TRIBOLOGICAL PERFORMANCE OF WASTE SLURRY POWDER REINFORCED (POLYPROPYLENE) USING PIN ON DISK TRIBOMETER

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A report submitted

in fulfilment of the requirements for the degree of

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2018

DECLARATION

I declare that this project report entitled “Tribological Performance of Waste Slurry Powder Reinforced Polypropylene Using Pin on Disk Tribometer” is the result of my own work except as cited in the references

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Date	:	……………………………………..

APPROVAL

I hereby declare that I have read this project report and in my opinion this report is sufficient in terms of scope and quality for the award of the degree of Bachelor of Mechanical Engineering (with Honours)

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Date : ………………………………………………

DEDICATION

To my beloved father and mother.

ABSTRACT

Tribology is the branch of knowledge that gives important role in industry. Begins, with small appliances in our household such as washing machine, table fan until to huge machinery that relates towards friction and wear. The tribology give effects of overall efficiency of equipment as its relates on maintainability for specific machine. Hence, this shows vital findings to get suitable solution for lubrication in order to bring lower maintenance cost that cause from wear and tear parts. Nowadays, the industry is expected to use the material that's friendly to environment. Besides, in order to reduce the pollution, the benefit of reduction cost from recycle usage of waste materials that's may be considered as secondary source of material that's high energy content that bring energetic advantages to industry. The waste material such as quarry dust is expected to bring good potential strength in reduce friction and wear. As for this paper, uses of quarry dust as to be new reinforcement substitutes in fabrication of polymer composites, which are supposed to bring zero waste strategy to improve tribological properties which bring benefit in reduction cost. The target of this study is to investigate the tribological performance of waste slurry powder reinforced Polypropylene (PP) under dry sliding conditions, and determine the wear mechanism when applied several load. The mechanism of material testing is using the pin on disk tribometer. The pin was shaped by compaction process of cylindrical mold to form pin sized of 30mm height and 10mm diameter. The composition were prepared using Polypropylene powder by 5%, 10, and 20% that being reinforce from quarry dust (QD). Through this study, the collection of data towards the coefficient of friction (COF) and wear rate concludes that effect of 5% presence of quarry dust will result of perfect mixing of reinforcement that's bring lower COF on various applied load. The findings shows the significant wear rate that reduce compared to other composition weightage that simulates under dry sliding condition.

ABSTRAK

Tribologi adalah satu cabang pengetahuan yang memberikan peranan yang penting dalam industri. Ia dapat dilihat bermula dari penggunaan perkakas kecil di rumah seperti mesin basuh, kipas meja sehingga jentera besar yang sering berhubung kait dengan geseran dan kehausan. Kesan dari geseran dan kehausan memberi kesan terhadap efisien bagi sesuatu mesin. Oleh itu, langkah penyelesaian adalah dengan menambah kesan pelinciran atau campuran bahan yang mempunyai kadar geseran yang rendah yang dapat mengurangkan kos penyelenggaraan yang lebih rendah yang menyebabkan bahagian-bahagian haus dan lusuh. Pada masa kini, industri kini tertumpu kepada penggunaan sisa buangan yang dijangka dapat mengurangkan pencemaran serta lebih mesra alam. Selain itu, dalam usaha mengurangkan pencemaran, dengan mengambil kira seperti penggunaan daripada bahan buangan yang telah diguna semula sebagai sumber kedua yang membawa kelebihan kepada industri. Bahan buangan seperti debu kuari dijangka membawa kekuatan yang baik serta mengurangkan geseran dan kehausan. Seperti di dalam kajian ini, penggunaan habuk kuari sebagai pengganti pengukuhan baru dalam fabrikasi komposit polimer, yang dilihat membawa strategi sisa sifar dan juga memperbaiki sifat-sifat tribologi yang membawa manfaat dalam kos penyelenggaraan. Sasaran kajian ini adalah untuk mengkaji prestasi tribologi terhadap polipropilena (PP) diperkuat habuk kuari di bawah keadaan gelongsor kering, dan menentukan mekanisme haus apabila dikenakan beberapa beban tambahan. Mekanisme pengujian bahan adalah menggunakan ujian "pin-on-disc" yang membuat permukaan cakera bercalar dan haus. Pin telah dibentuk oleh proses mampatan dalam acuan silinder untuk membentuk pin bersaiz 30mm tinggi dan diameter 10mm. Komposisi itu telah disediakan menggunakan serbuk polipropilena diperkuatkan dari habuk kuari (QD) sebanyak 5%, 10, dan 20% yang dicampurkan bersama. Melalui kajian ini, pengumpulan data ke atas pekali geseran dan kadar haus yang mempengaruhi komposisi yang berbeza dan beban yang dikenakan di bawah keadaan gelongsor kering. Hasil kajian telah dicapai, dan ini dapat dirumuskan dengan hasil campuran habuk kuari diperkuat dengan bahan polimer dapat meningkat sifat tribologi dengan 5% campuran bahan tersebut dapat mengurangkan pekali geseran dengan kadar isi padu yang terbebas lebih rendah berbanding campuran komposisi yang lain.

ACKNOWLEDGMENT

Firstly, I would like to express my sincere gratitude to my supervisor for final year project Mr. Mohd Rody Bin Mohamad Zin, from the Faculty of Mechanical Engineering Universiti Teknikal Malaysia Melaka (UTeM) for his continuous support, patience, guidance and also encouragement during the final year project. His guidance helped me throughout my experiment and report writing in this project.

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PP	-	Polypropylene
QD	-	Quarry Dust
CO_2	-	Carbon Dioxide
NO_x	-	Nitrogen Oxides
COF	-	Coefficient of Friction
wt%	-	Weightage Percent
ρ	-	Density
T	-	Temperature
RPM	-	Revolutions Per Minute

CHAPTER 1

INTRODUCTION

1.0 Background

Waste slurry powder can be generated from cement plant. High production of cement will cause waste from all over the world. (Jamin & Mahmood, 2016). It is indicate that the production of cement will emit CO_2 due to calcination of raw material and combustion of fuel. This will give impact towards emission of by 7% of CO_2 worldwide. This scenario can be seen in Malaysia as high development country located on the Southeast Asia. It's have the separation of population between peninsular and east Malaysia. This shows the country have created significance different level of development. Usually the plants will be handle from big company played by local producer and multinationals. The cement as the generally produced from calcium carbonate, silica, alumina and iron ore by extracting limestone rock, chalk, schist or clay from quarry. This continuous development will increase the pollution due to mass production from cement plant. The end result based on unethical dispose of waste into the open landfill will cause of dust, emission of CO_2, nitrogen oxides (NOx) and sulphur dioxide (Stajanča & Eštoková, 2012). Then, it will harm all the environment and also the live communities.

The slurry powder result from the factory that usually contains marble slurry dust as cement additive. The proves from previous study back in 2009 from United States Environmental Protection Agency (USEPA) focussed on future for reducing greenhouse gas emission in the construction sector Anita Brown (2015). Besides, most of their path towards in improving fuel efficiency and recycling material.

In this studies, the potential waste usage from slurry powder from cement plant can be reuse in material matching with polymer matrix composite as new material in automotive components. The tribological properties of the proposed material will be explored based on their mechanical, friction and wear properties. The study against polymer tribology can be extensive knowledge based on the analysis of abrasion, adhesion, and fatigue (Myshkin, Pesetskii, & Grigoriev, 2015). This will bring beneficial effects on study of tribology that highlighting about friction, wear and lubrication.

1.2 Problem Statement

In recent years, the waste slurry cement powder are known as main adverse effects to the environment which is now addressed as a challenge of global issue. Now, the global tendencies concerned about the causes of climate change because of CO_2 emissions. Besides, this issue can be rise in the way to reduce carbon footprint as an important step to save our environment.

Therefore, substantial studies to discover on the global demand towards the greener environment by focussing on usage of waste composite materials that lightweight, renewable, high performance, eco-friendly, wear and corrosion resistant materials to meet the global demand are required. This study was conducted in order to discover the usage of waste slurry powder reinforced polypropylene as to propose a new automotive material component. This is because the tribological performance of said material is yet not been discovered. Hence, more information is important, to clarify the mechanical, friction and wear properties of the proposed material.

Auxiliary source getting from waste material can be considered that have energetic advantage due to its high energy content. Besides, the other interest on minimization and elimination of resulting from friction and wear at all level of technology where rubbing of surfaces is involve become the root of research in tribology. Hence, the result is lead to greater plant efficiency, better performance, and significant savings. Accordingly, presenting more efficient lubrication or self-lubricating materials may be the solution in overcoming these problems.

Several study of literature review in order to generate some idea for this project. Based on previous study, there are several research towards waste material such as (Sivaraos et al., 2013) in waste tyre in order to achieve low friction. Besides that, it also been assesses in (Rahman, Hassan, Yahya, & Lafia-Araga, 2013) on application of fiber reinforced polypropylene composite. Another analysis also been done in where usage some other natural sources to be reinforced with polymer.

1.3 Objective

This objective of this study was the inspiration from the previous studies. Previous studies reported that every materials have their own coefficient of friction. This study is dominant towards using slurry powder as potential waste to get low wear rates and low friction. The objective of this study as follows ;

a) To investigate the coefficient of friction (COF) of waste slurry powder reinforced polypropylene composite pin under dry sliding conditions
b) To investigates the substantial wear mechanism of waste slurry powder reinforced polypropylene composite pin under dry sliding conditions

1.4 Scope of Project

In this study, there are several limitation as to finish this project;

a) This study only focusing on waste slurry powder reinforced polypropylene

b) The measure specifications in dry sliding distance ranging 500 m to 2500 m and temperature range between 27 ^{o}C up to 150 ^{o}C.

c) The sliding speed is limited ranging from 500 rpm to 1750 rpm.

CHAPTER 2

LITERATURE REVIEW

2.1 Tribological Study

Tribology is the study that relatable in mechanical engineering, material science, technology and chemistry. That which is focussing on friction, wear and lubrication science. The scenario behind this study can be seen when the two different surface contact each other and have resistance on moving surface due to its coefficient of friction cause from the load. The notion of tribology was introduce by Peter Jost in 1966, that change the view of industry to create new demand, more reliable products, and better the quality of life. The study of friction, lubrication and wear are not just in the industry only, but it's also have important in our life of humankind and vehicle.

In automotive sector, the friction and lubrication have their significant result in the internal combustion engine (ICE) for better fuel consumption. Based on (Holmberg, Andersson, & Erdemir, 2012), the study shows that internal combustion engine (ICE) are not fully utilize their fuel that supposed to move the vehicle. They are several loses that happen when vehicle is moving.

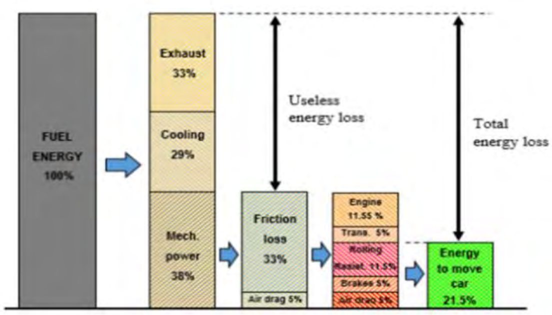


Figure 2.1 : Breakdown of passenger car energy consumption

[Source : Homberg et. Al (2012)]

To enlighten this matter, as shown in Figure 2.1 the present study tells that the effective percentage usage of fuel for combustion engine in order to move the vehicle. Eventually, not 100 % usage of fuel to combust, but only 21.5% of fuel consumption in order to give car in motion. The remain value of efficiency was release as the loss that have to bare due to friction in the vehicle itself and other circumstances. The minor loses starts when the engine start to combust. This will create initial friction of moving piston and crankshaft as the mechanical power take place that makes the slowing moving engine which take place as 11.5 % of loses. But the technology start to increase by the discovery in order to find suitable lubricant that have general viscosity for certain temperature. Unfortunately, this result also cannot be assume as fully solution in order to eliminate the friction. The result of combustion of engine will lead to emission from the exhaust produce that will generate losses of energy consumption by 33 %. As the result, we also can be assume that heat losses also be happen with directly proportional and make some loses in terms of cooling system cause to 29 % inefficient of fuel. Due to motion of vehicle, the air resistance start to consume cause from external air drag that create 5 % of loses. For the remain loss analysis was from the wheel where its counted as the friction from the rolling resistance, transmission and brake by 12.5 % for the total loses.

As for this study, the way in order to improve the efficiency of the engine by reduce the energy loss cause from mechanical interaction of the system. Which can be highlight in terms of friction, and wear of the moving component in the engine such as pistons, bearings and clutches. This result will be give benefit in terms of reduction of maintenance cost and also replacing certain part as be beneficial for financial savings.

There will be a challenge to the engineers to produce a vehicle which have better fuel efficiency as the improve in the ICE engine. Due to unstable price of global oil and also concerning on CO_2 emission that lead to global warming. Hence it will be other solution to be better in maximizing the efficiency use of fuel and also towards the renewable energy like electric energy through the introduction of hybrid electric vehicle (HEV) and fuel cell technology by using hydrogen as replacement of conventional fuel like petroleum. The optimization in improving friction problem will save a lot of operational cost and manageable of percentage of fuel demand with find more efficient lubrication for the engine.

The broad field of study in tribology is not only focusing on machinery but it also in human nature. The previous study proves that the skin also has their own frictional properties like hand in order to grip or hold anything. The studies by (Ramalho, Szekeres, & Fernandes, 2013) to illustrates the coefficient of friction toward the sliding of human skin against the types of fabric. Hence, the result demonstrates that wool was the highest coefficient of friction for both gender. While the lowest value goes to polyamide-based fabric. From this study each volunteer will be measured on the ventral forearm for their friction effect from both gender.

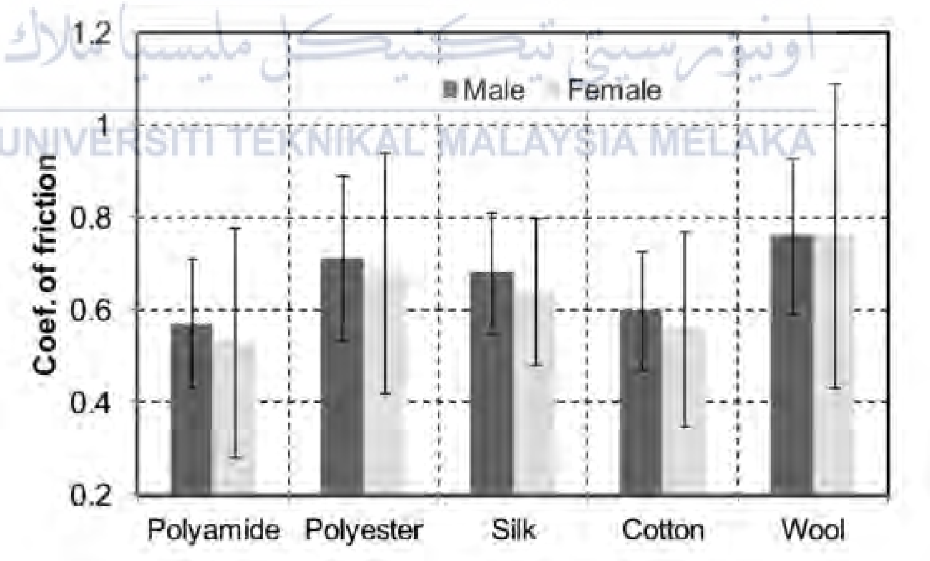


Figure 2.2 : Coefficient of friction (COF) for different fabrics against skin (ventral forearm)

[Source : (Ramalho et al., 2013)]

Then, after several of years the author comes with new discovery in friction of human skin against different fabrics for medical. The study from (Vilhena & Ramalho, 2016) e that the study toward of human skin in tribology is vital to improve and optimize materials and surfaces contact with the skin. Moreover, in the formation of skin injuries was be taken as critical factor on friction between the textiles and the human skin, if the shear forces and loads are high if longer period of time. The experiment was on material testing on four type of hospital fabrics in bed linen, like sheets and pillows. By determining the coefficient of forearm beneath in natural skin conditions.

