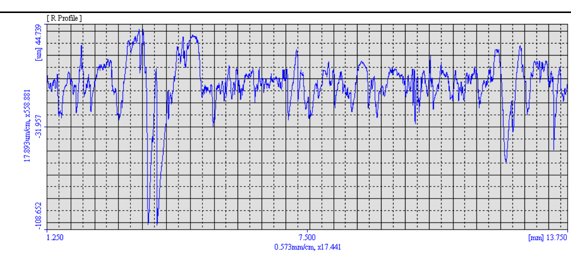
Sample	Ra (µm)	Ra average (µm)	Graph
Sample 'a'	10.237	10.195	
	10.066		
	10.282		
Sample 'b'	10.394	11.212	
	12.287		
	10.955		
Sample 'c'	10.087	10.685	
	10.610		
	11.359		

Table 6: Arithmetical mean deviation 'Ra' for sample 2

- Metallic - sample 3

Sample	Ra (µm)	Ra average (µm)	Graph
Sample 'a'	12.173	10.750	
	10.038		
	10.038		
Sample 'b'	13.335	12.232	
	12.232		
	11.129		

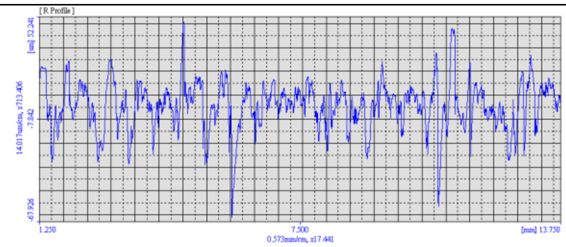
Sample ‘c’	10.400	10.400	
	10.400		
	10.400		

Table 7: Arithmetical mean deviation ‘Ra’ for sample 3

4.1.4 Rockwell Hardness Test

Test	Rockwell Hardness Value (HRR)		
	Sample 1	**Sample 2**	**Sample 3**
1	87.2	88.2	73.7
2	89.3	81.7	72.0
3	89.1	79.2	61.8
4	88.6	82.0	72.2
5	88.4	85.3	63.9
6	88.0	82.6	70.7
7	88.8	88.8	66.2
8	88.7	86.3	67.2
9	88.2	85.0	67.7
10	88.5	90.6	71.7

Table 8: Hardness test result of all samples of brake pads

- The average hardness of sample 1;

$$= \frac{(87.2 + 89.3 + 89.1 + 88.6 + 88.4 + 88.0 + 88.8 + 88.7 + 88.2 + 88.5)}{10}$$

$$= \frac{(884.8)}{10}$$

= 88.48 HRR

- The average hardness of sample 2;

$$= \frac{(88.2 + 81.7 + 79.2 + 82.0 + 85.3 + 82.6 + 88.8 + 86.3 + 85.0 + 90.6)}{10}$$

$$= \frac{(849.7)}{10}$$

= 84.97 HRR

- The average hardness of sample 3;

$$= \frac{(73.7 + 72.0 + 61.8 + 72.2 + 63.9 + 70.7 + 66.2 + 67.2 + 67.7 + 71.7)}{10}$$

