PRELIMINARY STUDY ON EFFECT OF SPRAY COATING PARAMETER ON HYDROPHOBIC COATING SURFACE

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PRELIMINARY STUDY ON THE EFFECT OF SPRAY COATINGS PARAMETER ON HYDROPHOBIC COATING SURFACES

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A report submitted
In fulfillment of the requirement for the degree of
Bachelor of Mechanical Engineering (Structure and Materials)

UNIVERSITI TEKNIKAL MALAYSIA MELAKA

2017

DECLARATION

I declare that this project entitled "Preliminary Study on the Effect of Spray Coatings Parameter on Hydrophobic Coating Surfaces" is the result of my own work except as cited in the references

Signature :..................................

Name :..................................

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 (Structure & Materials).

Signature :.................................

Name of Supervisor :.................................

Date :.................................

DEDICATION

To my beloved mother and father

ABSTRACT

Hydrohobocity means the surface of water is repelled with the surface of the sample or specimen. To determine the hydrophobicity surfaces the contact angle has to be measured which are the angle of contact between surfaces of the solid with the surface of liquid or water. The hydrophobic contact angle will be about 90° to 140° where the water will beads up on the surface of solid. The purpose of the invention of hydrophobic surface is to avoid the problem s including corrosion, higher cost in maintaining the cleanness such as curtain glass of building and solar cell. Besides, by applying the hydrophobic also, the materials can be protected. The effect of thickness of spray coating and the effect of surface roughness of the surface was studied further. Two different layers of spray coating was represent the thickness of spray coating where the specimen was sprayed with one layer spray coating and two layer spray coating. The thickness of coating was only being tested on the aluminum plat. For the roughness of the surface, the sand paper grit represented the roughness where the sand paper used were 2000 grit, 1200 grit, 360grit and 180 grit. The lower the sand paper grit, the higher the roughness of surface of sand paper. So, 180 grit of sand paper is the roughest sand paper. For the roughness, aluminium with coating, uncoated copper and uncoated stainless steel was tested. This is to observe whether the trend of effect of roughness on contact angle followed. For the effect of thickness, it showed that as the thickness of the spray coating increased, the contact angle of hydrophobicity decreased. The surface with two layer spray coating has lower contact angle compared surface one layer spray coating. Then, for the effect of surface roughness on hydrophobicity, the results show that by increasing the roughness of surface, the contact angle of hydrophobicity also increased. The contact angle for 180 sand paper grit has highest contact angle followed by 360grit, 1200 grit and 2000 grit.

ABSTRAK

Hydrohobocity membawa maksud bahawa permukaan air ditolak dengan permukaan sampel atau spesimen. Untuk menentukan permukaan hydrophobicity, sudut sentuh telah diukur dimana ia merupakan sudut hubungan antara permukaan pepejal dengan permukaan cecair atau air. Sudut sentuh hidrofobik adalah diantara 90 ° ke 140 ° di mana air akan membentuk titisan manik pada permukaan pepejal. Tujuan penciptaan permukaan hidrofobik adalah untuk mengelakkan beberapa masalah termasuk pengkaratan, kos yang lebih tinggi dalam mengekalkan kebersihan seperti tirai kaca bangunan dan sel solar. Selain itu, dengan menggunakan hidrofobik juga, sifat bahan-bahan boleh dilindungi. Kesan ketebalan salutan semburan dan kesan kekasaran permukaan permukaan telah dikaji melalui projek ini. Dua lapisan yang berbeza salutan semburan telah mewakili ketebalan salutan semburan di mana spesimen disembur dengan satu lapisan salutan semburan dan dua lapisan salutan semburan. Ketebalan lapisan hanya diuji pada plat aluminium. Untuk kekasaran permukaan, gred kertas pasir mewakili kekasaran di mana kertas pasir yang digunakan adalah 2000 gred, 1200 gred, 360gred dan 180 gred. Semakin rendah gred kertas pasir, semakin tinggi kekasaran permukaan kertas pasir. Jadi, 180 gred kertas pasir merupakan kertas pasir yang paling kasar. Untuk kekasaran, aluminium dengan salutan, tembaga tidak bersalut dan keluli tahan karat tidak bersalut telah diuji. Ini adalah untuk melihat sama ada trend kesan kekasaran pada sudut kenalan diikuti. Untuk kesan ketebalan, ia menunjukkan bahawa apabila ketebalan salutan semburan meningkat, sudut sentuh hydrofobik menurun. Permukaan dengan salutan semburan dua lapisan mempunyai hubungan sudut lebih rendah berbanding permukaan satu lapisan salutan semburan. Kemudian, untuk kesan kekasaran permukaan pada hydrophobicity, keputusan menunjukkan bahawa dengan meningkatkan kekasaran permukaan, sudut kenalan hydrophobicity juga meningkat. Sudut kenalan untuk 180 gred kertas pasir mempunyai sudut sentuh tertinggi diikuti oleh 360gred 1200 gred dan 2000 gred.

ACKNOWLEDGEMENT

First and foremost, I would like to take this opportunity to express my sincere thanks to my supervisor Professor Dr. Ghazali bin Omar from the Faculty of Mechanical Engineering Universiti Teknikal Malaysia Melaka for all the supported, ideas and essential supervision for me to complete this project report. I also thanked for helping me improving my presentation skills.

I would also like to express my gratitude to Mr. Mahader, the technician from material science laboratory Faculty of Mechanical Engineering for assisted me with the machine in the lab and gave an idea to improved regarding my project.

Then, special thanks to all my parents, siblings and friends for their moral support in completing this project and my degree. Lastly, thank you to everyone who had been to the crucial parts of realization of this project.

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LIST OF ABBREVIATION

SEM	Scanning electron microscope
PC	Personal computer

CHAPTER 1

INTRODUCTION

1.1 Background

Hydrophobic is a word from Greek where the words *hydro-* which means water and -*phobia* which means fearing of heating. So, the general means of hydrophobic is naturally repelled or fails to mix with water. In another words, it also means that the surface of water will repelled from the surface of the materials coatings and causing the droplets to form. Water will forms a film on the surface without a hydrophobic surface which leading to the high losses. Hydrophobic can be determined if the droplets forms a sphere that barely touch the surface and it will have contact angle more than 90 degrees. Superhydrophobic surfaces exhibit superior water repellent properties. It has the same nature as the lotus leaf. When two hydrophilic bodies are brought into contact, any liquid present at the interface forms menisci, which increases adhesion/friction and the magnitude, is dependent upon the contact angle. Though the definitions of these terms are less precise, surfaces where tight droplets form a contact angle of more than 160 degrees are considered super hydrophobic. It exemplifies the behavior of the super hydrophobic from nature comprises micro-Nano roughness on its surface structure. One of the examples of super hydrophobic is lotus leaf as the contact angle is greater than 150 degree. The effect of hydrophobicity on lotus leaves will be showed in Figure 1.1. Water drops that fall onto them bead up and roll off leaving the leaves dry. Lotus leaves also have the ability to stay clean because when the droplets roll, they will pick the dirt together which is called as self-cleaning (David, 2013).

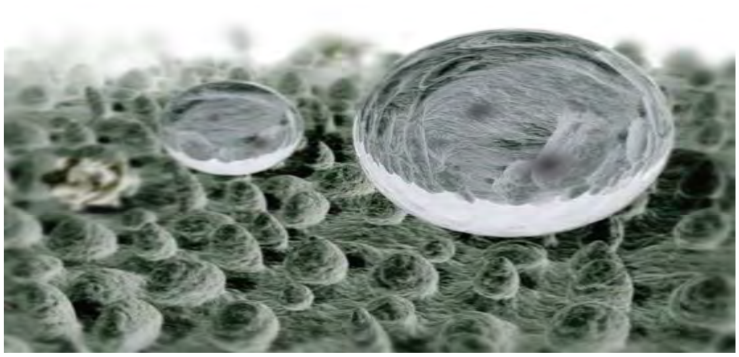


Figure 1.1: Computer Graphic of the ‗Lotus Effect'(David, 2013)

Hydrophobicity can be applied as waterproof devices, anti-corrosion, anti- icing, self-cleaning and some kind of similar function that are non-wetting related application. As water is the main reason of corrosion mechanism, it is important to reduce the presence of water contact with the surface. Hydrophobic and superhydrophobic coating can be used in every area. There are a few types of application that using hydrophobic such as solar panels, displays, windows, paints and fabric which coated by hydrophobic coating (Ramakrishna et al. , 2015).