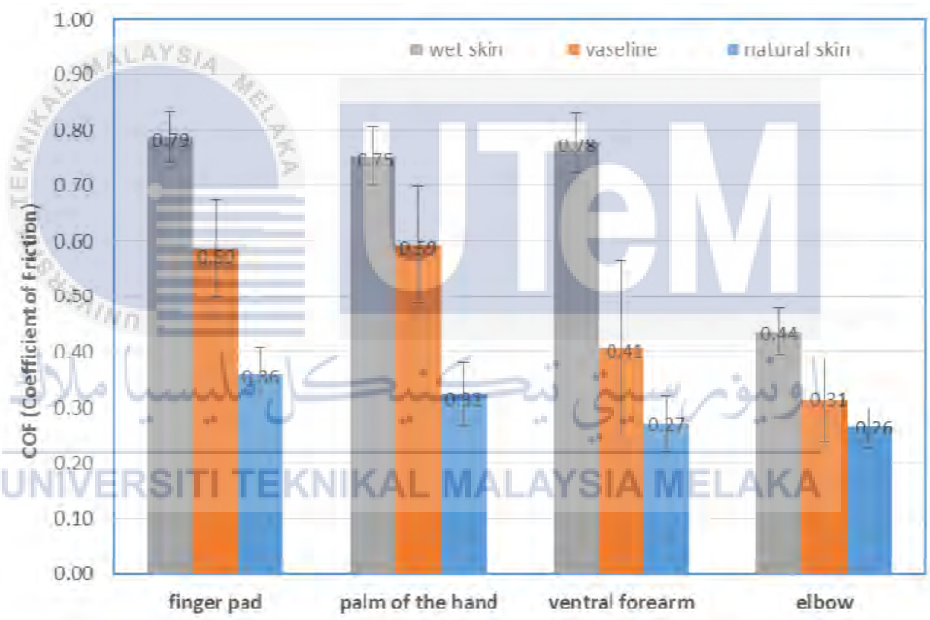


Figure 2.3 : Coefficient of friction (COF) for a reference hospital rubbing against different body region under different lubricating condition

[Source : (Vilhena & Ramalho, 2016)]

In vivo skin friction were conducted using a reference hospital fabric which across the four different skin regions (finger pad, ventral forearm, elbow, and palm of hand) with beneath different lubricating condition (wet skin, natural skin, and skin after spreading of

Vaseline). The figure 2.1(3) shows the average values of the coefficient of friction depends on different testing condition. The several analysis the been made by the presence of Vaseline that effect lubrication conditions. The coefficient of friction was consistently increase with the addition of Vaseline compared to the natural skin condition.

2.2 Ways to Reduce Friction

The application has been done as to apply the uses effect of friction in daily life. The friction can be known as the body of an object resist to motion during sliding or rolling when it moves tangentially over in contact. Sometimes, it is desirable to have low friction, in order to save energy. Also, the material that high friction is also beneficial in order to achieve the grip and stopping mechanism like in the case of brakes and shoes. They are several method in order to reduce the effect of friction ; lubrication, polishing surfaces, uses of ball bearing, and the correct combination of surfaces in contact. Its depend by adding lubricant, use different material or by surface coatings.

(Holmberg et al., 2012) explains that the history of mankind had faced a challenging cause by resistance of motion due to friction. The primal invention that's been struggle to overcome friction to lubricate moving contact by uses of water and later natural oils to transport heavy stone in construction of the pyramids in Egypt, 2400 BCE. The lubrication is the vital purpose to reduce wear. Besides, it's also act as a cooling agent as the thermal flow through the contact surface. When the lubricant flow to the stream channel it will react as protective film while allowing the two moving surface but stay separated. Therefore, the friction cause of moving motion will be lesser and the wear and tear are reduce.

According to Bharat Bushan (2013), he evaluates that clean solid surfaces when it slides generally can be define as high coefficient of friction and serious wear that expected on its exact properties of the surfaces, such as low hardness, high surface energy, reactivity and mutual solubility. Foreign substances, such as organic compounds will make the clean solid surfaces to readily adsorb and build new layer surface. Also, the coefficient of friction and wear will be lower on the newly formed surface compared to clean surface. Unfortunately, the foreign material of the presence layer cannot be guaranteed the credibility during a sliding process. The lubrication can be in several states ; solid lubrication or fluid film lubrication (liquid or gaseous).

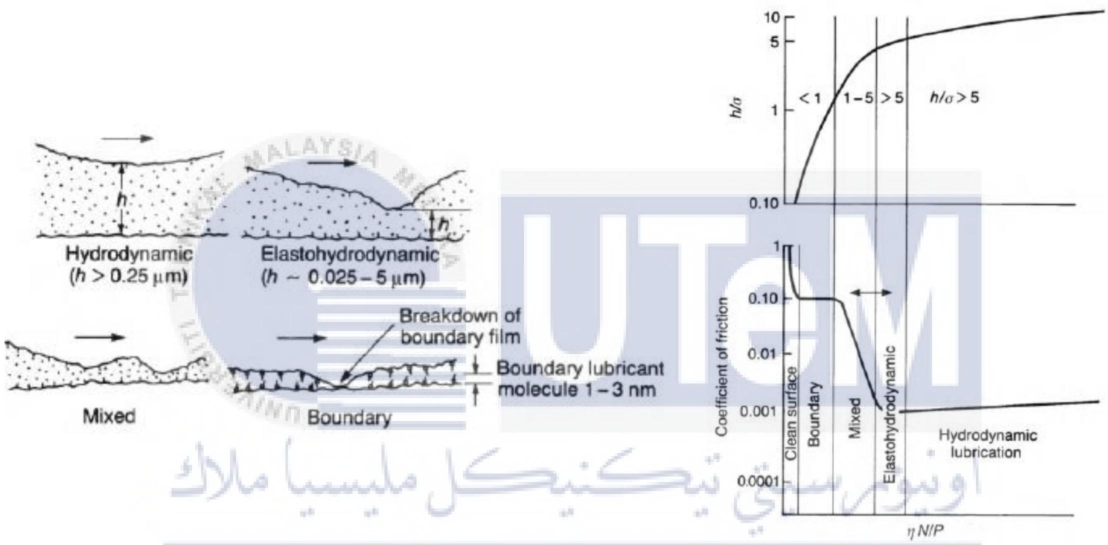


Figure 2.4 : Lubricant film parameter and coefficient of friction as a function of N/P (Stribeck curve) showing different lubrication regimes observed in fluid lubrication without an external pumping agency.

[Source : (Bhushan, 2013)]

This figure shows the parameter of lubricant film and lubrication regime. This, in turn, results in lesser number of parts to be repaired or replaced, along with longer life cycles of the parts and components. Lubrication is also used to reduce oxidation, and hence prevent rust.

There are numbers of studies investigates the uses the polymer and composite in order to achieve better coefficient of friction. Polymer have some characteristic that have lower coefficient of friction but higher wear rate.

2.3 Polypropylene (PP)

Polymeric composites are comprising of polyethylene (PE), polypropylene (PP) and polystyrene (PS) and loaded with filaments of polytetra fluoroethylene (PTFE) up until 25 wt. % together with distinctive sorts of normal oils, for example corn oil, olive oil, paraffin oil, glycerin oil, castor oil and sunflower oil (Kumar, 2017). The composites properties (i.e. frictional activities and resistant towards wear) were examined at different load (Kumar, 2017).

Polypropylene has the lowest density as compared to other plastics with high durability and malleability making it a versatile material which can be converted into various mould (Maddah, 2016). The monomer of polypropylene is polypylene. It can withstand high temperature which makes it a perfect material for the making of pails, bottles and trays which needs to be autoclaved for clinical usage (Maddah, 2016)

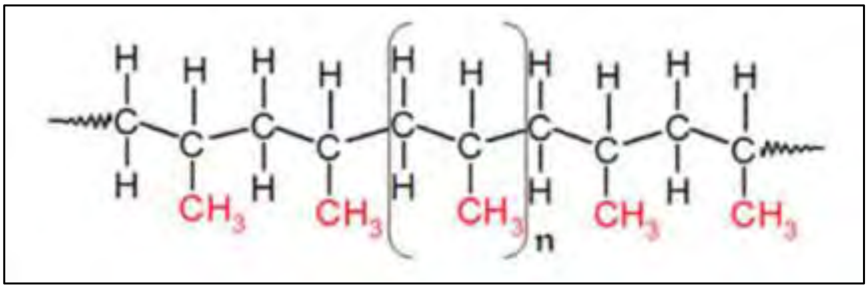


Figure 2.5 : Polypropylene Structure

[Source : Madah 2016]

CHAPTER 3

METHODOLOGY

3.1 Overall Flow of Experiment

Every studies must have their operational flow in order to conduct the experiment. This purpose of this study is to find the tribological characteristics of slurry powder reinforced polypropylene by testing in dry sliding condition from pin-on-disk tribometer. The operational flow of experiment consist by four stages. It's begin by getting more literature review from the previous studies about the properties of slurry powder and also the characteristics in polypropylene. This is important in order to make their correct ingredient in order to blend the waste material with polymer composite. There are four stages in order to achieve the discussed objectives has been stated in Chapter 1. The flow chart of this experiment as shown in Figure 3.1.

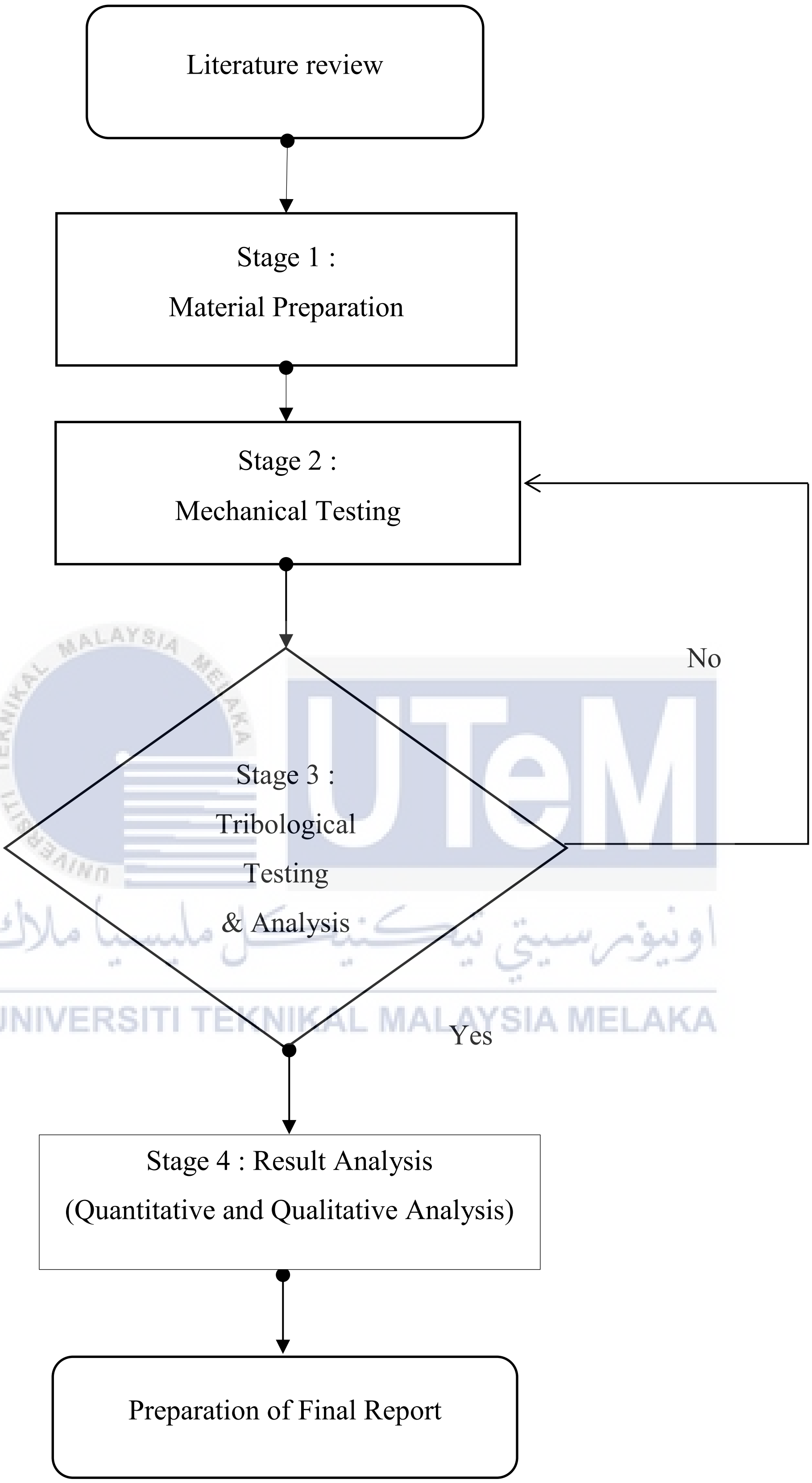


Figure 3.1 : Flow chart of the methodology

Stage 1 is start with the preparation of the material. This part consist of designing the mould. The mould will be design based on the required size of sample according its pin holder size. The waste slurry powder will be crush and sieve. After that, the powder will be mixed the granule polypropylene. Besides the, hot press machine will compress and heat in specific pressure and temperature with the compressor and the heater in order the polypropylene to be molten. The result of specimen pin was taken out, the sample will set aside for cooling and curing session before to proceed into mechanical test.

Stage 2 is proceed for mechanical testing. This procedure is start when the pin was taken out from the mould and after curing session. The several testing was been conducted in order to endure the reliability of the pin before simulate in pin on disk tribometer. The testing consist of hardness test, density test, porosity inspection and testing.

In Stage 3, for the tribological testing by setting the standard method. The test were conducted at different sliding distances and temperatures. Minitab statistical software also been used by testing in different surface roughness, composition, applied load, sliding speed and temperature. The specimen pin was grinded by sand paper and weighted before simulate in the pin-on-disk machine. Then, after finish the dry sliding test, the specimen will reweight again.

In Stage 4 was the crucial part that consist of quantitative and qualitative analysis. The quantitative result are focussing on the finding the coefficient of friction (COF) and specific wear rate depend on the result data obtain from the pin-on-disk machince. While for the qualitative analysis is to analyse the wear mechanism result from the tribological testing.

Finally, for the last part was the writing the final report. This included of the whole aspect in research method on detailing on background of study and its literature review and also the procedure on conducting the experiment.