$$= \frac{(687.1)}{10}$$

= 68.71 HRR

Thus the averages hardness of each brake pad is:-

- Deluxe (Trestor) = 88.48 HRR
- MINTYE = 84.97 HRR
- Metallic = 68.71 HRR

4.2 Result

4.2.1 Effect of load

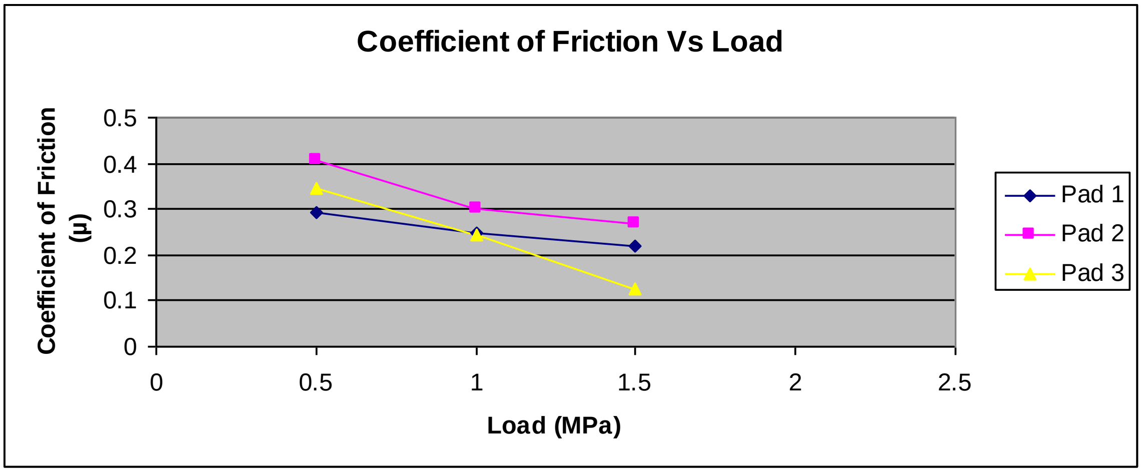


Figure 13: Coefficient of friction vs load

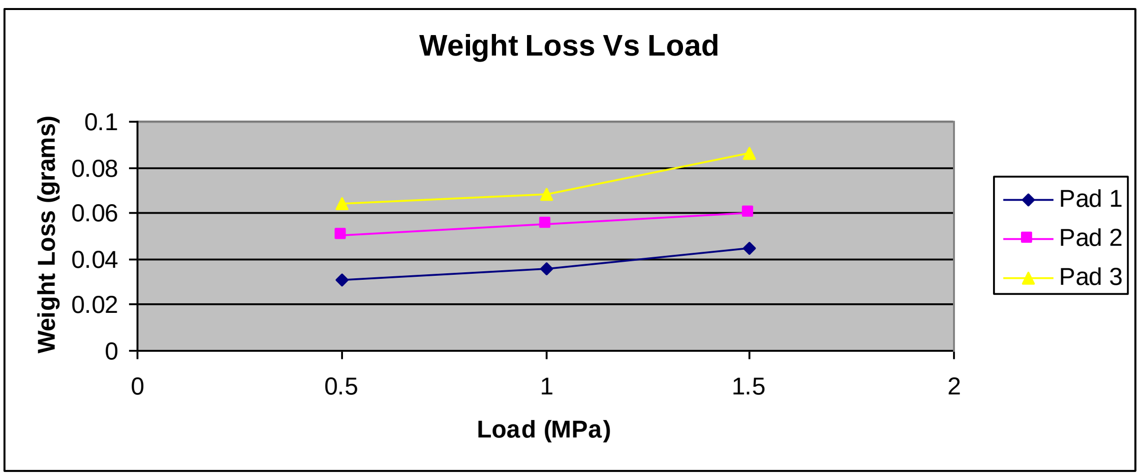


Figure 14: Weight loss vs load

Effect of load to the coefficient of friction and weight loss are shown in **Figure 13** and **Figure 14**. It was found that the mean coefficient of friction of all samples was decrease when the applied load was increased. It was shown that the Pad 2 has a better coefficient of friction among the other pads. From the **Figure 14**, Pad 3 has less resistant to wear compare to other pads. It also found that Pad 2 not much affected by the increasing of load. Maybe it was caused by the compositions of the brake pad material. Pad 2 has a higher ferum (FE) component than the other pads as shown in SEM results. This factor may increase the strength of the brake pad.