So, for this project, two factors that affecting the hydrophobicity that will be studied which are effect of the thickness of coating on the hydrophobicity and the effect of surface roughness on the hydrophobicity. The detailed of the both two factors will be studied further throughout the experiment. By studied the two factors, improvement on the surface coating can be made.

For fundamental and aspects, one of the important properties of solid surface is wettability. The most factors that affect the wettability are surface energy and surface roughness. The hydrophobicity will be enhancing if only the surface energy is lower. So, for higher hydrophobicity, it is important to provide proper surface roughness. Contact angle of water also is one of the criteria for the evaluation of the hydrophobicity of the surface. The higher contact angle shows that the surface is more hydrophobic. Wettability is affected by surface microstructure, roughness and surface free energy. It shows that the higher of the surface roughness can affect the hydrophobicity (Bharathidasan et al., 2014).

In this project, the surface of the hydrophobic can be observed by light microscope. Light microscope is easy to handle. It contains two basic concepts which are magnification and resolution power or numerical aperture. The magnification power is provided by ocular lens which usually the power is 10x and 15x. There also four objective lenses on a microscope consisting of 4x, 10x, 40x and 100x (Fabio, 2009). Then, the roughness of the surface can be calculated by using profilometer or portable surface roughness tester.

1.2 Problem Statement

Hydrophobic has the application of water proofing, self-cleaning, anti-corrosion, and anti-icing. It can help to protects things like fabrics, electronics devices and glass window from water. There are a few problem faced that need to be solved by the application of hydrophobic coating. For example, air friction produced high amount of fuel consumption and pollution when it is applied to the hull of the ship and flight vehicle. Other than that, the high cost in maintaining the clean of the curtain glass of building, solar cell, surface of the satellite antenna and front windscreen of the vehicle. So, by applying the hydrophobic coating, the problem faced can be reduced Other than that, some materials also easy to corrode when are being exposed to the water that it is hard to maintaining the shape or strength of the materials. This problem can be reduced by makes the devices as the hydrophobic where it can be water proofing devices.

1.3 Objectives

The objectives of the project are as follows:

1. To investigate the effect of coating thickness on contact angle.
2. To observe the surface morphology on different surface roughness of the polymer coating surface.

1.4 Scope of project

The scopes of this project are:

Four different grit of sand paper used in this project was 2000 grit, 1200 grit, 360 grit and 180 grit to differentiate the surface roughness. The grit of sand paper will represented the surface roughness. Only two different thickness of polymer coating used which are one and two layer. Others thickness of polymer coating will not be included in this study. For the first method, the material used is aluminum with polymer coating while for second method the materials used are aluminum with polymer coating, copper and stainless steel.

1.4 General Methodology

The actions that need to be carried out to achieve the objectives in this project are listed below.

1. Identify the problem statement.

   The problem related of the needed of the hydrophobic coating will be studied.

2. Write literature review.

   The journals and articles regarding the effect of thickness and surface roughness to hydrophobicity will be reviewed. The information regarding the machine that will be used also will be reviewed.

3. Find the material and fabricate.

   Find the aluminum, copper and stainless steel that will be used in the experiment and fabricates by following the specific parameter.

4. Prepare the sample.

   After fabricate, the sample will be prepared by spraying the coating on the surface of the sample. Four different grit of sand paper will be used to study the effects of the surface roughness.

5. Testing.

   Different spots on the sample will be dropped with water before being tested. Then, the roughness will be observed by using light microscope.

6. Data and results.

   The result of the contact angle will be tabulated by following the thickness of the spray coating and the different roughness of the coating surface. The figure from the light microscope also will be included.

7. Report writing.

   A report on this study will be written at the end of the project.

The methodology of this study is summarized in the flow chart as shown in Figure 1.2.

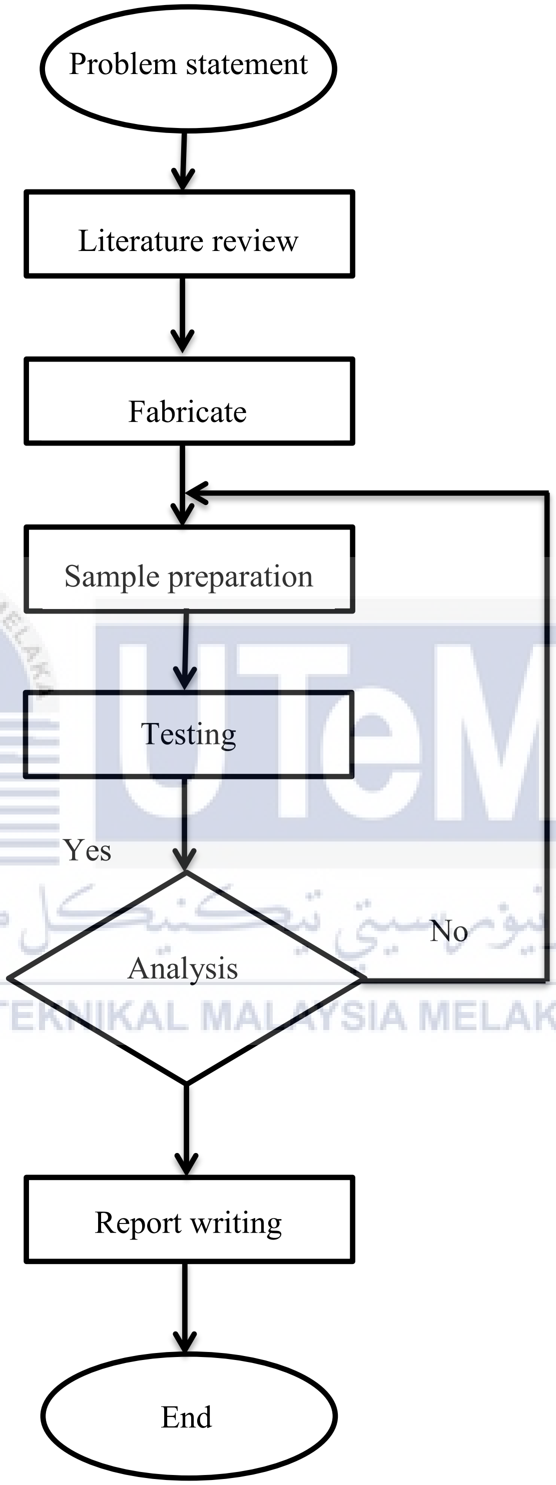


Figure 1.2: Flowchart of general methodology

CHAPTER 2

LITERATURE REVIEW

2.1 Overview

In this chapter, the properties of hydrophobicity including hydrophobic, and superhydrophobic will be duscussed. Other than that, the parameter that affected hydrophobicity also will be covered which are the thickness of coating and the surface roughness of the coating surface. Besides that, the machine used in this experiment also will be discussed which are, portable microscope, light microscope and profilometer.

2.2 Hydrophobicity Properties

2.2.1 Hydrophobic and Superhydrophobic

A hydrophobic can be defined as the molecule that will not combine with water. The definition of hydrophobic comes from the Greek words which ‗hydro‘ means ‗water‘ and ‗phobic‘ is a derivation from word ‗phobos‘ which means ‗fearing‘. So, in simple words, hydrophobic molecules have a water repelling characteristic where they do not mix with water molecule (Mark, 2004). For more understanding about the behavior of hydrophobic surfaces towards water, the contact angle need to be measured as the contact angle provides the information on the interaction energy between the surface and the liquid. Hydrophobic surfaces have a surface with a contact angle between water and surface of coating in between 90° to 140° where the water beads-up on the surface (Thomas, 2012). The illustration of hydrophobic will be showed at Figure 2.1.