3.2 Material Preparation

Material for fabricating mould is by using stainless steel rod. The selection of stainless steel as it anti rust and easy excess of material in the mechanical lab. Drawings had to be done before fabricate the mould by using SolidWorks sketcher. The dimension was depends on the size of the desired pin. The counting measure will be taken for punching mechanism to compress the slurry powder with the required pressure and temperature in order make a rigid pin. The lathe machine will be used to make the cylindrical shape with some fillet for the edge of mould as a safety measure on handling the mould.

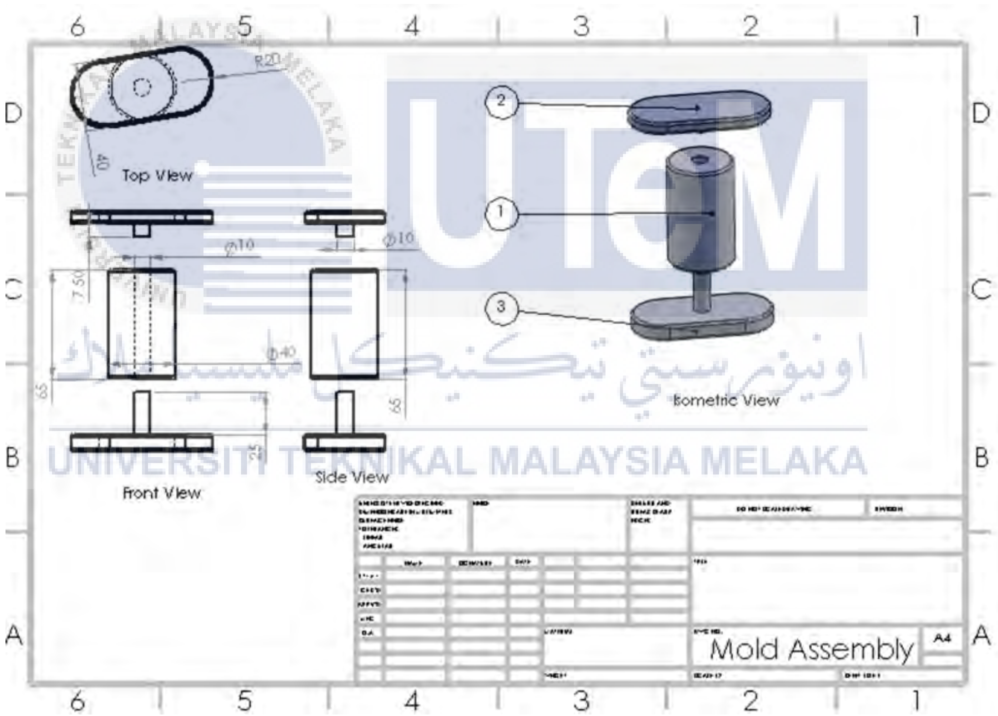


Figure 3.2 : The Assembly of Mould

The length of specimen pin must be suit after compaction process before run into the pin-on-disk machine by 4 mm length. While the diameter is 10 mm to clamp the pin by the pin holder. Several visual and physical inspection will be determined to ensure the specimen is reliable to be test.

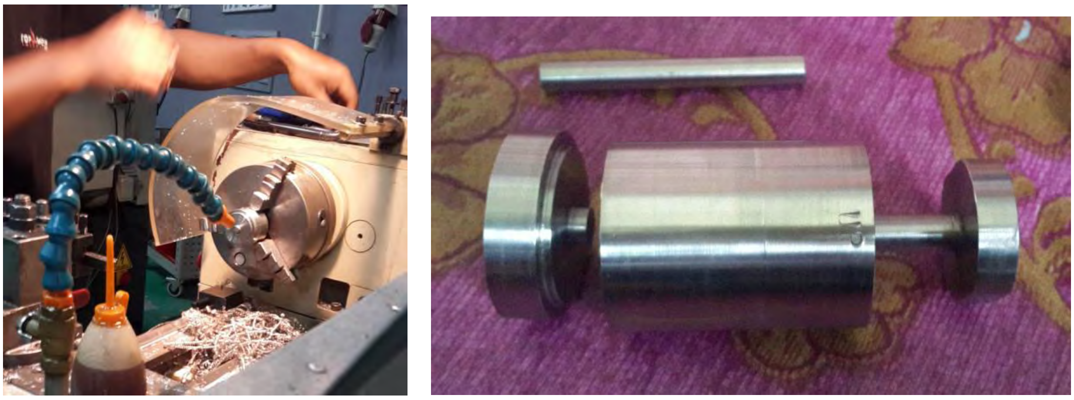


Figure 3.3 : The mould that been produce

The next process will be on the compaction process. The weight for slurry powder and polypropylene will be calculated in order to match the composition that accurate length and their bonding hardness. The measurement on weight will be made in order to get the correct length of specimen pin using analytical balance machine.

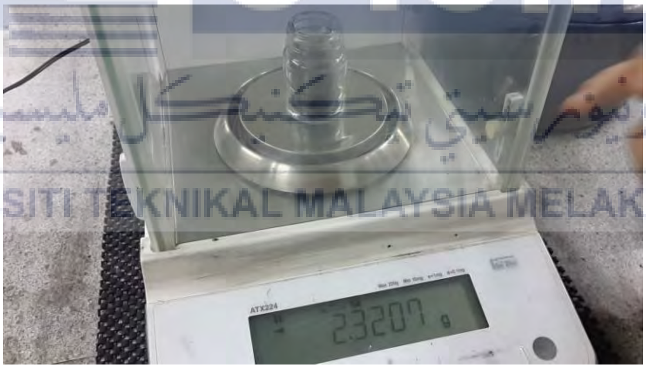


Figure 3.4 : Weighing the composite

Figure 3.5 : Preparing the compaction process by inserting the slurry composite the mould and compaction process

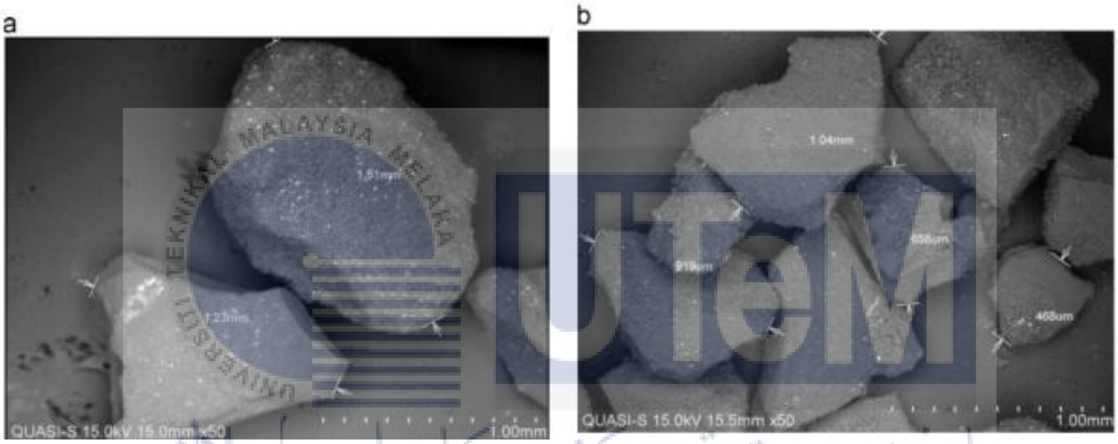


Figure 3.6 : SEM micrograph of PKAC particles for (a) before (b) after sieving process

[Source : (Mat Tahir, Abdollah, Hasan, & Amiruddin, 2016)]

There are some on morphological surface result. The process of sieving by (Mat Tahir et al., 2016) to refine the composite that being crush into the blender. From that study the researcher have use composite from palm kernel activated carbon (PKAC) with the reinforced of resin and hardener epoxy. The operation before compaction process by blended the composite using blender and sieved with 1mm seiver. She also have their own weighted composition ratio with 70 % weightage of PKAC and 30 % epoxy that consist (1:4 of resin and hardener). The procedure of that research by uses of scanning electron microscope (SEM) micrograph for finer view of composite for qualitative analysis. The mixture of PKAC and epoxy will be in compaction process where its be hot-pressed at 80°C in duration of 10 minute with the pressure of 2.5MPa. After that, the specimen pin will pressed out from the mould after left for cooling at room temperature. The dimension pin approximately in 30-mm height and 10-mm diameters and have the curing process in order to get more stable linkage for an adhesive bond resulting in a tougher, harder of substance before proceeding to pin-on-disk test.

As for this experiment, the specimen pin contains the bond of slurry and polypropylene composite will be pressed out and take some inspection for physical pin. The composition study for specimen pin on the density, hardness and porosity.

3.2.1 Testing on Density

Table 3.1 : Typical physical properties of polypropylene (Profax 6501)

[Source : (Zampaloni et al., 2007)]

Property	
Melt flow rate	4 g/10 min
Density at 23 °C (73.4 °F)	0.9 g/cm^3 (56.18 lb/ft^3)
Tensile stress at yield	34 MPa (4.93 kpsi)
Tensile elongation (%)	12
Flexural modulus	1.4 GPa (203.1 kpsi)
Notched izod impact strength at 23 °C (73.4 °F)	39 N (8.77 lbf)

The several testing on the specimen pin after compaction process. It is important to determine their strength of hardness, density and porosity of the composite. The Table 3.1 shows the physical properties of polypropylene. This previous study is for the natural fibre reinforced material in order to need of sustainable materials as replacement of glass and carbon fibre as to be more environmental friendly and sustainable materials.

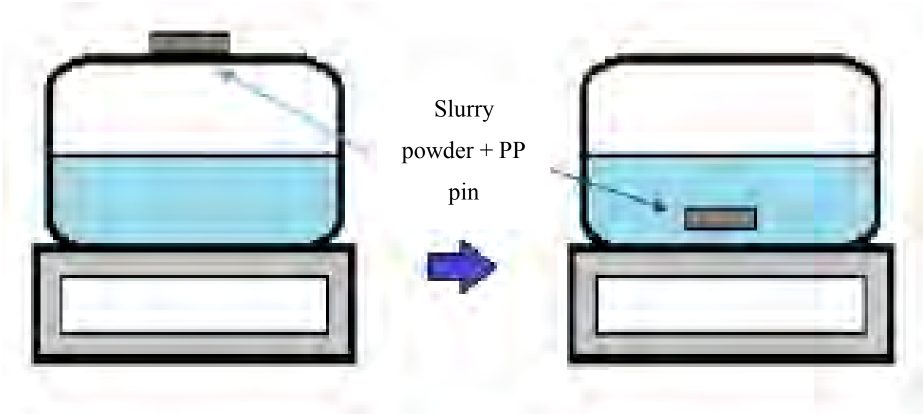


Figure 3.7 : Densimeter on the pin composite

The concept to find its density of composite based on Archimedes Principle. The principle when the material immersed in a fluid, the buoyant force makes the body to upward whether its partially or fully submerged. The result of weight of body is on the weight of fluid displaced as uses of densimeter in Figure 3.8.

The density or also called as volumetric mass density is the mass per unit volume. The pin composite submerge into distilled water act as hydrostatic weighing in order to determine volume of water displaced.

The general formula in order to obtain the density

$$\rho = \frac{m}{V} \tag{3.1}$$

Where ρ is the density, while m and V is the mass and volumes of the composite.

3.2.2 Testing on Hardness

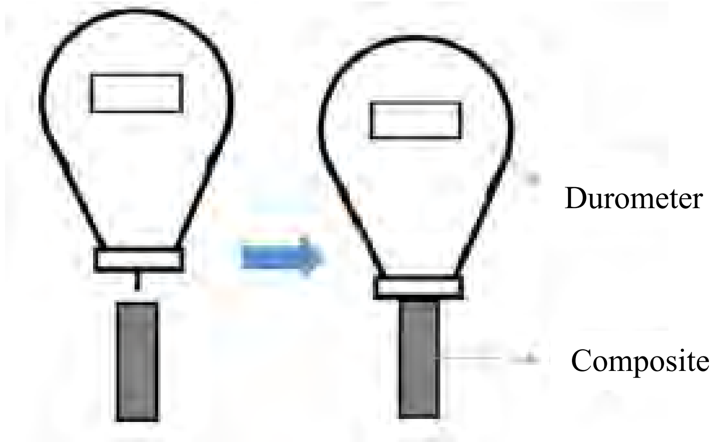


Figure 3.8 : Uses of Shore Durometer for Hardness Test

Shore durometer was used to determine the hardness of composite after specimen pin being pull out from the mould. Hardness is the ability of material to resist indentation under scratching or apply the static load. The hardness test is crucial in order to determine the suitable pin to perform in pin-on-disk machine obtain wear rate measurement. (Mat Tahir et al., 2016) have used shore hardness durometer D-type for their composited from PKAC-E to measure the hardness It is use for measurement of rubber, plastic and other non-metallic materials. The apparatus of shore durometer must be comply for American Society for Testing and Material specification (ASTM D2240) standard test method for rubber property – durometer hardness which is which is the recognized specification for the instrument and test procedures

In the laboratory, there are two types of durometer which is durometer A-type and D-type. The types is depend of the material hardness such as, for A-type use for rubber and elastomers. While for D-type durometer is suitable for hard rubber, plastics and thermo-plastics. Several type of durometer have different indenter notch for suit the specific surfaces. Mechanism of harness tester by penetrate the durometer indenter foot into sample to obtain the hardness value.

3.2.3 Porosity Test

Porosity test or also called as void fraction is to measure of solid material in terms of space or void volume. The test is doing by submerge the composite into water. As for this experiment, the measurement from fraction of the void volume comparing percentage of total composite volume. The specimen pin will weighted first, and then submerged it into water. The porosity of specimen will appear when air bubble escape from the pores of material when it submerge. Hence, the specimen will contains some volume of water cause of porous material.

The calculation of percentage will be obtained based on Archimedes Principle according mass of water displaces. The variable of mass of specimen before and after to determine the porosity value.

$$\text{Porosity}\ \% = \left[\frac{m_{after} - m_{before}}{m_{after}}\right] \times 100\% \qquad (3.2)$$

The porosity test being calculated by following Equation 3.3. Where m_{before} is the mass before submerge into water. While m_{after} is the mass after the specimen taken out from the water.