4.2.2 Effect of sliding speed

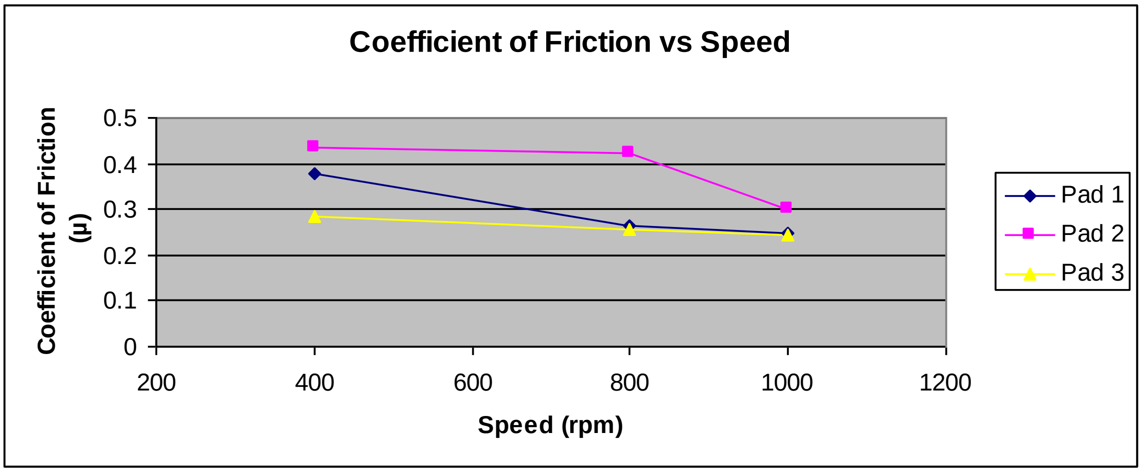


Figure 15: Coefficient of friction vs sliding speed

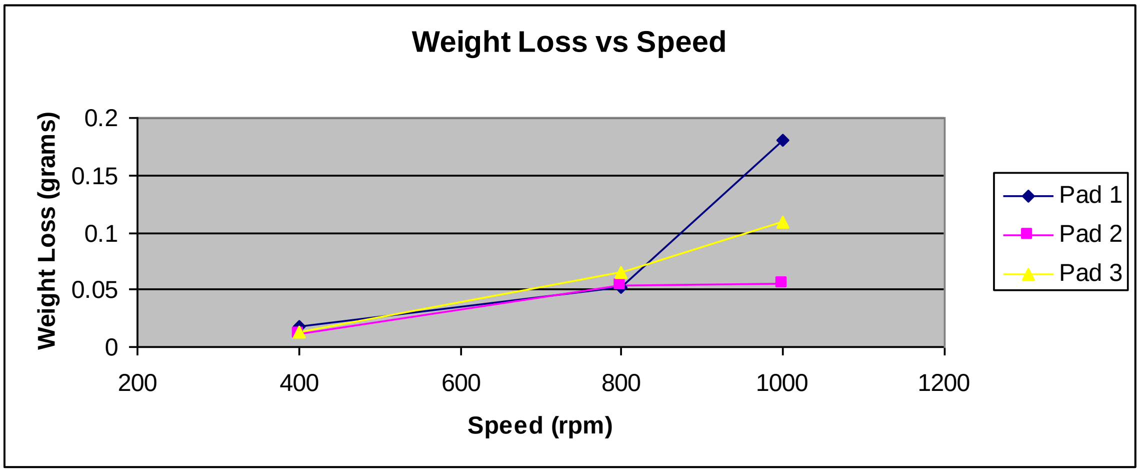


Figure 16: Weight loss vs sliding speed

The effect of sliding speed to the coefficient of friction and weight loss are shown in **Figure 15** and **Figure 16**. It shows that Pad 3 was not affected much by the sliding speed. It shows that only slightly decreasing in coefficient of friction when the sliding speed was increased. For the Pad 1, it was obvious that the friction coefficient was decreasing. Same goes to Pad 2, the sliding speed was obviously affected its coefficient of friction.