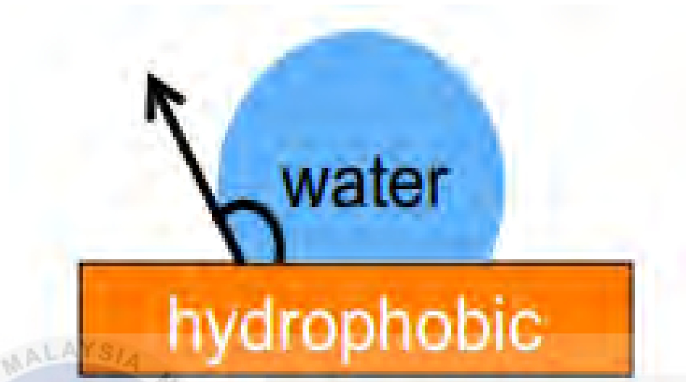


Figure 2.1: Hydrophobic surface (Mark, 2004)

Hydrophobic molecule tends not to combine with water or in the other word; they are incapable of dissolving in water because of lacking affinity for water. The substance in hydrophobic cannot be dissolved is water are because of their nonpolar molecules and also the long chains of carbon that do not interact with water. The molecules of hydrophobic also known as hydrophobes or in the simple definition are the water-insoluble molecules, that have the tendency to attract nonpolar solvents and neutral molecules. Hydrophobes interaction will be illustrated at Figure 2.2. In term of polarity, hydrophobic molecule has low polarity either as a whole or just in part. Unlike water, hydrophobes cannot form their own hydrogen bonds that make hydrophobes repel with water when they have contact. This is referred and known as hydrophobic effect or hydrophobic interaction. Instead of spreading, the molecules tend to cluster together that makes it have less contact with water (Anonymous, 2016). Hydrophobic interactions are the study of the relationship between water and hydrophobes (low watersoluble molecules). Walter Kauzmann is a american chemist who discovered that nonpolar substance has a tendency to clump up together rather than distributing itself in a water medium (Justin, 2016)

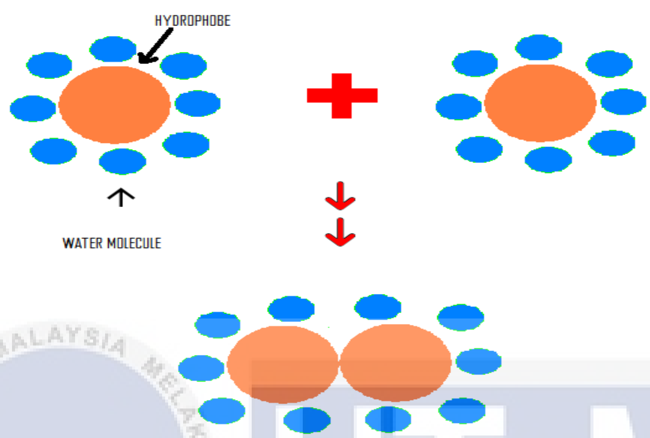


Figure 2.2: Hydrophobes molecules with water (Mark, 2004)

There are various sectors of economy that applied hydrophobic coating including electronics, textiles, optical devices, and in scientific and commercial equipment (Vipul, 2012). Hydrophobic has applications such as self-cleaning, waterproofing, corrosion resistant and also stable against inorganic and organic pollutants. So, hydrophobic materials can be used in many sectors such as to decrease corrosion rates, manage oil spills and remove oil from water. For examples, an experiment for water-shedding surfaces had been conducted by a team of researcher at MIT where the objective of this experiment was to produce a hydrophobic material that could benefit power plants and cooling system (David, 2013). By making the steam-condenser surfaces hydrophobic, the efficiency of condensation can be improved by causing the water that from condensation to quickly become droplet of water.

Hydrophobicity concepts also have been applied in paints, coatings and textiles. For examples, to enhance their clothing range, a clothing company made their cloths by using hydrophobic materials. Before fitting it into Berghaus' clothing, they coated the cloth with durable water repellent. It was showed that, the jacket becomes water-resistant and also kept the person who wears it warm (Thomas 2012).

Researchers have been focused much attention on hydrophobic coatings for microfluidic last few decade. There are only few products were launched using hydrophobic concept despite all the research. This is because, the hydrophobic surfaces are generally fragile and by applying hydrophobic concept, both chemical stability and mechanical stability are needed. The coatings are needed to survive long-term exposure to water as the coatings are applied to deal with harsh chemical environment. It was a challenge to build a strong hydrophobic surface to make it able to resist the different environmental conditions they are exposed to. Any coating is faced crucial problem to its practical application to withstand long term stability. There are two possible failure mechanisms that could occur in these coating which are the delamination of the films and the degradation of the surface properties of the coating (Arun, n.d)

So, in order to make the ability of the coating to withstand long term stability, there are studies about superhydrophobic. Superhydrophobic coatings are a nanoscopic coating that has the function to protect the surface from water and repel it (Anonymous, 2016). There are many scientists and researchers that extended their studied from hydrophobic to superhydrophobic as it shows excellent water repulsion and self-cleaning properties. It also shows outstanding water blocking capabilities and has the functions as anti-bacterial, anti-corrosion, anti-icing, self-cleaning and some similar kind of functions (Ramakrishna et. al., 2015). Superhydrophobic also has extraordinary properties and wide range potential applications in various industrial and domestic fields. For superhydrophobic, the water contact angle are greater than 150° and sliding angle less than 10° which providing superior water repellency and self-cleaning property (Satish et.al, 2013). The effect of superhydrophobic will be showed at Figure 2.3. Two approaches can be used to derive superhydrophobic surface where the first approach is the chemical enhanced between solid surfaces with a low-surface material. The other approach is the combination of Nano and micro-scale structures on the surface layer that make the surface to be completely not contact with water.

Figure 2.3: Superhydrophobic surface (Mark, 2004)

There are a lot of practical applications of superhydrophobic where it the coating surface acts as the protection to coated equipment or material from corrosion, contamination prevention and protection from other hazardous chemicals. For examples, superhydrophobic coatings are widely used in maritime industries. By applying superhydrophobic concept, the growth of unwanted microorganism on the hull of the ships can be prevented and the speed of ships can be increased at the same time the fuel costs will be reduced. Other than that, automotive industries also have been using the concept of superhydrophobic coatings where it is applied on the windshield of the cars to prevent water clogging. Besides that, in medical industries, surgical instruments are using the coatings because of their extreme resistance and anti-bacterial properties. As superhydrophobic coatings depend greatly on a delicate micro or Nano structure for their repellency functions, it will be easily damaged by abrasion or cleaning. Because of the problem, the coatings are mostly used for the electronics comp1nts which are not pr1 to wear. As the objects such as boat hulls require constant friction, it will be required constant reapplication of coating to maintain a high degree performance (Anonymous, 2016).

There were many experiments conducted based on superhydrophobic coatings. For examples, (Yuxuan et. al., 2016) had been conducted an experiment about the superhydrophobic ceramic coatings by solution precursor plasma spray. In this experiment, the coating technique to manufacture ceramic coatings rapidly and economically was present. The material used in this experiment was a rare earth oxide (REO) and stainless steel substrates by solution precursor plasma spray (SPPS) and the things investigated were various spraying condition that included standoff distance, torch power, number of torch passes, types of solvent and plasma velocity. As the results, a hierarchically structured surface topography was demonstrate and the angle of contact was determined where it showed that the contact angle on the SPPS superhydrophobic coating was up to 65% higher than on smooth REO surfaces. From the experiment, it was found that as the standoff distance decreased, the water contact angles and surface roughness will be higher. For torch power, the change in torch power effect the coating thickness and water contact angle.

Other than that, (Hai et.al. 2013) had been experimenting about the formation of superhydrophobic biomimetic coating upon raw corroded steel surface. This experiment was conducted to study about the superhydrophobic biomimetic coating that was coated upon raw corroded steel surfaces by chemical modification. Different types of corroded conditions were utilized with the micro scale feature of the superhydrophpobic biomimetic coating. The formation of biomimetic coating that was bonded chemically with the steel surface was showed by spectra of Fourier. This superhydrophobic coating was studied so that it can be applied for the anticorrosion of pipelines in the future.

2.2.2 Lotus Effect

‗Lotus concept‘ that had been introduced in 1992 was inspired by the lotus leaf properties because it has the superhydrophobicity and self-cleaning properties of plant surfaces and suitable model for technical analogues. Lotus or their scientific name Nelumbo Nucifera is a semiaquatic plant and develops palate leaves up to 30 cm in diameter with remarkable water repellency (Hans et. al., 2011). Remarkably, despite being exposed constantly to dust, dirt, rain and other element, the leaves of the lotus plant always remain clean and dry. This is because there are nanometer-sized waxy bumps on the surface of each leaves that prevent water and dirt from adhering to the surface of the lotus leaves. The dirt and water will always suspended on top of the bumps because of the size of valleys between the bumps are too small. A lot of surface tension is created on top of the surface of the bumps (Jeanne, n.d).

Generally, water is a polar molecule where it always been stick or pull on other water molecules. The attraction between molecules causes them to bead up on a surface of the lotus leaves. Each molecule inside a drop of water is being pulled in every direction by all the other water molecules that are in surrounding. However, water molecules are being pull 1 way on the surface that make it form back 1 drop of water. Surface tension created as the water molecule pulled back inwards towards the center of the drop. Instead of becoming flat, the water makes the drop. Normally, only the top of the water drop will be affected by the surface tension and not the bottom of the water drop where it will stick to the surface of material. But, as the lotus leaves has nanoscales bumps on the surface, the drop of water is almost entirely surrounded by air and not touching the surface of leaves. It makes the drop of water to roll smoothly off taking the dirt particles with them makes the leaves self-cleaning (Jeanne, n.d). The lotus leaves and the surface morphology will be showed at the Figure 2.4.