3.3 Tribological Testing

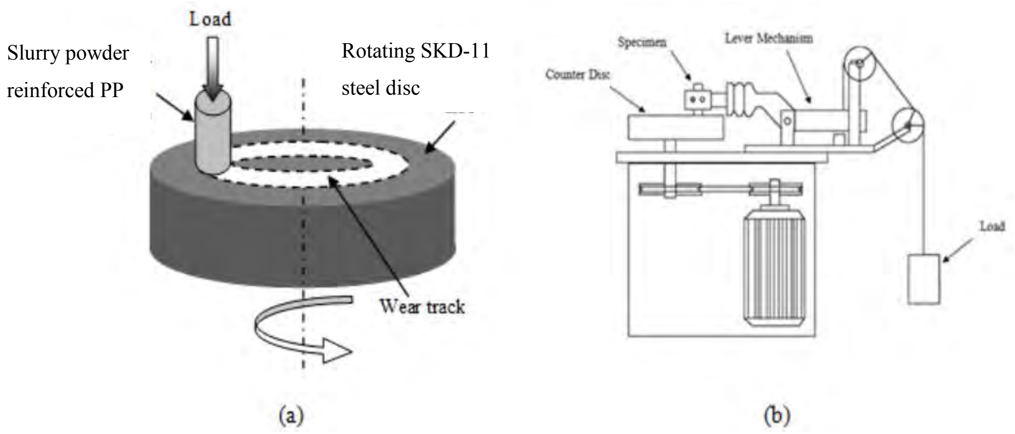


Figure 3.9 (a)(b) : Illustration of sliding test and schematic diagram of pin on disk machine

Tribological testing have been proceed after the compaction and other parameter being tested. The specimen will place in the pin holder with 10mm diameter size to be place on pin on disk tribometer. The procedure on performing dry sliding test is according on ASTM G99 Standard Test Method for Wear Testing with a Pin-on-Disk Apparatus. Sliding distance being performed between 500 m until 2000 m at range of temperature from 27 °C to 160 °C. Early phase in testing is to clean the disk by acetone in an ultrasonic bath. The disk will rotate in order for sliding mechanism while pin will be heated by heating element

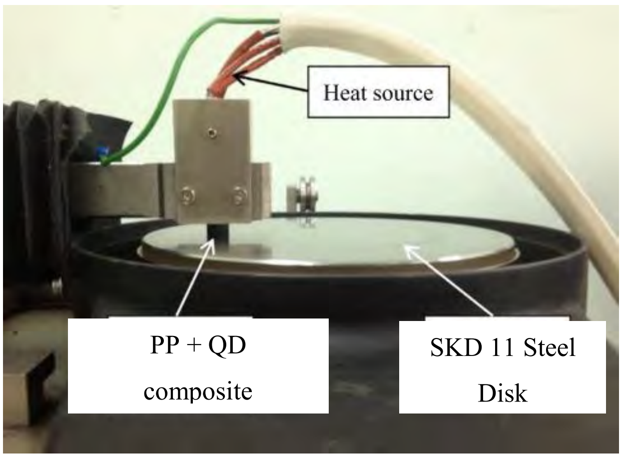


Figure 3.10 : Pin-on-disk Operation

The coefficient of friction (COF) and frictional force were measured using a PC-based data logging system. There were some important formulas needed to find the coefficient of friction (COF) and wear rate (k) The general formula for the equation is,

$$COF = \frac{F}{N} \qquad .. (3.3)$$

$$k = \frac{V_{loss}}{WL} \qquad (3.4)$$

$$V_{loss} = \frac{m_{before} - m_{after}}{\rho} \qquad (3.5)$$

The calculation of formula based on result from the density, and hardness test. Where *COF* is for Coefficient of Friction, *F* is the applied load, *N* is the normal force, k is the specific wear rate, V_{losss} is the volume loss W is also the applied load, *L* is the sliding distance, *m* is mass, and ρ is the density of pin.

CHAPTER 4

RESULTS AND DISCUSSIONS

4.1 Preliminary Data

The activities that been performed to conduct the experiment by reading of literature review, and start for initial stages in performing mould material. The several findings had to be made in order to get the specification of specimen pin for the slurry powder with reinforced polypropylene. Expected result for this experiment in order to find the coefficient of friction for the composite. The initial process must be on determine the correct composition ratio of waste slurry and the polypropylene ratio.

Table 4.1: Calculated weight of Palm Kernel Activated Carbon (PKAC) with Epoxy

[Source : (Mat Tahir et al., 2016)]

W_{pin} (g)	PKAC		Epoxy	
	Composition %	Weight (g)	Composition %	Weight (g)
3.35	60	2.01	40	1.34
3.30	65	2.145	35	1.16
3.25	70	2.275	30	0.98
3.20	75	2.4	25	0.80

From the result conduct by (Mat Tahir et al., 2016) the properties of composite will be varies when the ratio between the composite and the reinforce take count for the specimen pin. Their experiment was conducted to determine the tribological performance of a palm kernel activated carbon-epoxy composite by the effect of sliding distance at different temperatures. As for this project, the weightage of slurry and PP will make several variable in order to performing the effect of temperature after the sliding distance such in Figure 4.1 and Figure 4.2.

It is expected to have different of coefficient of friction due to number of composition ratio of slurry powder and the reinforce from polypropylene. This result is estimate value for coefficient of friction in order to proceed the next process on different temperature but in constant distance travel. This estimate result for pin-on-disk machine operation of pin with temperature and sliding distance of 27 °C

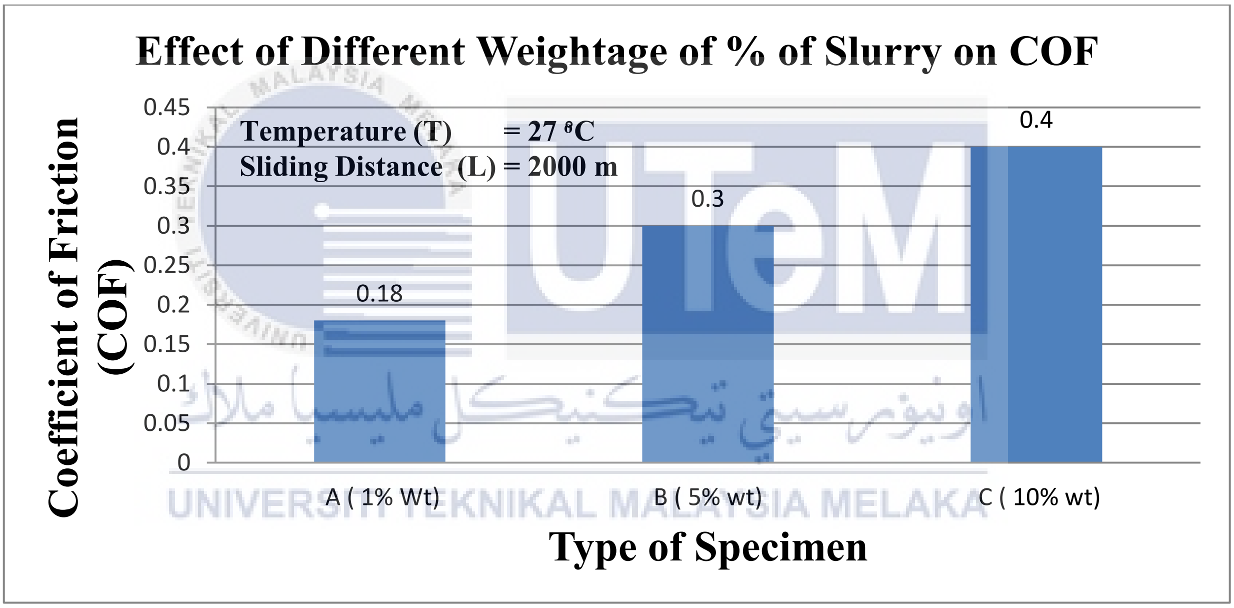


Figure 4.1 : Effect of different weightage of percentage of slurry on coefficient of friction at room temperature

The result of the composite will be different due to temperature that reach the melting point of polypropylene. The temperature for melting point will give the effect of the hardness of specimen.

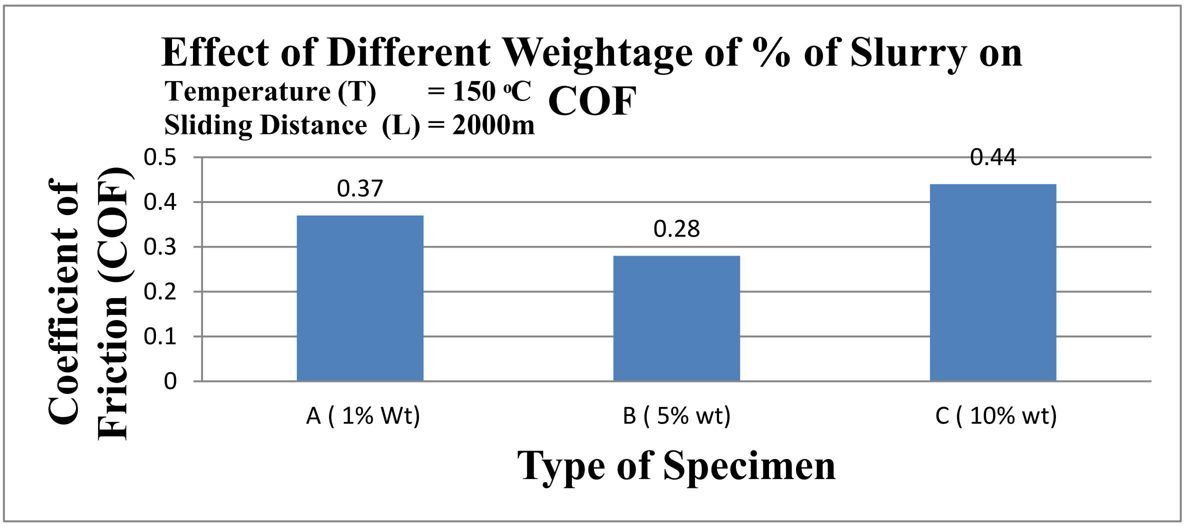


Figure 4.2 : Effect of different weightage of percentage of slurry on coefficient of friction at 150 °

4.2 Powdering Polypropylene

In the previous chapter, it was explained about the objective and scope of the project. And also about the methodology of the subject. Now it's about the preliminary result by getting specimen pin for pin on disk tribometer. This figure below shows the sequence of activity for conducting this project. The next activity by preparing the polypropylene powder as for the material preparation. Where the getting material of polypropylene comes in granule shape. The discussion with lecturer from composite department about the material preparation in order to getting polymer mould cylinder shape by getting hot compaction process by the temperature of 160C or higher in order the polymer composite to reach its melting point.

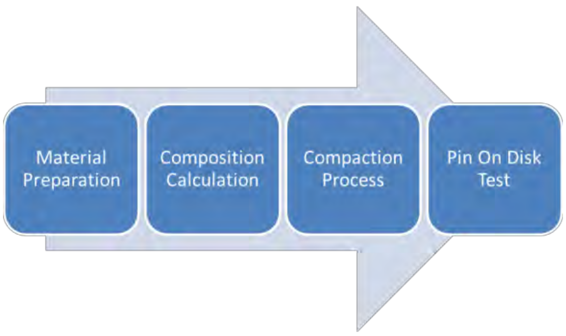


Figure 4.3 : Process for the experiment

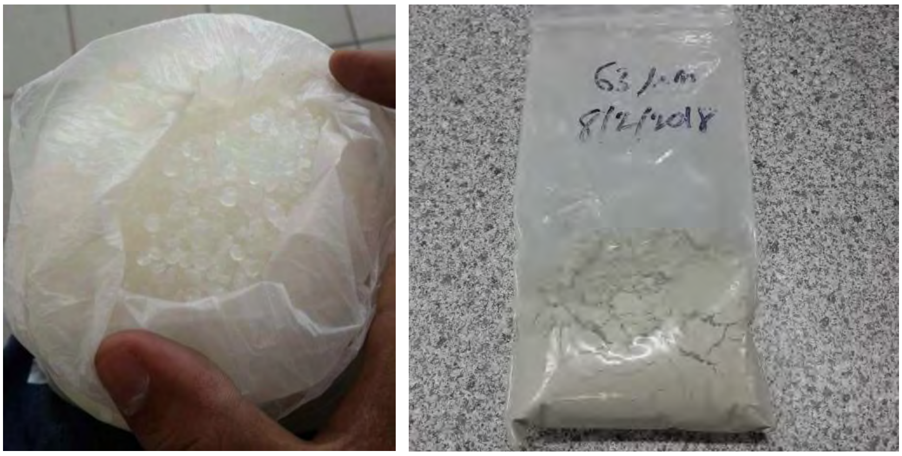


Figure 4.4 : Polypropylene granule and quarry dust

Before getting closer to conduct experimental process, the composition test had been conducted in order to find the chemical properties of quarry dust. The XRF (X Ray Fluorescence) was used to analyse the composition of material. X-ray emitted to the sample and the element contains in sample produce the certain set of characteristic radiation as for qualitative and quantitative analysis of material composition.

Table 4.2 : XRF Result

Analysis Method: Minerals

Analyte Concentration Table

Element	Concentration	Tolerance
Na2O	4.577 Wt %	0.053
MgO	1.686 Wt %	0.009
Al2O3	18.803 Wt %	0.015
SiO2	66.388 Wt %	0.032
P2O5	0.196 Wt %	0.003
SO3	0.245 Wt %	0.002
Cl	193 mg/kg	4
K2O	3.540 Wt %	0.011
CaO	1.527 Wt %	0.006
TiO2	0.431 Wt %	0.002
Cr2O3	55 mg/kg	3
Mn2O3	0.055 Wt %	0.000
Fe2O3	2.524 Wt %	0.002
ZnO	32 mg/kg	2
SrO	0 mg/kg	0

Based on the quantitative result based on Table 4.2, the main composition comes from silicon dioxide which is found in major constituent of sand. Besides that, it also shows the composition have the aluminium oxide element. Which is a chemical compound of aluminium and oxygen that denotes for chemical formula Al_2O_3. It is also common called alumina that have significant use in production of aluminium metal. The other element in this quarry dust is sodium oxide that shows Na_2O formula. This element is used in ceramic and glasses. This result will be beneficial in order to get initial hypothesis that the polymer composite reinforce waste quarry dust can increase its hardness and lower the coefficient of friction.

4.3 Pulverizing Process

The next process is to make the polypropylene granule into powder by using pulverize machine. The process doing by getting granule of pp in 20 gram or lower into the container with contain 2 rings as the grinding effect. The operational condition of pulverize machine by apply the vibrating effect of the container cup and the ring grinds by hitting the wall with the granule to become chips material. Polypropylenes for this project need to rerun 6 times for every 300 second in order the chip of PP turn to powder.

Figure 4.5 : Pulverizer machine and its mechanism

Figure 4.6 : Grinding bowl with heavy duty blender

For every pulverizing process, the heavy duty also been use to shear the powder to break the chip material. The result of the PP powder will count their weight to know the volume produced.

Figure 4.7 : Ultrasonic sieve

For getting the better powder for compaction process, the sieving process have to be done. The sieving by partially reduce the small the size of powder by using ultrasonic sieve. The several size of sieve being use such as 250µm, 150 µm, and 63 µm as to be smallest sieving size. The process had to be done several times to get much powder to be use.

4.4 Compaction Process

Figure 4.8 : Weighing the composite

Now, its for compaction process, after several weeks from preparing the material. The compaction start with the determination on getting suitable volume for getting the correct size of the pin. The pin should size around 30mm. Polypropylene powder will composed with the quarry dust with composition of ratio 100%PP, 5%QD, 10%QD, and 20%QD. The purpose of using several composition of polypropylene in order to get several range of result of polypropylene toward the tribological characteristics under constant speed and sliding distance but in different applied load.

In preparing the compress material, there are two element that be accounted to compose. The element which is matrices and reinforcements. Matrices is the element in forms of organic or non-organic which in this project use of polypropylene in non-organic form. While, the reinforcement is in the form of fibres, tubes, and like in this case use of ashes from quarry dust.