It was found that the sliding speed also affected the wear of the samples of brake pads. From the **Figure 16**, it can be concluded that when the sliding speed increase, the wear rate also increase. When the detachment of the wear debris from sample getting higher, friction film growth rapidly and several wear mechanism will occurs. At low sliding speed, wear mechanism such as adhesive wear, abrasive wear, fatigue wear not much occur at the contact surface. It caused less wear debris developed at the contact surface. But when the sliding speed increase, the wear mechanism growth rapidly and caused a more weight loss.

CHAPTER 5
CONCLUSION

We can conclude that when the load is increased, the indentation of the pin to brake pad samples getting deeper. The sliding speed also affected wear of the materials. When the sliding speed is increase, wear also increase.

Usually the branded and expensive brake pads use a material that can stand firm a high temperature friction and wear. It gives a better handling and high performance when driving. It also can stand with the loading force and sliding speed.

The results obtained from this study into the effect of loading and sliding speed to the tribological properties of brake pad material is hoped to give a benefit and improvement in designing a better brake pad in the future.

As a conclusion, the performance and quality of brake pad is depends on the coefficient of friction, ware rate and last but not least the properties of the brake pad composition.

Appendix 1: Suggested Milestone for the First Semester of 2-Semester

No.	Detail/ Week	1	2	3	4	5	6	7		8	9	10	11	12	13	14
1	Selection of Project Topic	■	■													
	A study into the effect of loading and sliding speed to the tribological properties of brake pad materials speed to the tribological properties of brake pad															
2	Preliminary Research Work		■	■	■											
	• Search on internet. • Refer on the brake friction materials book. • Refer on the automotive braking system															
3	Submission of Preliminary Report				●											
4	Seminar 1 (optional)					■	■	■								
									MID SEMESTER BREAK							
5	Project Work					■	■	■								
	• Weight • Microscope: optical,SEM															
6	Submission of Progress Report									●						
7	Seminar 2 (compulsory)										■	■	■	■		
8	Project work continues									■	■	■	■	■		
	• Surface roughness test • SEM-EDAX															
9	Submission of Interim Report Final Draft														●	
10	Oral Presentation															●

● Suggested milestone

■ Process

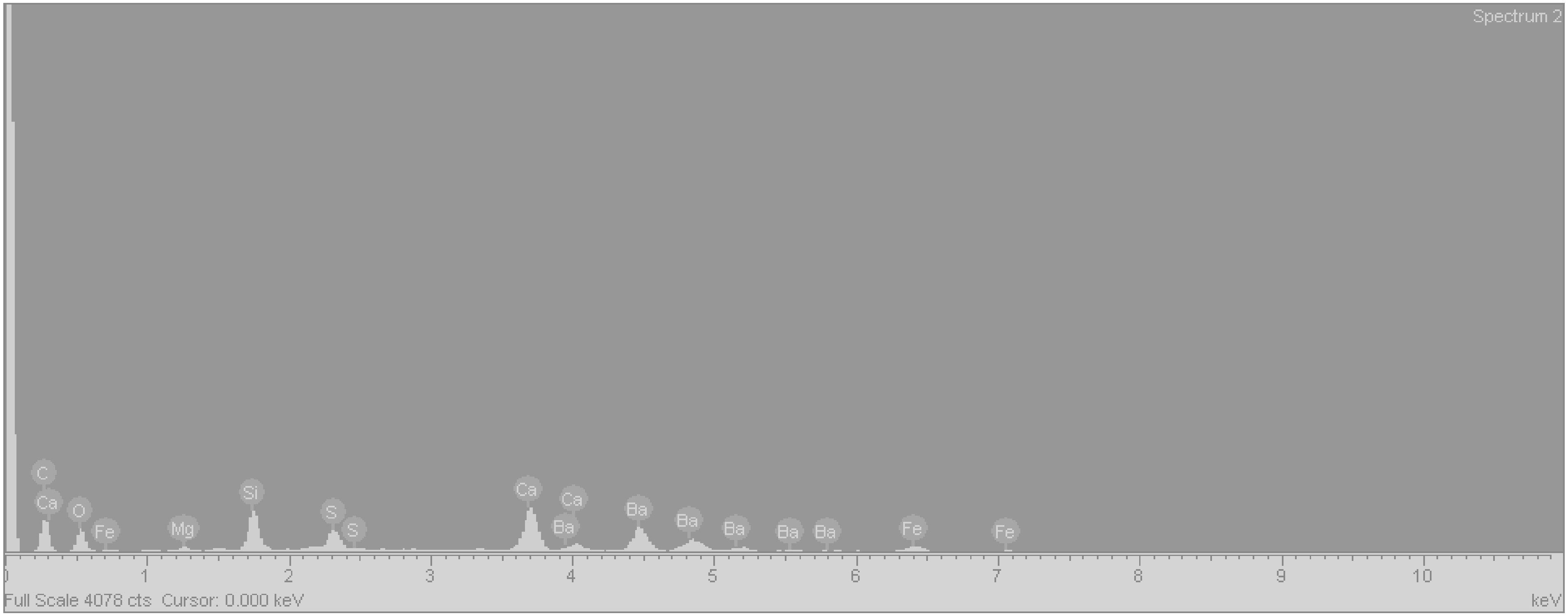
Appendix 2: Suggested Milestone for the Second Semester of 2-Semester