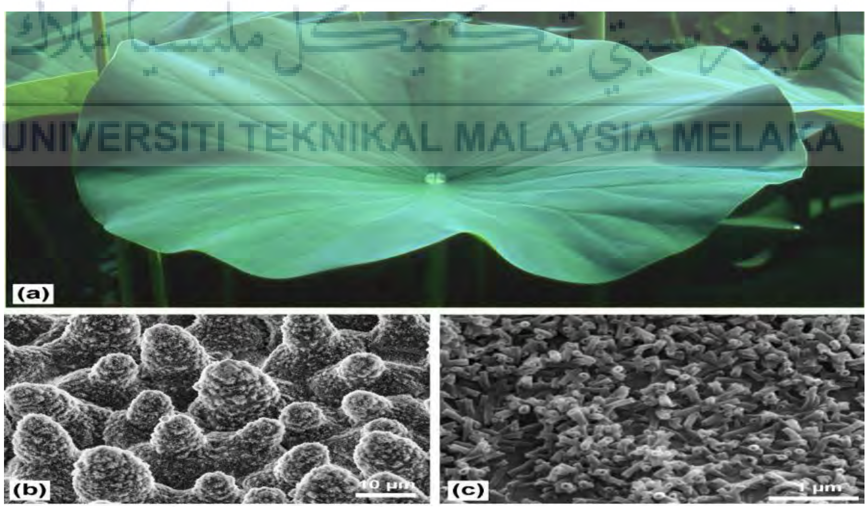


Figure 2.4: (a) Lotus leaves, (b) SEM image of hierarchical surface structures of lotus leaf, (c) Wax tubules on upper leaf side (Jean,n.d)

For hierarchical structure, lotus leaves has higher contact angle which are 150°. It has been known that lotus leaves has structure that induces strong water repellency. This is because the surfaces of the lotus leaves are covered with particular wax crystal that are water repellant and as the epidermis has additional structures such as papillae or hairs enhanced the features (Hans et al, 2011). Because of their feature, there were some engineers that have been duplicated this _nano-mountain‘ structure in a product that was called as Lotusan© paint. The painted was used in painting the building and the buildings self-clean every time it rains. The surface of building also always stays dry due to the effect of lotus leaves. Materials with bumpy surfaces also had been studied and created by scientist to mimic the features of lotus leaves. There are applications that used the lotus effect. For examples, self-cleaning windows, non-stick medical instruments to avoid blood clots and also kitchenware that can simply be rinsed and reused (Jeanne, n.d).

To fabricate the coatings based on the lotus effect, facile and general methods had to be generated. For the traditional method, there are various method of fabrication such as lithography, etching, plasma treatment and electro spinning. For etching process, it is restricted to special materials while plasma treatment requires special facilities. The method of electro spinning produced weak coatings. Therefore, superhydrophobic coating that was formed by using particles on complex shapes is attractive. However, additional post-modification with hydrophobic compounds is required to create the hydrophobic performance (Haili et al, 2015).

2.2.3 Wettability and Contact Angle

Wettability of a surface or material can be measured. one of the ways to measured it is by contact angle. The definition of wetting is the study about the ability of water to form boundary surfaces with the solid states. It had been studied before whereas the contact angle decrease, the wettability will increase. Wettability is divided by two categories which are a wetting liquid where the contact angle form is smaller than 90º and a non-wetting liquid that creates a contact angle of water between 90º and 180º (Keren, 2015).

Contact angle is the measurement of the angle of a surface contact that created by liquid with solid surface or capillary walls of a porous material. The properties of solid and liquid will determined the angle besides the interaction and repulsion forces between solid and liquid and also by the three phase interphase properties which are solid, liquid and gas. The intermolecular forces of cohesion and adhesion are describing the interaction of solid and liquid. The contact angle of the contact between solid and liquid will be determined by the balance between the cohesive forces of similar molecules such as between the liquid molecules which are hydrogen bonds and Van der Waals forces. Other than that, it also will be determined by the adhesive forces between dissimilar molecules such as between the liquid and solid molecules which are mechanical and electrostatic forces. Contact angle in traditional definition is the angle of liquid creates when it deposited on the solid or liquid surfaces. Contact angle also have a less traditional definition where the angle of a liquid creates when it rises at the sides of capillary to create a meniscus. When the cohesive forces are weaker than adhesive forces, the contact angle will be smaller as the molecules of liquid have a tendency to interact more with solid molecules rather than liquid molecules. This behavior shows the hydrophilic surfaces. However, when the cohesive forces are stronger than adhesive forces, the contact angle will be larger as the liquid molecules have a tendency to interact more with each other rather than solid molecule. This shows hydrophobic surfaces (Keren, 2015). Figure 2.5 will showed the contact angle for hydrophobic and hydrophilic.

Figure 2.5: Hydrophobic and hydrophilic (Keren, 2015)

The topic regarding wetting and contact angle has received tremendous interest from both fundamental and applied points of view. There are many application related to wetting and contact angle in industrial processes. For examples, oil recovery, lubrication, liquid coating, printing and spray quenching. Due to the potential application of hydrophobic surfaces such as in self-cleaning, Nano fluidics and electro wetting, the study of wetting had been increased. To measure contact angle, two main groups of the techniques has been classified which are direct optical method and the indirect force method. A few examples of method used for contact angle measurement are direct measurement by using Telescope-Goniometer, captive bubble method, tilting plate method, Wilhelmy balance method, capillary rise at a vertical plate, individual fiber, capillary tube, capillary penetration method for powders and granules and capillary bridge method. Each method can be used to measure the contact angle (Yee and Lee, 2013). The illustration of contact angle will be showed at Figure 2.6.

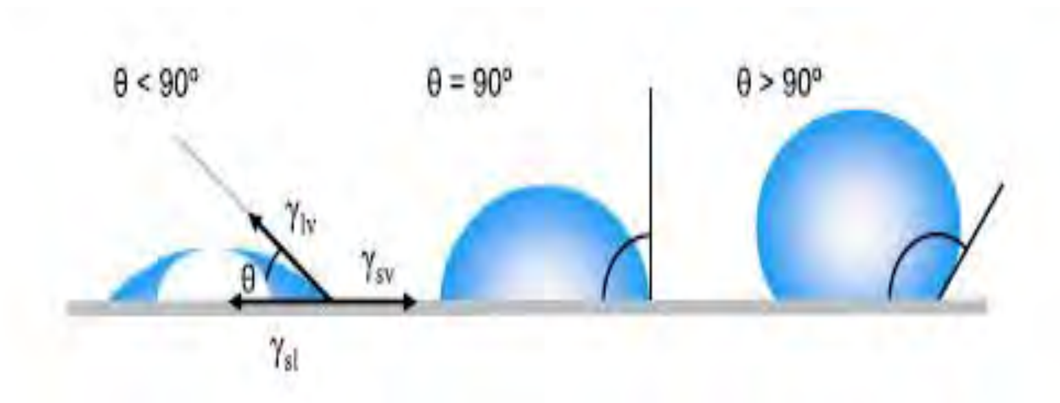


Figure 2.6: Illustration of contact angles formed by sessile liquid drops on a smooth homogeneous solid surface (Yee. Et.al, 2013)

2.3 Factor Effecting Hydrophobicity

There are many factors that will be affecting hydrophobicity contact angle and wetting behavior of solid particles. They can be influenced by many physical and chemical factors. For examples, thickness of coating, surface roughness and heterogeneity as well as shape and size. There were many efforts to study and examine the correlation between these factors and surface wettability. This paper will be reviewed about the effect of thickness of coating to hydrophobicity and the effect of surface roughness. Depending on the many experimental conditions, it was difficult to measure the meaningful contact angle values as such values are reliant on careful experimental control. From this review, it was concluded that as the surface roughness increase, the contact angle for hydrophobic materials increased.

2.3.1 Surface Roughness

Surface roughness is one of the important criteria that will evaluate the hydrophobicity. Hydrophobic phenomena have a tendency on depending on surface tension and surface roughness. The study from researches shows that hydrophobicity is directly proportional to the roughness of coating layer. So, as the surface roughness increase, the hydrophobicity will also increase (Wael et. al, 2015). Roughness structures in the micro and nano-ranges are importance for implementing the desired functionalities. There have been many papers had been writing and published about hydrophobic and superhydrophobic surfaces (Luisa, 2011).