The mixture process of the composite were done by manual procedure through the hand mixing. There was not specified technique or ASTM standard to refer in produce this material. The calculation for weightage of matrices and reinforcement by referring the equation below. The percentage will make different on volume for matrices and reinforment. The initial volume to produce the specimen pin will be 2.5gram. But, the volume of the composite will be different after compaction due to leakage on the pin mould. The result of the pin will be in 2.2gram – 2.35 gram (for Polypropylene 100wt%-80wt%). The calculation on weight composition have shown in table below.

$$\sum W_{\text{composite}} = w_{\text{matrix}} + w_{\text{reinforce}} \tag{4.1}$$

Table 4.3 : The composition of weight for polypropylene and quarry dust

No. of Pin	Weightage Composition	Polypropylene (PP)	Quarry Dust (QD)
		Weight (g)	Weight (g)
1	100%PP	2.2809g	0g
2	95%PP + 5%QD	2.375g	0.125g
3	90%PP + 10%QD	2.34g	0.26g
4	80%PP + 20%QD	2.08g	0.52g

There were no ASTM standards in producing a composite. Since the composite were done manually based through hand mixing, the calculation of weight distribution were done by referring to equation 4.1, and include the table for the composition weight for PP and quarry dust.

Figure 4.9 : Compaction process with pressure of 150 psi

The compaction process is using hot press moulding machine. For every one pin that be produce, the suggested volume is 2.5 gram. Due to leakage on the compaction mould after being high temperature and pressure the volume after compress will be changing.

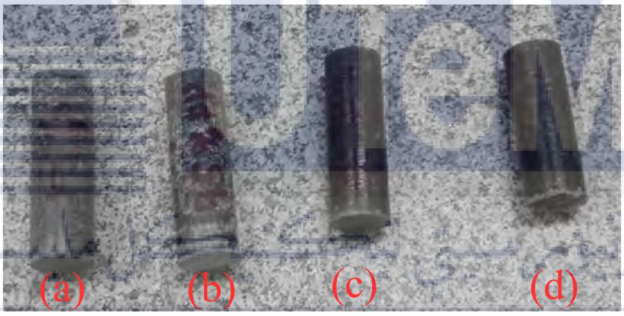


Figure 4.10 : Several composition of pin (100%, 95%, 90%, 80% PP)

After the compaction process, the surface of the both upper and lower surface will be resurface using sand paper to get the required standard for surface roughness according the G-99 Standard Test Method for Wear Testing with a Pin-on-Disk Apparatus. The surface roughness should be in 0.8-0.4Ra.

Figure 4.11 : Uses of surface roughness tester and sandpaper for resurface the pin

4.5 Calculating The Duration Time

In this study, pin on disk test was used in order to get the tribological behavior. The constant parameter that been used consist of sliding distance, track diameter, speed and applied load. By using the equation below will get the duration to run the pin on disk machine.

$$L = 2\pi NrT \tag{4.2}$$

Where ;
L = sliding distance (m)
r = track radius (m)
N = rpm
T = time in minute

The parameter in order to get the time to run the pin on disk tribometer consist of radius of pin, speed and the sliding distance according in the Table 4.3.

Table 4.4 : Parameter used to test pin on disk tribometer

Parameter	Value
Sliding Distance (L)	800m
Temperature (T)	27 ^{o}C
Applied Load	10 N , 20 N, 30 N

Wear Track Radius	20mm
Condition	Dry Sliding
Speed (N)	250RPM

$$L = 2\pi NrT$$
$$800 = 2\pi(250)(0.02)\mathrm{T}$$
$$\mathrm{T} = 25.465\,\mathrm{minute}$$

Hence, every the duration to run pin on disk is 25 minute and 28 second.

4.6 Result on Pin On Disk Test

4.6.1 Applied load for 0%QD

Based on the pin on disk test, the variable between different composition and applied load will be determined. The pin on disk operation was conducted for different weightage composition with several applied load for 10N, 20N, and 30N. The composition of PP and quarry dust (QD) will increased the coefficient of friction (COF) as for initial load applied at 10 N.

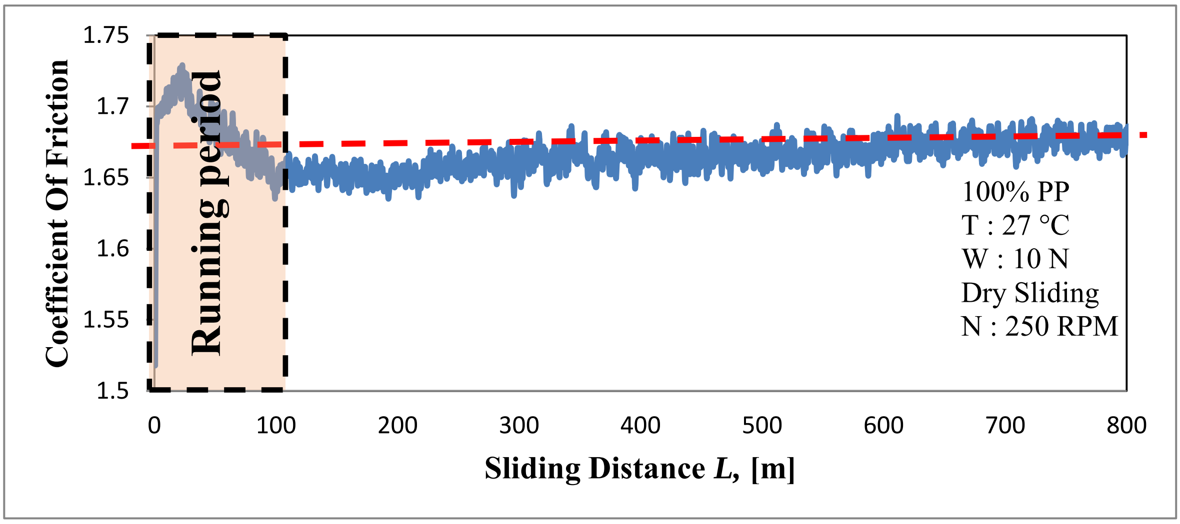


Figure 4.12 : 100%PP at 10N

The figure 4.13 shows the composite starts at higher COF at 1.67 for 100%PP wth 10N of applied load. The 100m early sliding distance shows the running period in order to get the stable the COF.The running period for certain distance due to initial static friction causing fluctuation on the graph. After the certain period the condition goes stable until reach the final sliding distance at 800m. The average of COF after test is 1.66995.

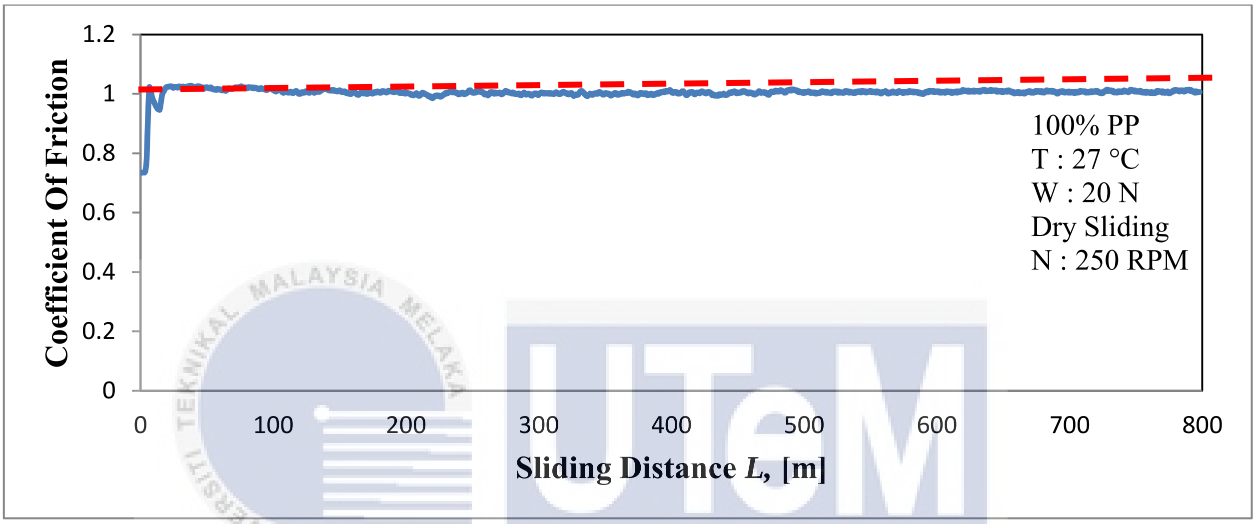


Figure 4.13 : 100%PP at 20N

The situation on PP at 20N quite different compared to the previous one. Now the 100%PP of pin is subjected to dry sliding with increase applied load to 20N. The result shows the running condition very much smaller compared on 10N dry sliding condition. The condition may happen cause of decreasing COF value when putting higher load. The surface condition of the pin become smoother due to abrassive debris after sliding on certain distance. The average COF for 100%PP at 20N is is 1.0048.

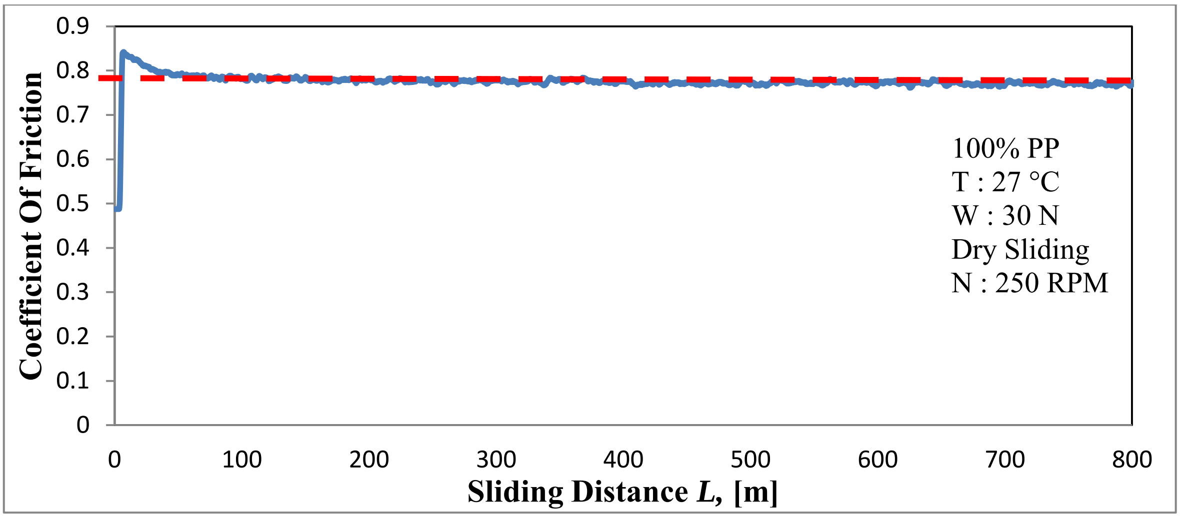


Figure 4.14 : 100%PP at 30N

For this result, the pin was tested in higher load at 30N. The several test on dry sliding with different applied load to get some inference of compostion behavior toward the COF and the rate of volume loses. The average COF for 100%PP at 30N is 0.773

Based the average value of COF it show different value of data. This is because, the COF will be different when increasing applied load. The additional applied load will give more wear on the specimen pin On Figure 4.16 shows the COF result for 100%PP after being different applied load. The result can be conclude that COF will be decrease if being heavier applied load.

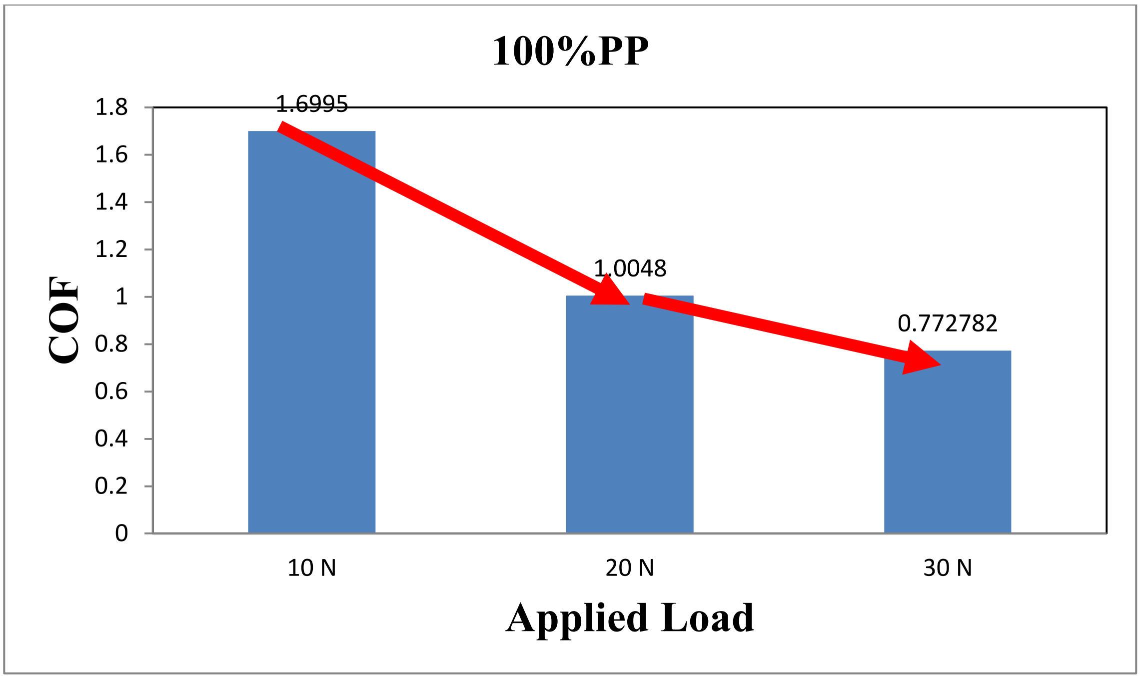


Figure 4.15 : Average COF on Applied Load

4.6.2 Applied load for 5%QD

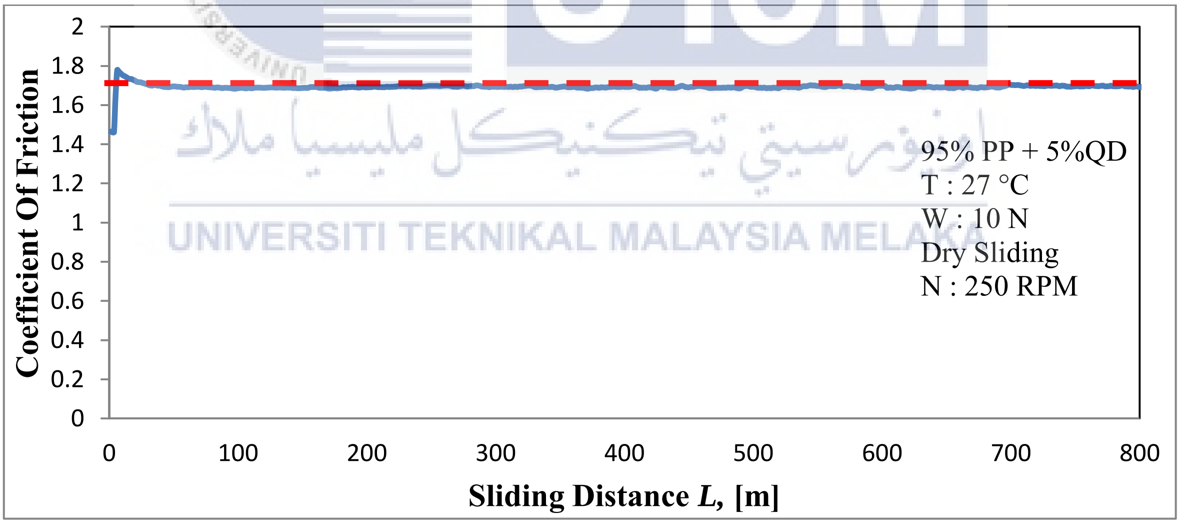


Figure 4.16 : 5%QD at 10N

The next result is for PP that being presence of quarry dust as the reinforcement. The composition of 5% weigtage from quarry dust give the significant result of COF. The graph shows the composition is not require much running time to get stable COF value.