No.	Detail/ Week	1	2	3	4	5	6	7		8	9	10	11	12	13	14
1	Project Work Continue	■	■	■					MID SEMESTER BREAK							
2	Submission of Progress Report 1				●											
3	Project Work Continue				■	■	■	■								
4	Submission of Progress Report 2									●						
5	Seminar (compulsory)										■	■	■			
5	Project work continue									■	■	■	■			
6	Poster Exhibition											●				
7	Submission of Dissertation (soft bound)													●		
8	Oral Presentation														●	
9	Submission of Project Dissertation (Hard															●

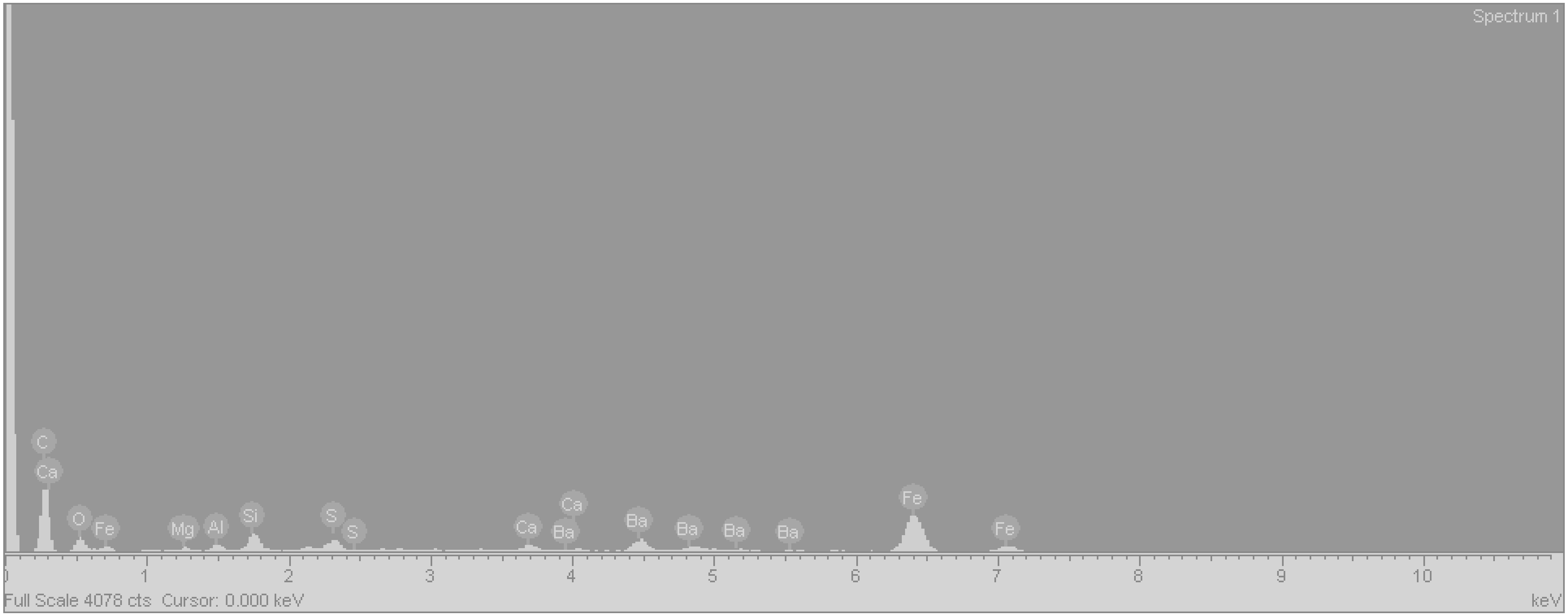
● Suggested milestone

■ Process

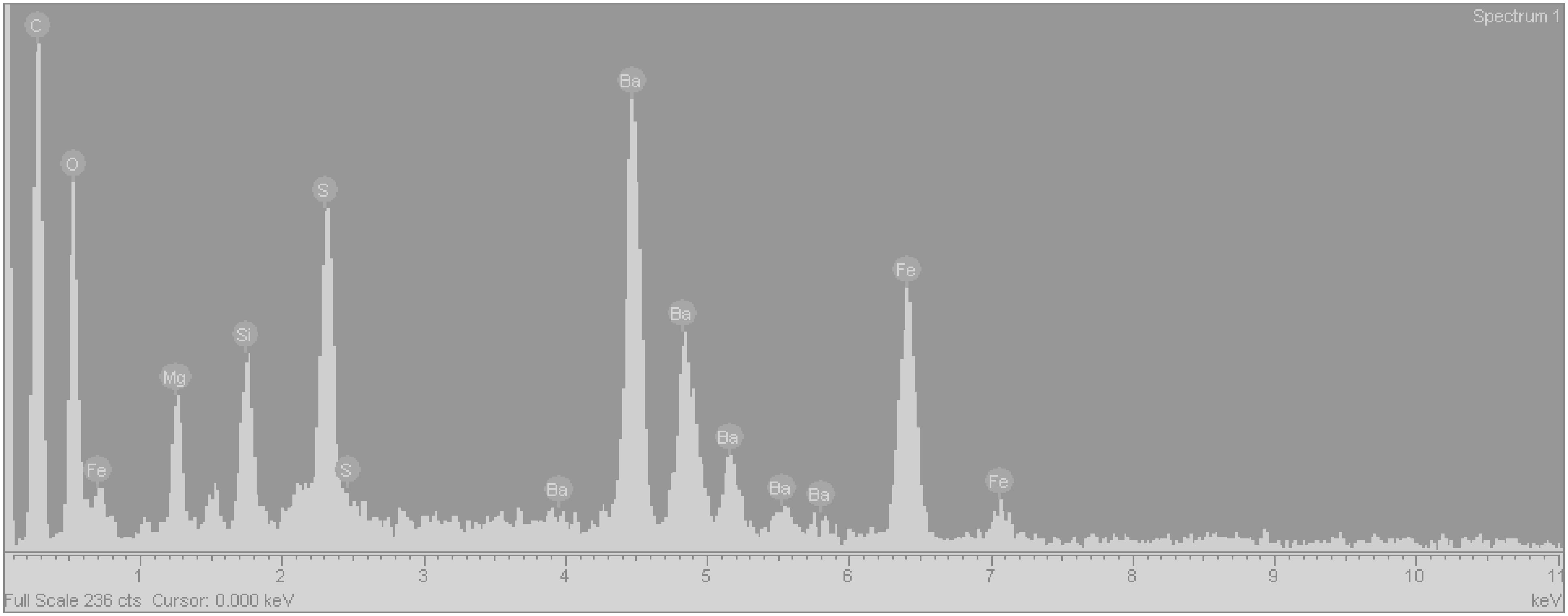
Appendix 3: Result of SEM for sample 1



Appendix 4: Result of SEM for sample 2



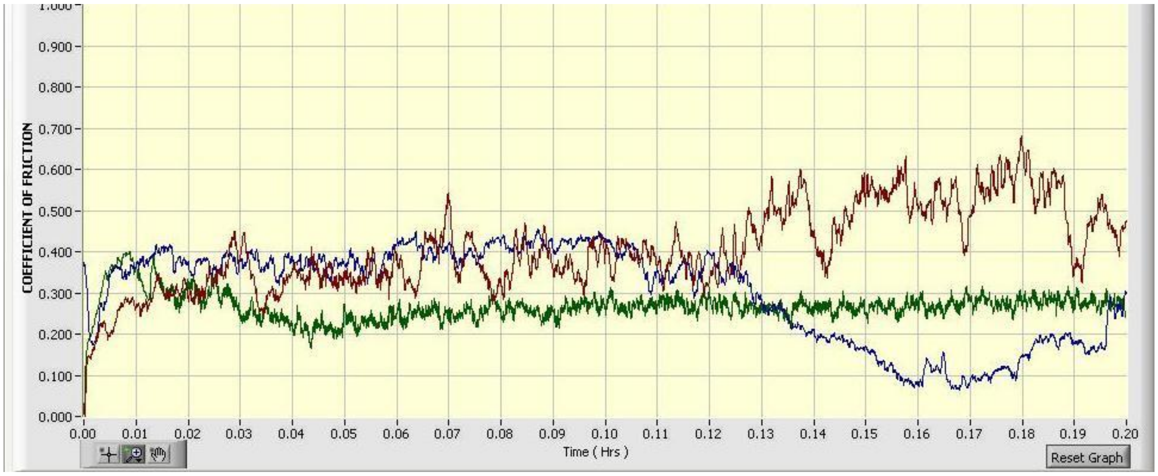
Appendix 5: Result of SEM for sample 3