The effect of surface roughness on hydrophobicity can be explained by the Wenzel and Cassie/Baxter theories where they have been studied about it. According to Wenzel, high adhesion forces obtained when the droplets of water have been in contact with rough surface and demonstrated high sliding angle when tilted. By using eqn. (2.1) which is Young's equation, the surface roughness factor (r), and a ratio of total surface area to projected surfaced area was introduced (Kantesh et. al, 2015).

$$\text{Cos } \Theta_c = \frac{\gamma_{sv} - \gamma_{sl}}{\gamma_{lv}} \tag{2.1}$$

This equation shows the correlated the intrinsic contact angle Ɵ where it is the angle of contact of a smooth surface with the solid-vapor, solid-liquid and liquid-vapor interface tensions. As the three phase intersection line tension of the tiny droplets may be crucial, the

Young's equation had been modified as the equation (2.2). This is also because the equation can only be used for the smooth surfaces, not the rough surfaces (Quanshui and Cunjing, 2014).

$$\text{Cos } \Theta' = \frac{r(\gamma_{sv} - \gamma_{sl})}{\gamma_{lv}} = r \cos \Theta_c \quad (2.2)$$

By analyzing the equation, it can be concluded that if Θ is smaller than 90°, the roughness decreases the apparent contact angle that is Θ' is less than Θ_c and as the Θ is higher than 90°, the roughness will increased apparent contact angle that is Θ' is higher than Θ_c (Kantesh et. al, 2015). As the surface become rough, the droplets of water had been attached to the surface but corrugations, it allows air pockets to be trapped under it.

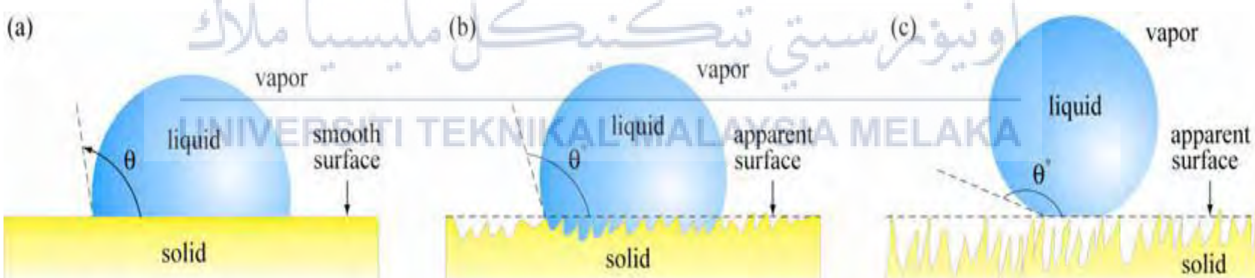


Figure 2.7: A droplet resting on (a) a smooth surface, (b) a small rough surface in normally the Wenzel wetting state, and (c) a large rough surface in normally the Cassie/Baxter wetting state. (Kantesh et. al, 2015)

Cassie/Baxter's model had been explained that droplets of water can easily roll off from the surface and having low sliding angle. It also explained that the water droplets rest on the heterogeneous surfaces composed of two different materials and adapts a non-contact mode. It also had been represents in an equation (2.3).

$$\text{Cos } \Theta' = f_1 \cos \Theta_1 + f_2 \cos \Theta_2 \quad (2.3)$$

In this equation, f_1 and f_2 are the surface area fractions of the two materials which are air and the base. The Θ_1 and Θ_2 are representing of the contact angles. As the air is present between the two hills of the surface, therefore, the water droplets subtend a contact angle of 180° in air. So, the equations had been modifying as follows in equation (2.4) and equation (2.5).

$$\text{Cos } \Theta' = \text{f} \cos \Theta_c + (1 - \text{f}) \cos 180° \quad (2.4)$$

And then becomes

$$\text{Cos } \Theta' = \text{f} \cos \Theta_c + \text{f} - 1 \quad (2.5)$$

It shows that as the area of fraction decreased, the contact angle will increased. It shows that, as the surfaces become rough, the contact angle also will be increased.

2.3.2 Thickness of Coating

Thickness of spray coating is one of the important criteria that can be used to determine the hydrophobicity. From the early research, it shows that a plot of the thickness of the overhang has a function to static, advance, and receding the contact angles. It was revealed that as the thickness of spray coating increased, the contact angle will decrease and the sliding angle will increase (Hong et. al, 2012). From the other experiment also, it shows that the water contact angle will decrease as the thickness of coating increase as the time for the contact angle drop through the microscopic pores of the coating.

Francesco et al (2015) was explained in their experiment where the ripple height values decreased as the film thickness increase. The ripple height also can be interpreted as the surface roughness. As the film thickness increase, the surface roughness will decrease. So, the thicker the thin film will decrease the contact angle. The theory of Kirchoff‘s Love also observed in this experiment and it based on the observation, the microstructural height decreased as the film thickness increased. The example graph of film thickness against contact angle is showed at Figure 2.8.

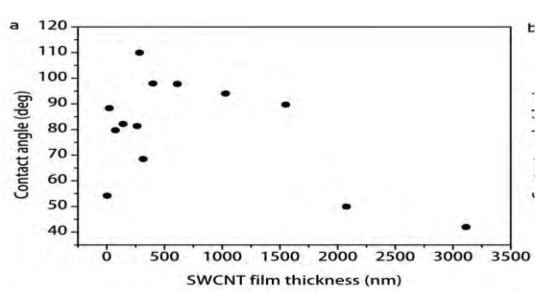


Figure 2.8: The graph of SWCNT film thickness against contact angle Francesco et al (2015)

2.4 Structural Characterization Utilizing

2.4.1 Portable digital microscope

Contact angle measurements are important in determining hydrophobicity. Contact angle will be measured by dropping droplets of water on the coating surface of the specimen. So, portable digital microscope was used to capture the image of droplets water and the angle of contact angle between specimen and water will be measured by using the image that been transferred to the computer. Portable microscope is a small, portable, inexpensive and easy microscope that attached with the light emitting diode (LCD) display (Anonymous, n.d). It can be connected directly to a PC where it allows to observe, capture, record and measure the real time image because of the supplied of software on the PC. So, immediate inspection on the image can be made as data from the microscope can be transferred at the fast rate. For this project, the microscope used was Panrico‘s USB3.0 digital microscope. The specifications of the product are as follows. The software of the product only allowed for the Windows7 and Windows8 users. The maximum resolution for the microscope is 8M pixels while the magnification rates are between 5x to200x. There are 8 LEDs adjustable lightening for the product. The power consumption needed for the microscope is less than 2.5 Watts. The advantages of the microscope are its 5Gbits bus bandwidth guarantees the fast data transfer rate and the microscope provides best image performance as the image sensor of the microscope has the high resolution and backside illumination pixel architecture

(Panrico,2013). Andrew (2016) stated that the portable microscopes usually mean a compromise on image quality, but for field use, it needs the instruments that can provide the detail and resolution needed for definitive diagnosis with large, sensitive and resource-intensive. For the microscope, the optical head that houses the lens and camera is rigidly supported over the stage and the bottom of illuminator (Andrew, 2016)

Figure 2.9: Panrico's USB3.0 digital microscope (Andrew, 2016)

2.4.2 Light microscope

For the project, it is important to observe the surface of the specimens. So, to observe whether the surface has the coarse or smooth surface, light microscope is one of the instrument that can be used. There are many different types of light microscope for examples, upright microscope, inverted microscope and stereomicroscope (Alan, 2007). Light microscope basically is the instrument that provides the enlarge view that helps in examining and analyzing the image of the specimen. The magnified image produced when a combination of 1 or more lenses used where the visible light transmitted through or reflected from the sample through the lens. (Douglas, 2001) stated that light microscope also called as compound light microscope where the word compound refers to the two lenses involves which are objective lenses and the eyepiece (or ocular); that are combined to produce the final magnification M of the image that will be shows in Equation (2.1).

$$M_{final} = M_{obj} \times M_{oc}, \quad (2.1)$$

There are three main parts for light microscope which are mechanical part, magnifying part and lastly illuminating part. Mechanical part consist base, c-shaped arm and stage where they are used to support and adjust the parts when taking the image. It is important to make sure the image captured clear and sharp. Then, the magnifying part consists of objective lens and ocular lens and that part have the responsibility to enlarge or magnify the specimen image. Lastly, the illuminating part consists of sub stage condenser, iris diaphragm and light and they are used to provide light.