Dry sliding condition after 30m show the stable COF condition after being applied load of 10N. The average COF for 5%QD at 10N is 1.693372.

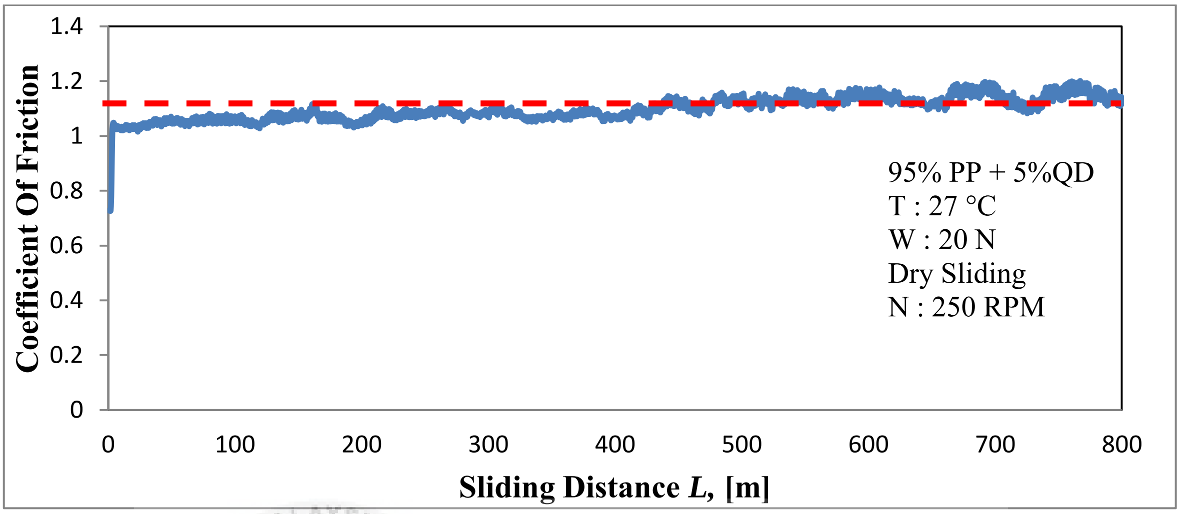


Figure 4.17 : 5%QD at 20N

From the observation on this result, we can analyze that that COF changing after increases applied load to 20N. The pin shows the COF decrease by 34.02% compared to 10N applied load. The result on the graph seen not stable due to vibration in the pin on disk macine. Hence, the result could be accurate needs to get the average value to get the correct COF.

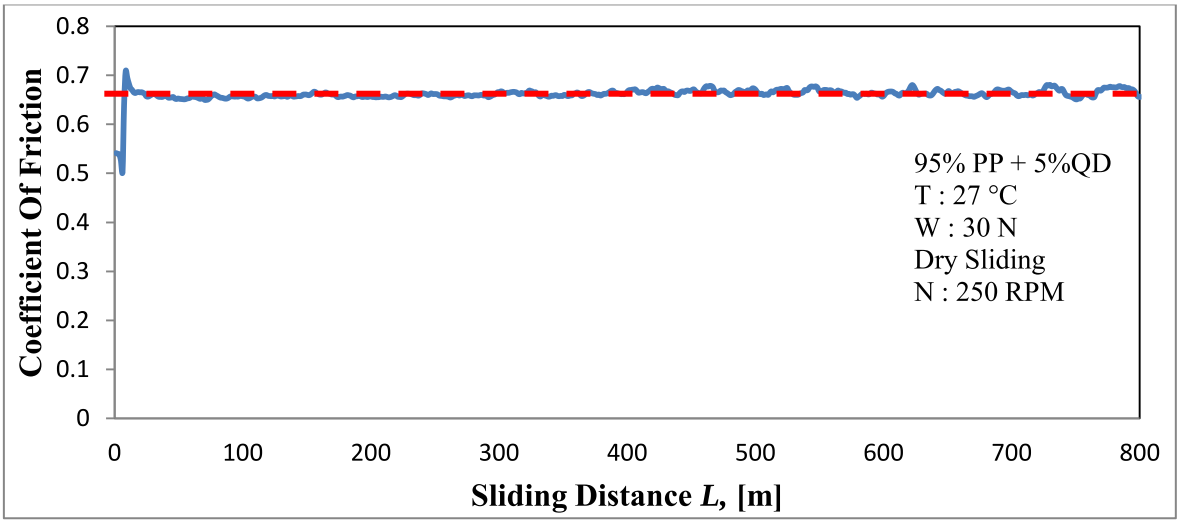


Figure 4.18 : 5%QD at 30N

On the last part, is the combination of PP with 5%QD at maximum load by 30N. The average COF for this test shows the result is stable after 30m sliding distance. Compared with 100%PP of pin ar 30N, the COF average is 0.772782. But in this test the mixture show the lower result of COF by 0.664675. This means that the QD as the reinforcement will help to reduce COF even in extreme applied load.

The overal test result in order to get the average COF can be seen in Figure 4.20. The condition is similar from the previous test where the COF value decrease in respect on the increasing applied load. The conclusion can tells the present of QD was bring better on reducing the COF under certain applied load.

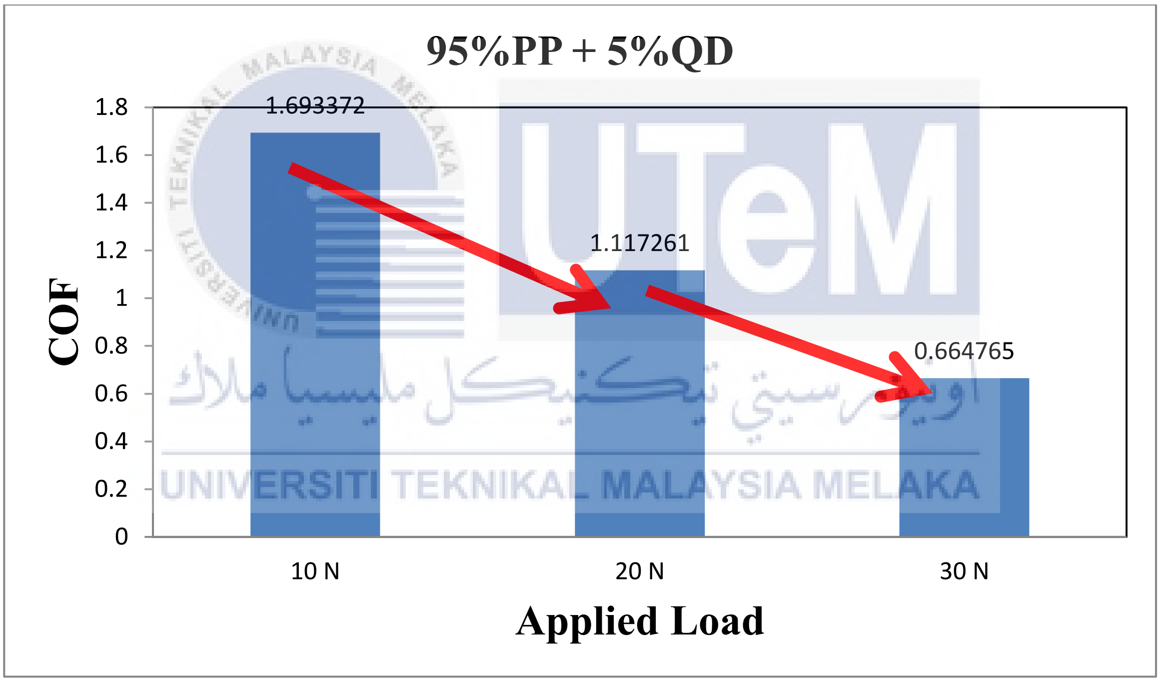


Figure 4.19 : 5%QD at Applied Load

4.6.3 Applied load for 10%QD

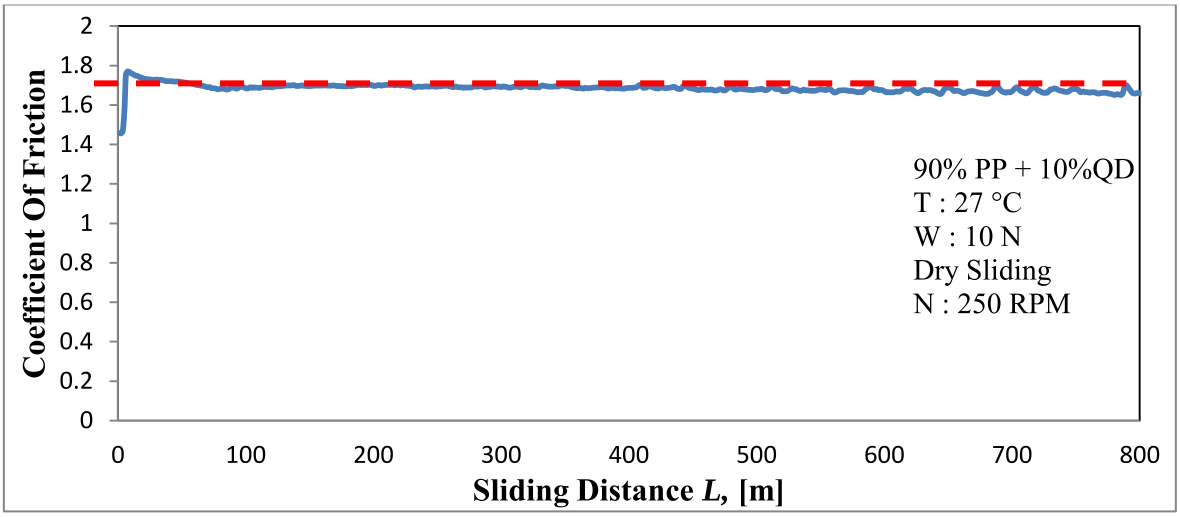


Figure 4.20 : 10%QD at 10N

Next, is the result of PP with additional composition by 10% of QD. The average COF show consistent result next 100m. The condition of dry sliding is on room temperature with rotational speed of disk of 250 RPM. Hence, the average COF for 10%QD at 10N is 1.677911.

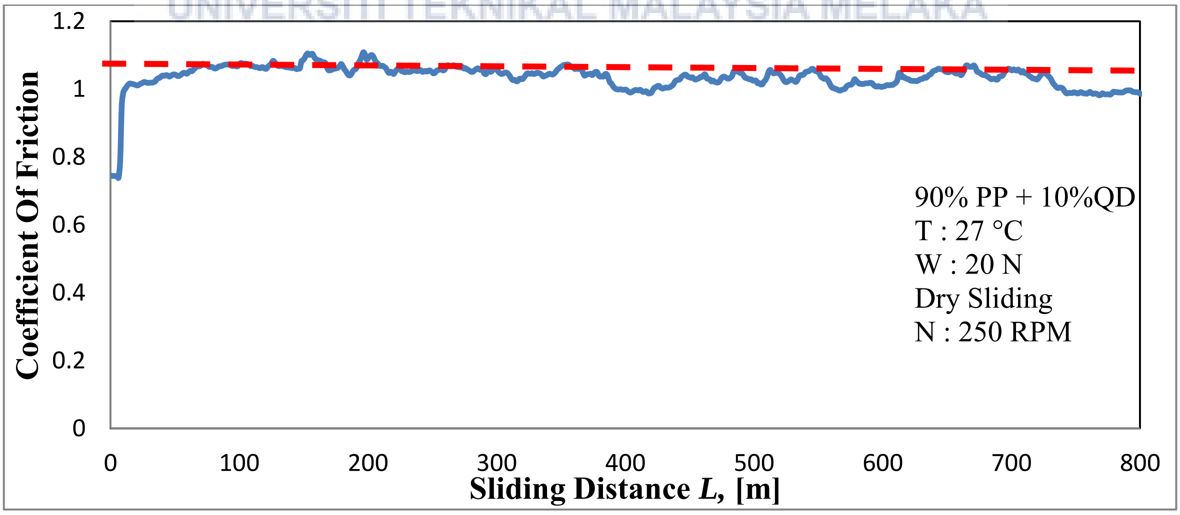


Figure 4.21 : 10%QD at 20N

The Figure 4.22 shows the result on average COF for PP with mixing of 10%QD. The average COF is 1.03129. At the initial start the composite starts it static friction on 0.78 of COF and keep increasing in according sliding distance and then its reach the dynamic friction condition.

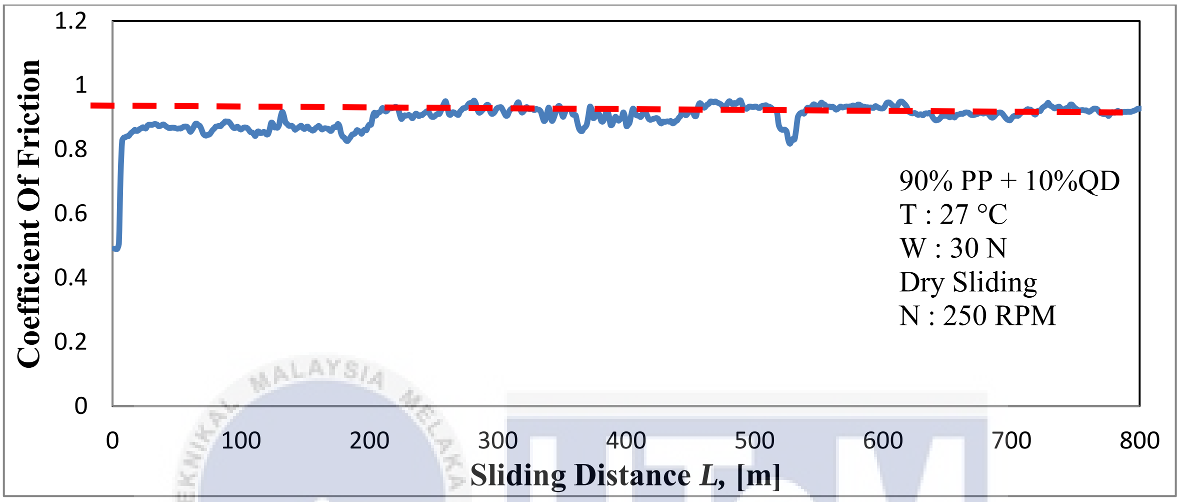


Figure 4.22 : 10%QD at 30N

In the final part in this test for 10%QD is on 30N applied load. The average of COF shows only slight decrease of COF. But, eventually the result toward sliding distance is not stable due to unsmooth on pin surface and effect of noise cause from vibration on pin on disk machine. The average COF for 10%QD at 30N is 0.916153.