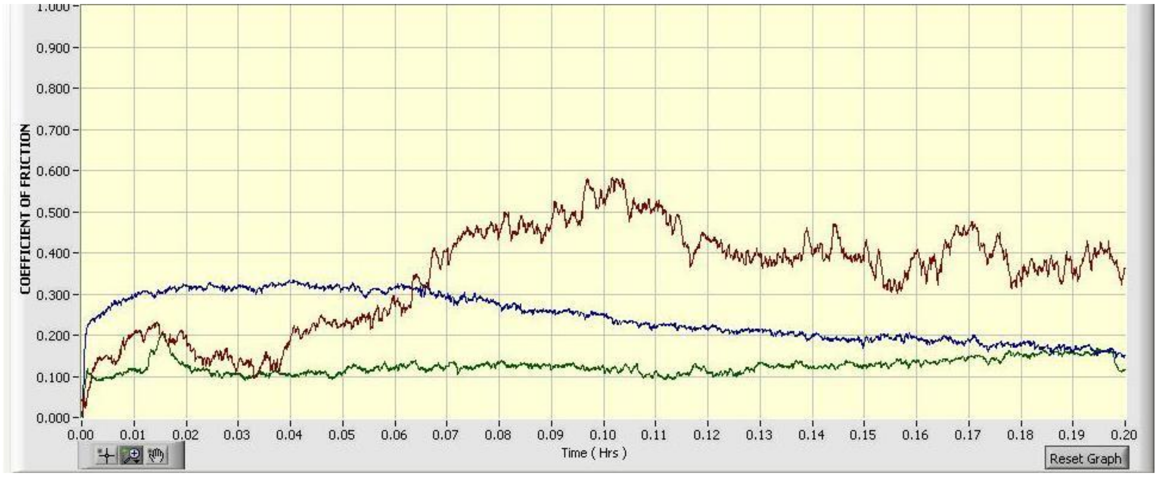
Appendix 6: Result of loading test

- Pad 1

- Pad 2

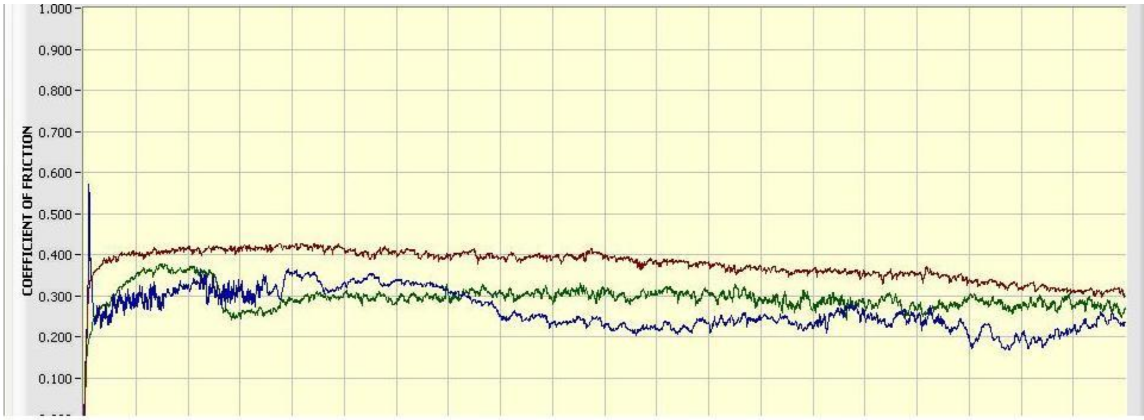


- Pad 3

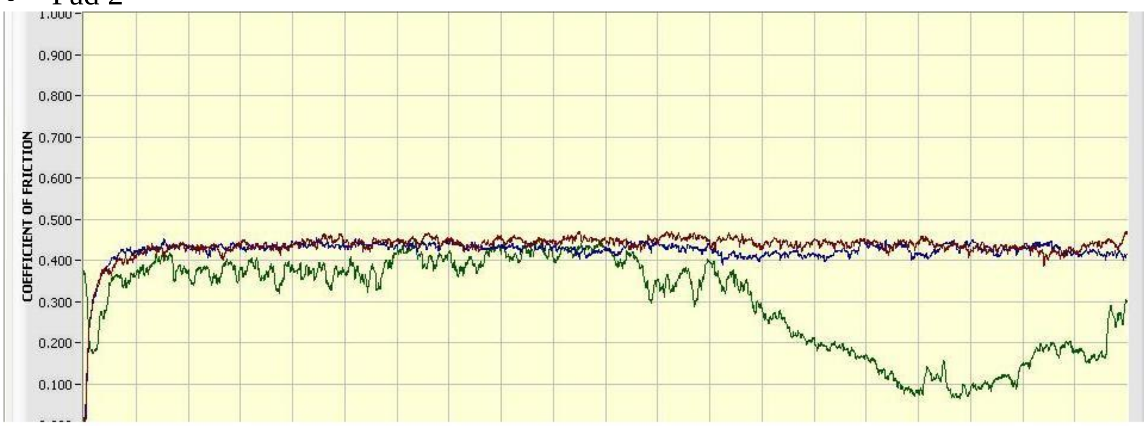


Appendix 7: Result of sliding speed test

- Pad 1



- Pad 2



- Pad 3