Figure 2.10: Example of light microscope (Douglas, 2001)

2.4.3 Profilometer

The surface of the specimen can be measured to determine the roughness of the surface of the specimen. To measure the roughness of surface, profilometer or surface tester is 1 of the instruments that can be used. For this project, portable profilometer was used in order to measure the roughness of the specimen. Surface texture is the repetitive or random deviation from the nominal surface that forms the three dimensional topography of the surface. There are many things included in surface texture such as roughness (nano- and microroughness), waviness (macroroughness), lay and flaws. The fluctuation in the surface of short wavelengths forms nano- and microroughness. In the production process, the features of nano- and microroughness intrinsic. The surface irregularities that have longer wavelength are waviness and referred as macroroughness. Other than that, lay is the principal direction of the predominant surface pattern and usually are determined by the production method. Lastly, flaws are simply the unintentional, unexpected and unintentional interruption in the texture (Bharat, 2001). For this project, the Portable Surface Roughness Tester - TR200 used to measure the roughness of the surface of the specimen. Some of the features of the profilometer are graphical display on large LCD, have 13 different roughness parameters which are Ra, Rz, Ry, Rq, Rt, Rp, Rmax, Rm, R3z, S, Sm, Sk, tp, data output RS232 to optional printer TA220 or PC and excellent battery power with Li-Ion technology. Some of the technical specifications of the portable surface roughness tester TR200 are detector stylus position indicator, battery level indicator, direct display of parameters and profiles, LCD brightness adjustment, auto-off after 5 minutes with auto-store and calibration trough software (each cut-off) (QII, n.d).

Figure 2.11: Portable Surface Roughness Tester - TR200(QII, n.d)

CHAPTER 3

METHODOLOGY

3.1 Overview

This chapter will explained about the step in conducting the experiment where each step from material description until the testing will be explained. The step will start from material description and will be followed by sample preparation to conduct the experiment. In this step, the process of dimensioning, fabricating, spray process and grinding process will be explained. Next, the testing that will be needed in getting the results also will be explained where the test of measuring the contact angle, observing the surface of the specimen by using light microscope and lastly measuring the roughness by using portable profilometer/ portable surface roughness tester.

3.2 Material Description

All the materials used in this project are including aluminum with coating plat, copper plat, stainless steel, sand paper, aerosol, lacquer and acet1. The sand papers used in this project were 180 grit, 360 grit, 1200 grit and 2000 grit.

3.2.1 Aerosol

An aerosol is a gaseous suspension that is hanging into air of solid or liquid particles. It also refers to the dispenser or package used to change the ingredient inside the container into an aerosol. It is the combination of a paint and gas propellant. The spray paint used in this project was ANCHOR spray paint with light blue color. The spray paint is quick drying hi-build lacquer. The spray had a function as a coating on the surface of the aluminum plate.

Figure 3.1: Light blue spray paint

3.2.2 Lacquer

Lacquer is a product that is a solvent-based. It is a mixture of volatile solvents that had nitrocellulose with plasticizers and pigments dissolve together. It form high gloss surface as it contains a solution of shellac in alcohol that creates a synthetic coating. For this project, the lacquer used is 496 HS clear coat. It is a crystal clear and have high gloss coat from 2K acryl system.

Figure 3.2: Crystal clear lacquer

3.2.3 Sandpaper

Sandpaper is an abrasive material that is used to rub on the surface of woods, metals, plastics and also glass. It has the function to smoother the surface and also to make the surface rougher. The few the grit of the sand paper, the rougher the sand paper. In this project, the grits of the sand papers used are 180 grit, 360 grit, 1200 grit and 2000 grit. The sand papers were chosen to have a big different grit to differentiate the surface roughness from coarser to smooth.

Figure 3.3: Sand paper

3.3 Sample Preparation

3.3.1 Dimensioning

For the first step, the specimens' plat of aluminum with coating, copper and stainless steel for the project had been dimensioning. The plate with thickness was chosen as it was not too thick and thin. The plate had been dimensioning with the 20 mm × 20 mm × 2 mm where it has the width and height of 20 mm and thickness of 2 mm. in a simple words, the plate had been dimensioning as square size to make it easy to fabricate.

3.3.2 Fabrication

3.3.2.1 Cutting Plat Process

The fabrication of the aluminum started with cutting the aluminum, copper and stainless steel by following the dimensions which were 20 mm × 20 mm. To cut the specimens plate, the shearing machine was being used. The shearing machine had been operated manually where the foot used to cut the plat. The specimen are placed at the table with the arms support to hold the plat, stops and guided to secure the plat so that the plat were always in position and not moving when the shearing process performed. After that, the foot used to cut the plat where foot was used to apply force to make the upper blade moves downward. The plat was placed in between the upper and lower blade. When the blade forced together, the plat was cut.

Figure 3.4: Example of sample with dimension (20mm × 20mm × 2mm)

3.3.2.2 Spray Process

After the plate had been cut, the next step was sprayed the surface of the aluminum plate with aerosol and lacquer. The first step before the plate had been spray was cleaning step. For this step, the surface of the aluminum plate was cleaned by using acet1. The purpose of cleaning the surface are to ensure the surface is free from the dirt or grease. A clean, dry surface is necessary prerequisite for adhesive bonding because the unclean surface makes the structural adhesive hard to penetrate through the surface contaminants. After the cleaning process, the plat had been left until it dried. Next, the aerosol had been sprayed on the surface of the plate. All samples of aluminum plate had been sprayed by one layer of polymer spray coating. Then, the plate had been left to let the spray coating to dry for about 10 minutes. After it dried, half of the aluminum samples from the samples that were sprayed earlier were taken to spray again to make the coating on the surface of sample as two layers of spray coating. Then, the last step for the spraying process was sprayed all of the samples of 1 layer and 2 layer of polymer spray coating with lacquer. For lacquer, it only needs to be sprayed a layer on the surfaces of all the samples of coating.

3.3.2.3 Grinding Process

For grinding process, there were two ways of grinding before the specimens undergoing the next step which was measurement of contact angle. For the first method, different specimen were used when the sand paper grit different while for the second method, the same specimen used for the grinding process which the process will start with 180 grit sand paper followed by 360 grit, 800 grit and 2000 grit. The first step for the first method started with divided the aluminum plate samples into four boxes to make an each box had consists of 16 samples of a layer of aerosol and 16 sample of two layer of aerosol. Then, the sand paper was been prepared which were 180 grit, 360 grit, 800 grit and 2000 grit. The sand paper was chosen with very big different grit to differentiate the surface roughness which was from the coarser to the smooth surface. The process of grinding started by wetting the sand paper with water before grinded the specimen with the 180 grit of sand paper. 8 samples of the aluminum plate where the 4 samples with a layer of spray coating and 4 other samples with two layer of spray coating were been grinded. The speed of the machine was set at 50 rpm.

Each of the samples had been grinded and polished for about 10 seconds. After the specimens grinded with 180 grit sand papers, the sand paper was change with the 360 grit, 1200 grit and 2000 grit and followed the same step as the 180 grit.

Figure 3.5: The process of grinding/polishing

For the second method, the grinding process started by grinding the aluminum with coating, copper and stainless steel by using 180 grit sand paper. The process of grinding were as same as the first method. The only different between the two methods was only the specimens used where in this second method, the same specimen were used rather than changing the specimen when the grit of sand paper different. The process starts with the 180 grit sand paper. After the specimen grinded, the specimens were taken to measure the contact angle. Then, the process of grinding started again with the 360 grit, 800 grit and 2000 grit on the same specimens. For this method, the sand paper was not wet by water to get coarser surface.

3.4 Testing

3.4.1 Contact Angle

The process of measuring the contact angle is important to determine the hydrophobicity. The process started by dropping 5 µl droplets of distilled water at the surface of the specimen by using digital pipette. The pipette was set to drop only 5 µl of water. Then, by using the potable digital microscope, the images of the droplets of water were taken and transferred to the PC by using the software. The digital microscope was adjusted to be parallel with the droplets of water so that the angle of contact between the water and surface can be measured. The specimen firstly was placed on the stage at the test rig. After the water drop, the focus point on the digital microscope had to be adjusted where there was a roller at the digital microscope that need to be adjusted until the image was sharp and clear. Then, the magnification rate that showed on the roller need to be input on the software at the PC. After that process, the image was captured before the value of contact angle measured by using the software. The angle is generally the angle between a tangential to the liquid surface at the line of meeting three phases and the plane of the solid surface on which liquid resides or moves.