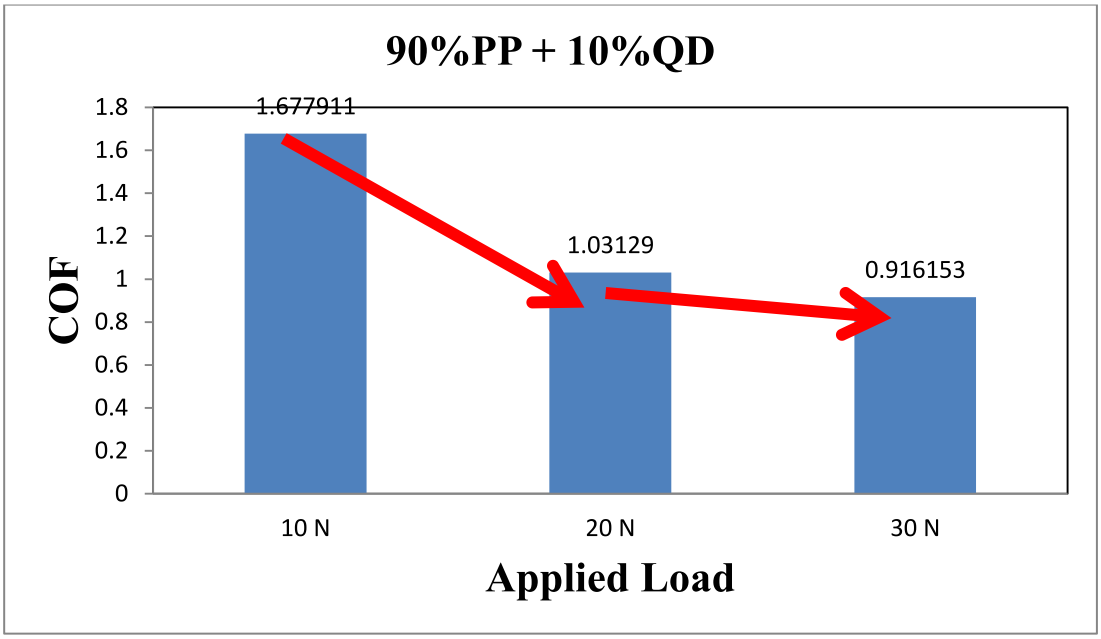


Figure 4.23 : 10%QD at applied load

4.6.4 Applied load for 20%QD

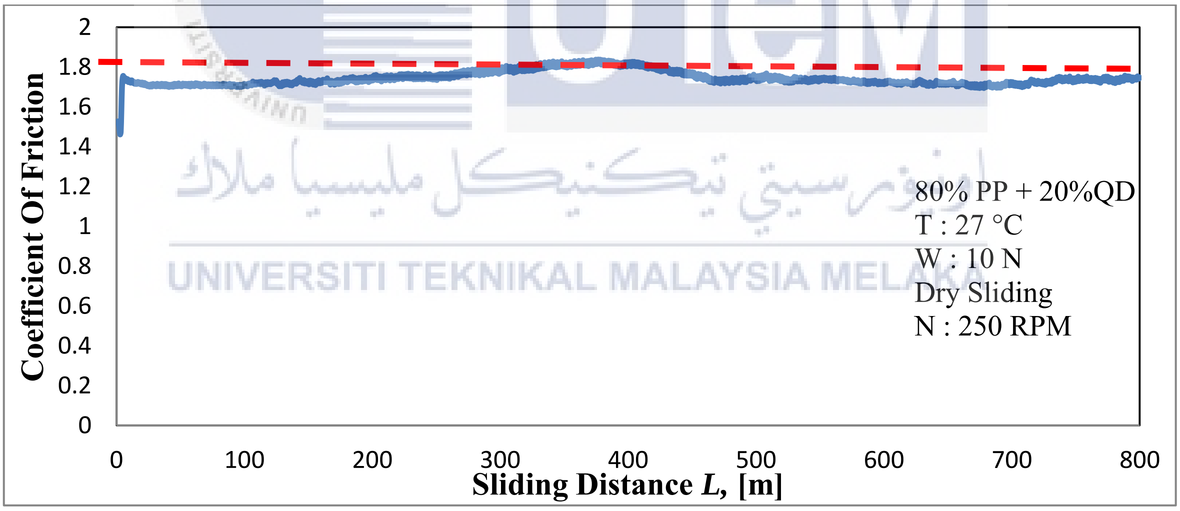


Figure 4.24 : 20%QD at 10N

The Figure 4.25 is the result of COF for composition of PP with 20% weightage from quarry dust. This composition is the biggest weightage as to reinforce the polymer composite. The running distance on 300m until 500m slight increase of COF. This is because the debris from QD is bigger will make rough of surface of PP pin. The average COF is 1.751665.

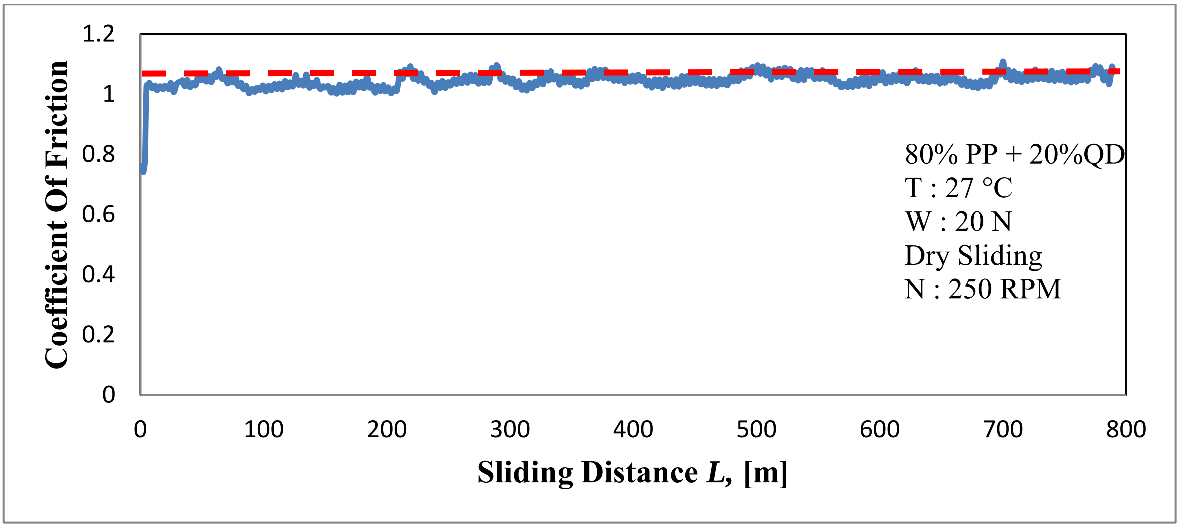


Figure 4.25 : 20%QD at 20N

The effect of more percentage on QD will result unstable COF value. This is cause from dynamic friction with additional applied load on dry sliding will result of Quarry Dust to be abrasive in required sliding distance. The average COF for 20%QD at 20N is 1.05207.

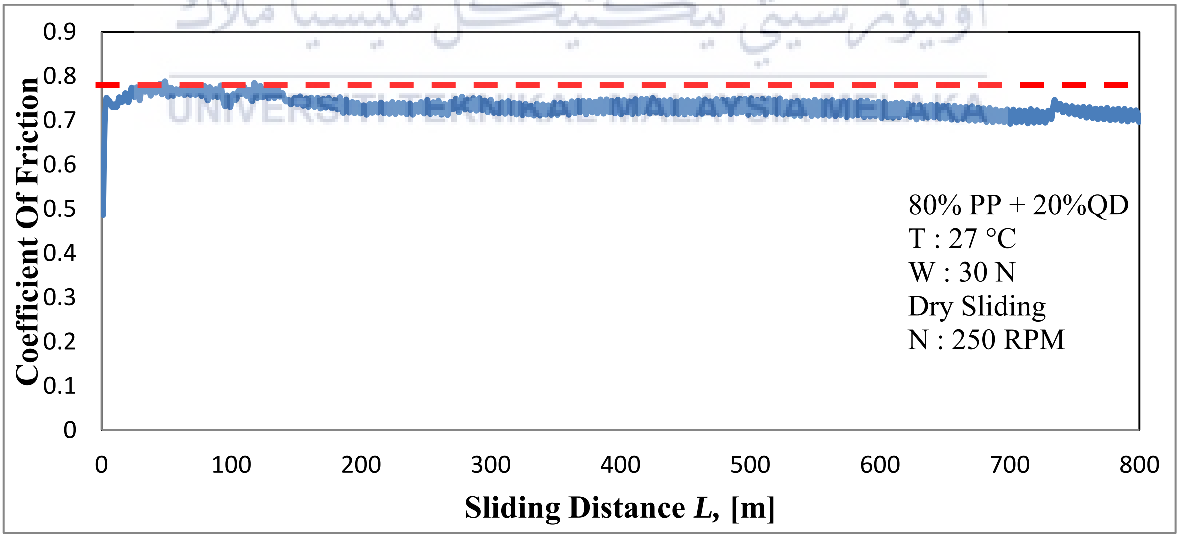


Figure 4.26 : 20%QD at 30N

For the final part on this pin on disk test is for PP reinforced of 20%QD at 30N of load. The graph shows the slightly decrease of COF when sliding distance of 150m. The contains Polypropylene will smooth the surface area with the density of QD will harden the composite. The applied load on the specimen pin will increase their hardness of material and result of lower COF. The average COF of 20%QD at 30N is 0.724856.

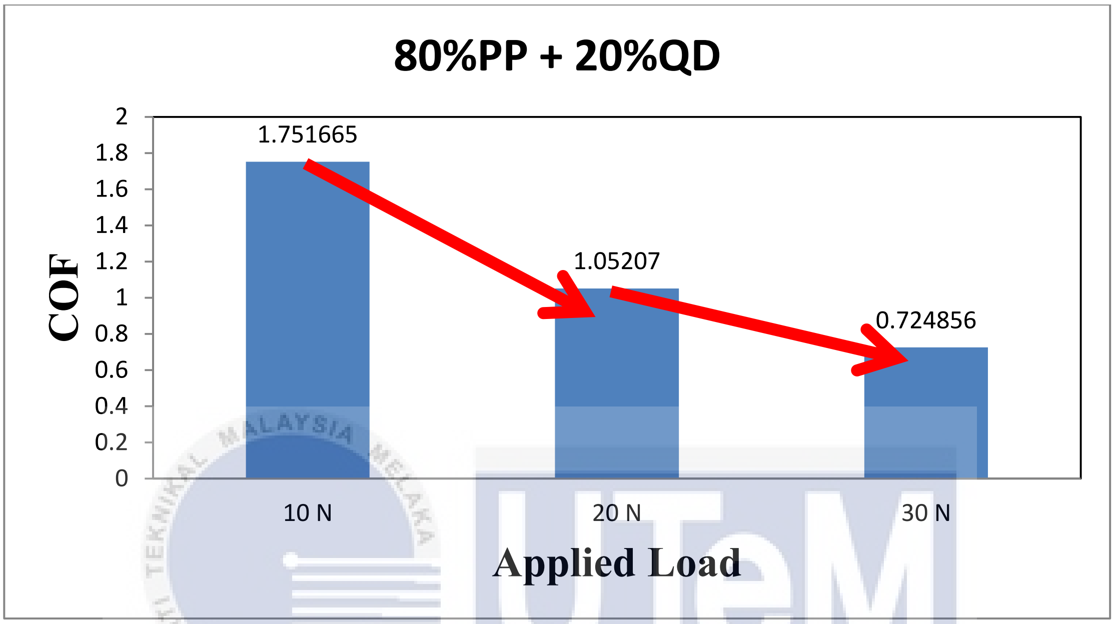


Figure 4.27 : 20%QD at applied load

4.7 Analysis on Average COF on several applied load

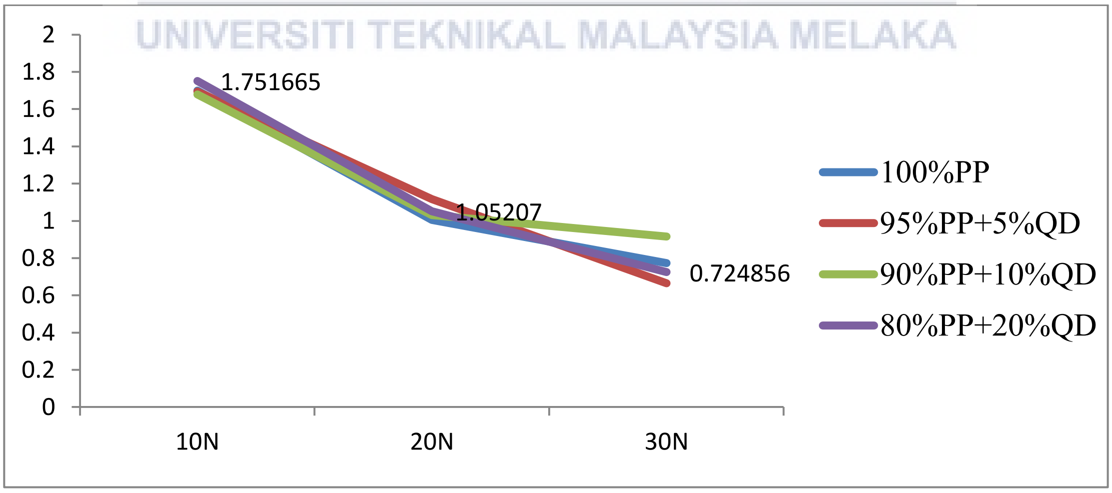


Figure 4.28 : Average of COF on applied load

Based on the figure above, the graph was consistently decrease in term of COF. The several composition of PP and QD will enhance the hardness that provide lower COF.

However, the present combination of QD will also increase the COF value when applied more load. This result shows the 95% of PP with 5%QD was the perfect combination to get better COF value reduction. Compared to other composition on 10% and 20% of QD will result COF increase when changing applied load.

4.8 Analysis on wear volume toward the applied load

Every running session of pin on disk need to measure their weight in order to get mass loss after test. This is because to get the wear volume as to achieve the objective in order to determine the wear mechanism from mixture of PP and quarry dust.

Table 4.5 Volume loss after 10N applied load

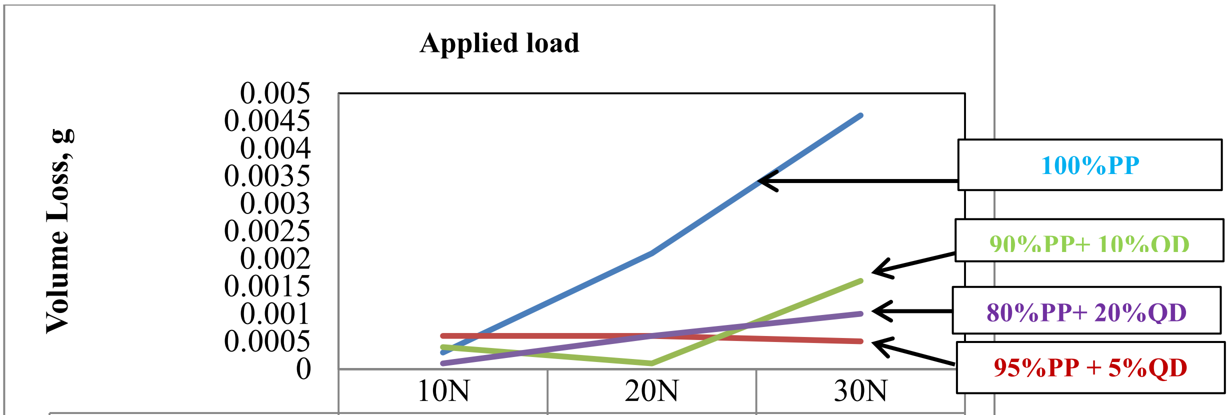
Applied Load	10N			
Material Composition	0%QD	5%QD	10%QD	20%QD
Volume loss(gram)	0.0003	0.0006	0.0004	0.0001

Table 4.6 Volume loss after 20N applied load

Applied Load	20N			
Material Composition	0%QD	5%QD	10%QD	20%QD
Volume loss(gram)	0.0021	0.0006	0.0001	0.0006

Table 4.7 : Volume loss after 30N applied load

Applied Load	30N			
Material Composition	0&QD	5%QD	10%QD	20%QD
Volume loss(gram)	0.0046	0.0005	0.0016	0.001



	10N	20N	30N
100%PP	0.0003	0.0021	0.0046
95%PP+5%QD	0.0006	0.0006	0.0005
90%PP+10%QD	0.0004	0.0001	0.0016
80%PP+20%QD	0.0001	0.0006	0.001

Figure 4.29 : Volume loss after pin on disk test

The overview from this Figure 4.30 above shows the significant increase of mass loss for 100%PP after apply some load on running pin on disk. Eventually, the presence of mixing with some composition show the small mass loss after test. Hence, its show the combination of polymer matrix with some natural waste from quarry dust resulting the material itself have self-lubricating material.