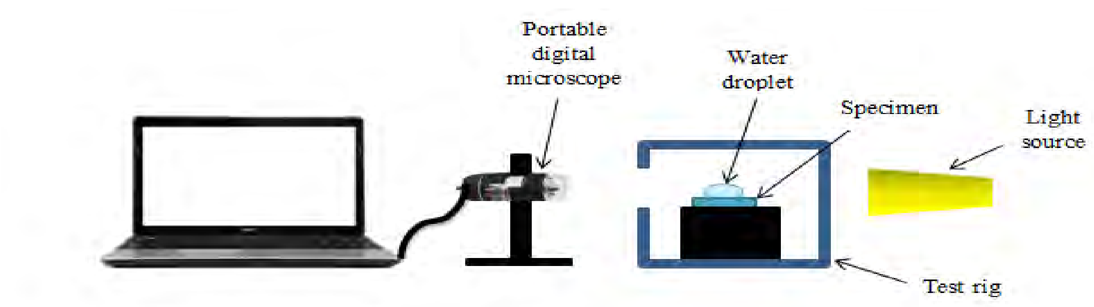


Figure 3.6: Set up apparatus for contact angle measurement

3.4.2 Surface Morphology/Profile

Surface morphology/profile will be observed by using light microscope. This is to observe the different surface morphology when different grit of sand paper is used as the different grit will show the different surface morphology. The specimens were sent to be observed by the light microscope after the contact angle measured. This is because; the observation of the surface of the specimen was at the point where the highest value of contact angle. The specimen was put at the mechanical stage of the microscope and the adjustment of the position of the specimen was made using coarse adjustment knob. Then, by using the fine adjustment knob, the adjustment to fine tune the focus on the specimen was made to get clearer and focus image. After that, the objective lens of 10X chosen before the image of the surface of the specimen captured then transferred to the PC.

3.4.3 Roughness

The last testing for the project was measuring the roughness of by using the portable profilometer. When the roughness of the surface of specimen measured, the specimen is placed under the sensor where it was in the form of built-in probe of the profilometer. Then, the sensor was slides uniformly along the surface of specimen by driving the mechanism inside the instrument. The results for roughness of the surface of specimen then were displayed. The process of the measurement of roughness started with switched on the profilometer. Then, clear the surface of the specimen that needs to be measured. After that, the sensor was put in vertical position to the direction of process line of the measured surface. The measurement of the roughness then was displayed.

Figure 3.7: Example of roughness measurement

CHAPTER 4

RESULTS AND ANALYSIS

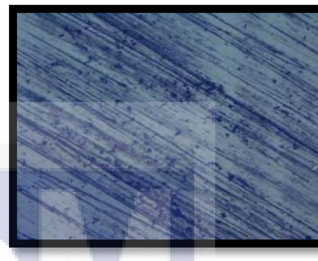
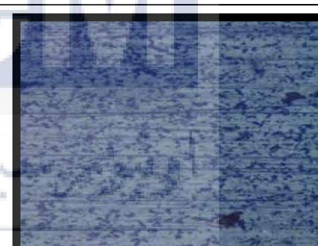
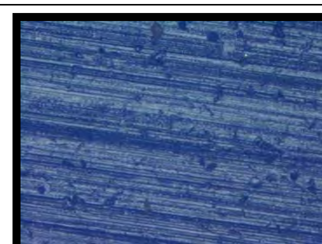
4.1 Results

There are two method used to differentiate the sample surface roughness when measuring the contact angle where for the first method, different samples were used for the different grit of sand paper. For this method, only the surfaces of aluminum with coating were used. The sand paper for the experiment in method one also was wet by using water before the grinding process. But, for the second method, the same sample was used for different grit of sand paper and the materials used for this experiment were aluminum with coating, copper and stainless steel. The grinding process was started by using 180 grit sand papers followed by 360 grit, 1200 grit and 2000 grit respectively. The sand paper for the second method was not wet by water. Then the surfaces of the samples were observed under the light microscope. The roughness with a mean Ra (arithmetic average of absolute values) of the surfaces also was measured by using profilometer.

4.1.1 First method

4.1.1.1 One layer spray coating

Table 4.1: Image of contact angle and surface of one layer spray coating

SAND PAPER GRIT	CONTACT ANGLE	SURFACE MORPHOLOGY
2000 GRIT		
1200 GRIT		
360 GRIT		

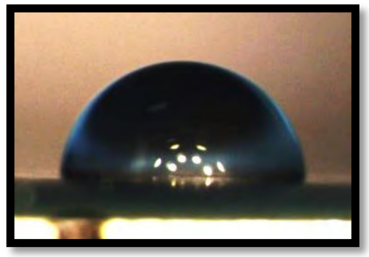
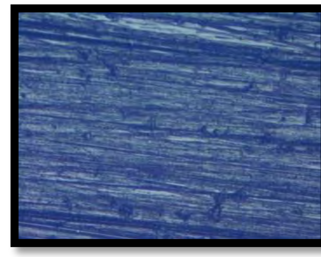
180 GRIT		

Table 4.2: Contact angle and roughness for one layer spray coating

SAND PAPER GRIT	**SURFACE ROUGHNESS (R_a)**	**AVERAGE CONTACT ANGLE (°)**	**STANDARD DEVIATION**	**UNCERTAINTY**
WITHOUT GRIT	0.097	71.67	4.38	0.98
2000	0.102	73.90	4.09	0.20
1200	0.185	75.27	2.74	0.61
360	0.880	81.60	2.05	0.46
180	1.061	86.14	1.71	0.71

4.1.1.2 Two layers spray coating

Table 4.3: Image of contact angle and surface of two layers spray coating

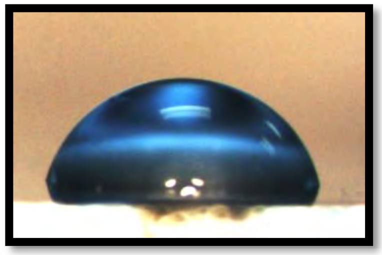
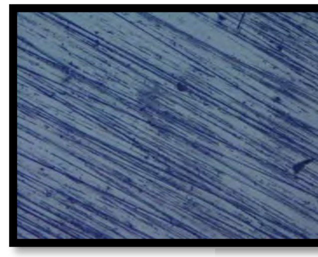
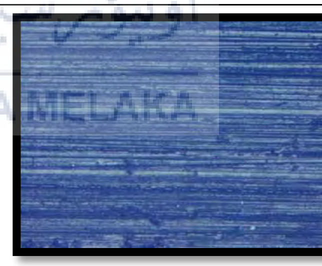
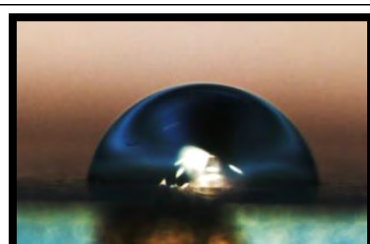
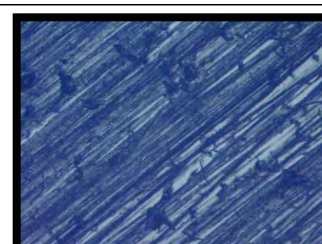
SAND PAPER GRIT	CONTACT ANGLE	SURFACE MORPHOLOGY
2000 GRIT		
1200 GRIT		
360 GRIT		
180 GRIT		