4.9 Analysis wear volume towards the applied load

The wear volume bring beneficial data that's shows after material from specimen being tested in pin on disk tribometer. Calculation of wear volume based in equation 3.4 from the previous chapter 3.

$$\text{Wear rate } (k) = \frac{\text{Volume Loss}}{WL} \tag{4.3}$$

The calculation needs in order to get wear is the volume loss (g), applied load value, and sliding distance that in this project will in 800m of distance. Besides, the value that needs to consider such as in table below

Table 4.8 : Parameter for calculate the wear volume

Density PP	$(\rho_{Polypropylene}) = 0.946 \frac{g}{cm^3}$
Density QD	$(\rho_{QuarryDust}) = 1.726 \frac{g}{cm^3}$
Applied Load	10N, 20N, 30N
Sliding Distance	800m

Table 4.9 : Result of wear volume at 10N

Applied Load	10N			
Material Composition	0%QD	5%QD	10%QD	20%QD
Wear volume (mm3/N.m)	0.000040392	0.000028619	0.00001907	0.000004766

Table 4.10 : Result of wear volume at 20N

Applied Load	20N			
Material Composition	0%QD	5%QD	10%QD	20%QD
Wear volume (mm3/N.m)	0.000141424	0.000014309	0.000238277	0.000014309

Table 4.11 : Result of wear volume at 30N

Applied Load	30N			
Material Composition	0%QD	5%QD	10%QD	20%QD
Wear volume (mm3/N.m)	0.000206532	0.000007946	0.000025433	0.000015897

CHAPTER 5

CONCLUSION AND RECOMMENDATIONS

5.1 Conclusion

The research focussing on friction and wear has been going on for many years. This context can be best understood that increasing demand on more efficient lubrication system that improve the performance from the machine and automotive industries. Beneficial effect of lubrication system and other combination material that protect from wear will bring benefit of cost reduction on maintenance as well as accident causing from inefficient lubrication system. Besides, in tribology industry, the accessibility of natural of self-lubricating material that bring benefit in reducing environmental pollution. Nonetheless, there are still have the gap of substantial knowledge in the field of lubricants. Hence, this study was conducted that provide sharing to add the existing body of knowledge. Hence, this study can be comes up with the following conclusions;

a) The COF of polypropylene with reinforce slurry powder is affected by the sliding distance. The value will increasing gradually with increment of applied load.
b) The mixing of slurry powder of quarry dust shows the small of volume loss for constant sliding distance with several applied load.
c) The composition of 5% of Quarry Dust reinforce Polypropylene shows the perfect mixing in order to get better coefficient of friction with significant lower volume loss.

5.2 Recommendation

For future studies, its recommend that's the composition of polymer and waste matrix should be more weightage in order to get more accurate data. Besides, more procedure details on preparing material in order to get correct matrix of composition.

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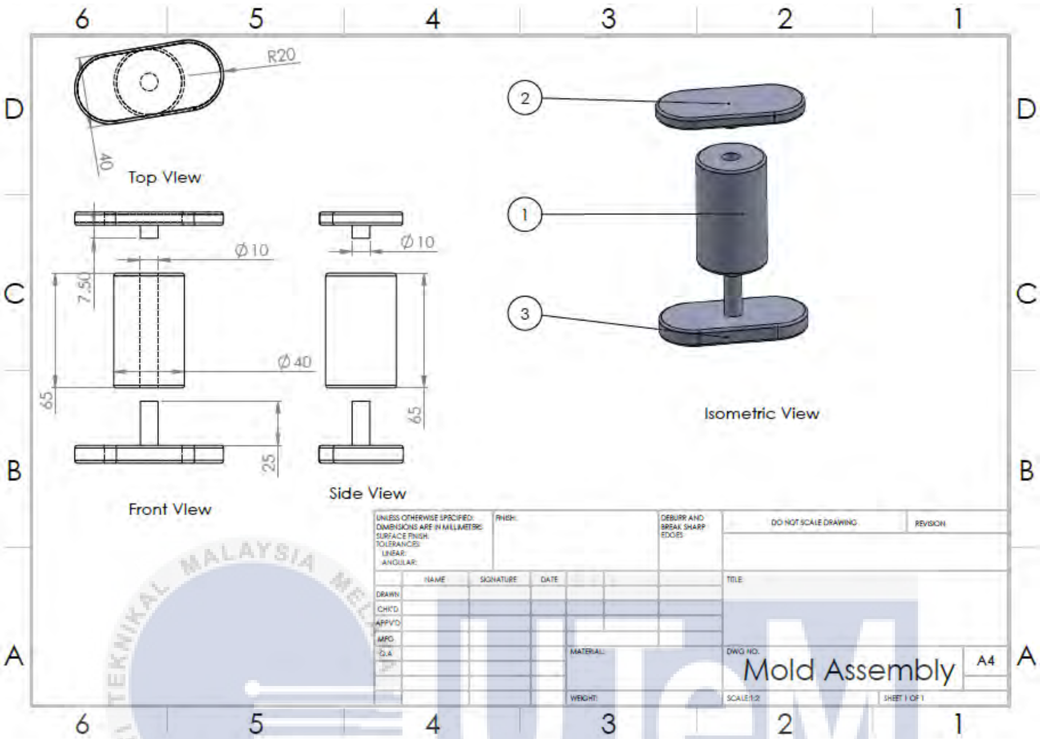
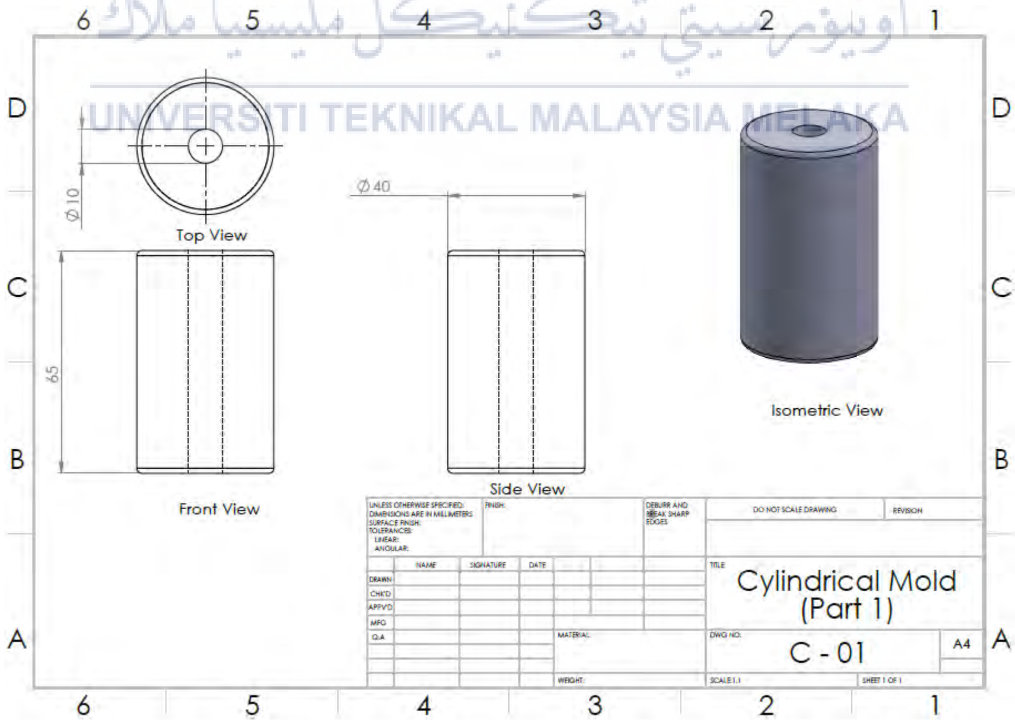
APPENDICES

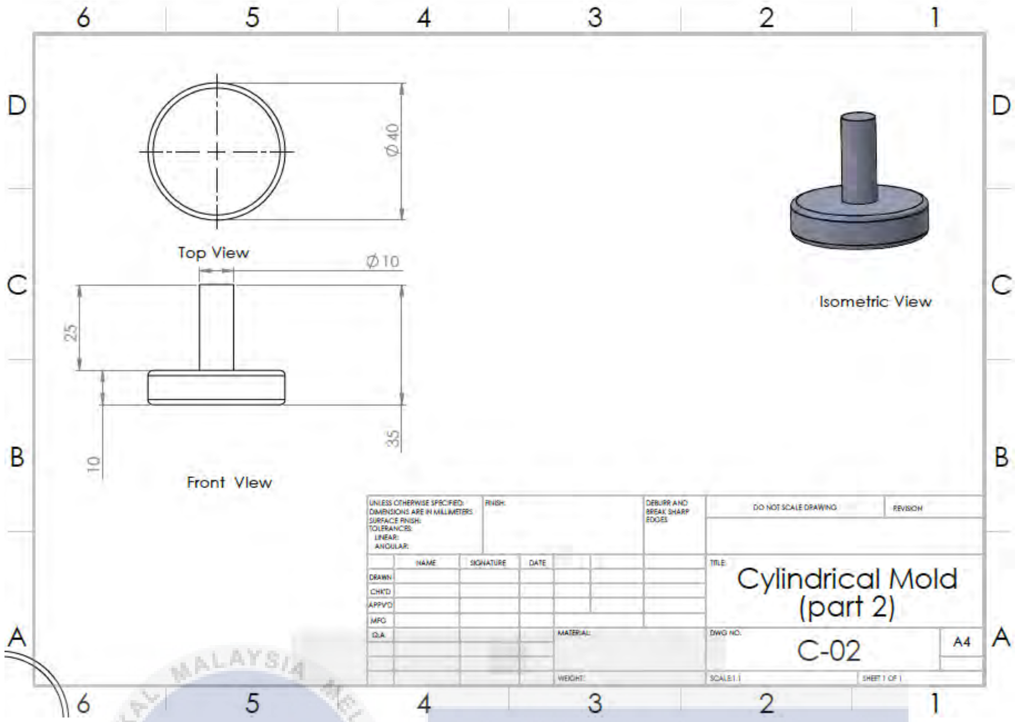
Appendix A1 : Assembly of Mold for Compaction Process



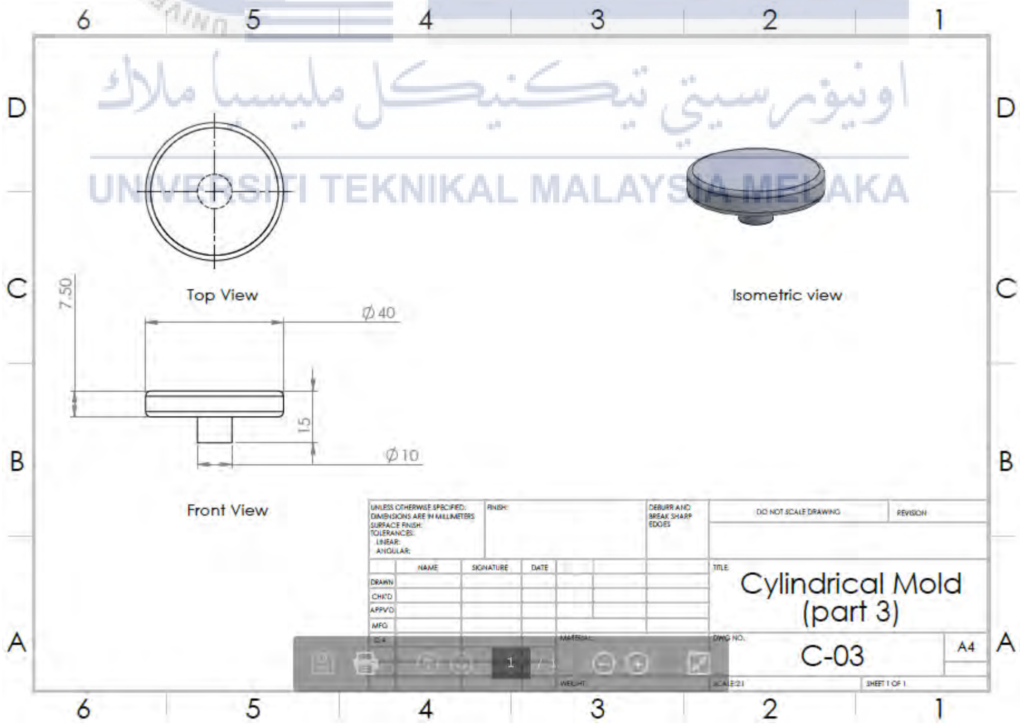
Appendix A2 : Body for Cylindrical Mold



Appendix A3 : Plunger for Cylindrical Mold



Appendix A4 : Bottom Part for Cylindrical Mold



Appendix B : XRF Result

KOLEJ KEMAHIRAN TINGGI MARA MASJID TANAH

OPERATOR: INSTRUMENT MANAGER

SAMPLE: Quarrydust utem

ANALYSED: 15/02/2018 11:29:05

Analysis Method: Minerals

Analyte Concentration Table

Element	Concentration	Tolerance
Na2O	4.577 Wt %	0.053
MgO	1.688 Wt %	0.009
Al2O3	18.803 Wt %	0.015
SiO2	66.388 Wt %	0.032
P2O5	0.198 Wt %	0.003
SO3	0.245 Wt %	0.002
Cl	193 mg/kg	4
K2O	3.540 Wt %	0.011
CaO	1.527 Wt %	0.006
TiO2	0.431 Wt %	0.002
Cr2O3	55 mg/kg	3
Mn2O3	0.055 Wt %	0.000
Fe2O3	2.524 Wt %	0.002
ZnO	32 mg/kg	2
SrO	0 mg/kg	0

Notes

KOLEJ KEMAHIRAN TINGGI MARA MASJID TANAH

OPERATOR: INSTRUMENT MANAGER

SAMPLE: Quarrydust utem

ANALYSED: 15/02/2018 11:29:05

Analysis Method: Minerals

Analyte Concentration Table

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Cl	193 mg/kg	4
K2O	3.540 Wt %	0.011
CaO	1.527 Wt %	0.006
TiO2	0.431 Wt %	0.002
Cr2O3	55 mg/kg	3
Mn2O3	0.055 Wt %	0.000
Fe2O3	2.524 Wt %	0.002
ZnO	32 mg/kg	2
SrO	0 mg/kg	0

Notes