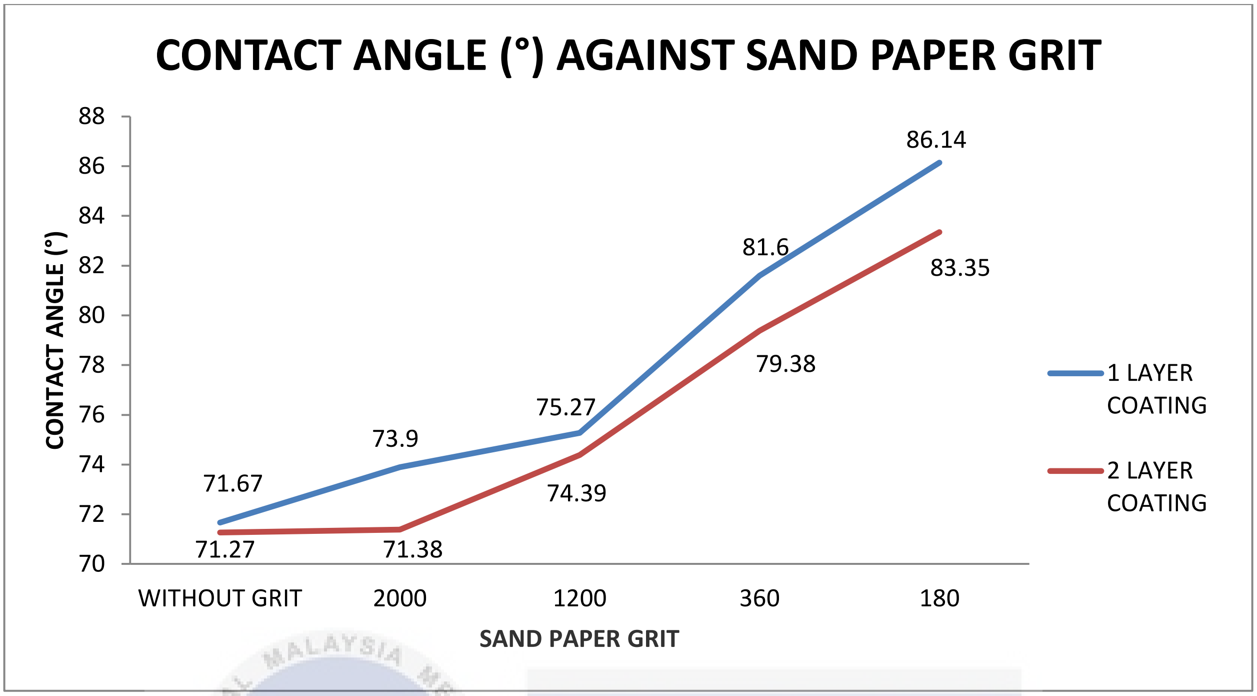
Table 4.4: Contact angle and roughness for two layers spray coating

SAND PAPER GRIT	SURFACE ROUGHNESS (R_a)	AVERAGE CONTACT ANGLE (°)	STANDARD DEVIATION	UNCERTAINTY
WITHOUT GRIT	0.083	71.27	3.19	0.71
2000	0.092	71. 38	2.93	0.66
1200	0.121	74. 39	2.75	0.61
360	0.806	79. 38	2.78	0.62
180	0.915	83. 35	1.69	0.71

4.1.1.3 Comparison between one layer coatings with two layer coating

Table 4.5: Comparison of contact angle between one layer coating and two layers coating

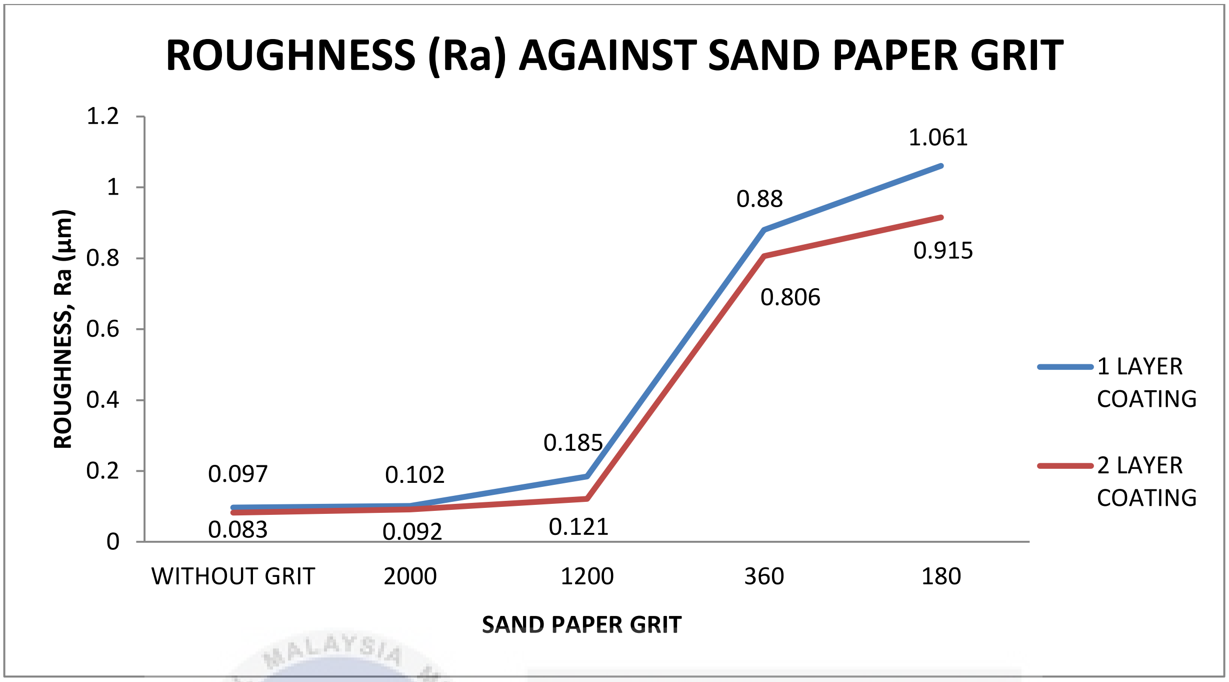
SAND PAPER GRIT	CONTACT ANGLE (°)	
	1 LAYER COATING	2 LAYERS COATING
WITHOUT GRIT	71.67	71.27
2000	73.90	71. 38
1200	75.27	74. 39
360	81.60	79. 38
180	86.14	83. 35



Graph 4.1: Comparison of contact angle between one layer coating and two layers coating

Table 4.6: Comparison of roughness between one layer coating and two layers coating

SAND PAPER GRIT	ROUGHNESS, R_a (µm)	
	1 LAYER COATING	TWO LAYERS COATING
WITHOUT GRIT	0.097	0.083
2000	0.102	0.092
1200	0.185	0.121
360	0.880	0.806
180	1.061	0.915



Graph 4.2: Comparison of roughness between one layer coating and two layers coating

From Table 4.2 and Table 4.4, the effect of surface roughness on the contact angle can be seen where the contact angle for both thickness of coating increase as the surface roughness increase. The results were demonstrated on the Graph 4.1. Sand paper grit represented surface roughness. The smaller grit of sand paper, the coarser the surface. So, when the sand paper grit decreased, the surface roughness increased. 180 grit sand paper shows the highest value of contact angle where the value of one layer coating and two layers coating are 86.14° and 83.35° respectively. For the flat surface, the lowest value of contact angle showed where the value for one layer coating and two layer coating are 71.67° and 71.27° respectively. The roughness of the sample calculated also shows the trend of increasing the roughness will increase the contact angle. Then, the effect of thickness can be seen from Table 4.5 and Graph 4.1 where two layers coating shows the lower contact angle than 1 layer coating.

4.1.2 Second method

4.1.2.1 One layer spray coating

Table 4.7: Image of contact angle and surface of one layer spray coating

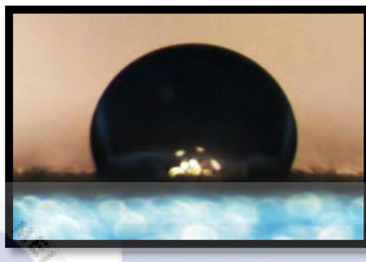
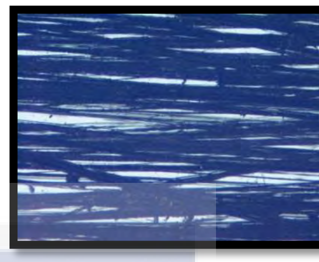
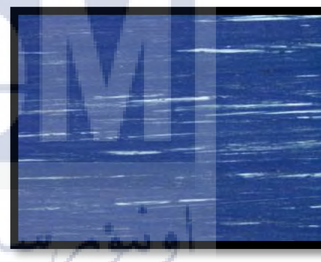
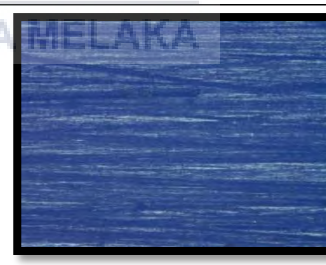
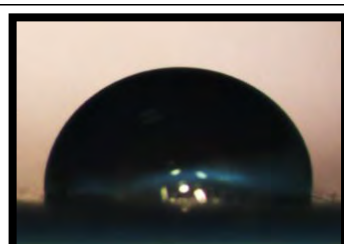
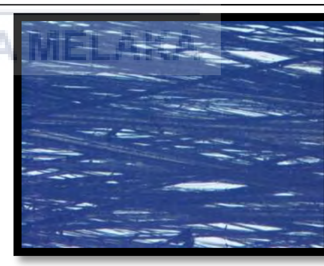
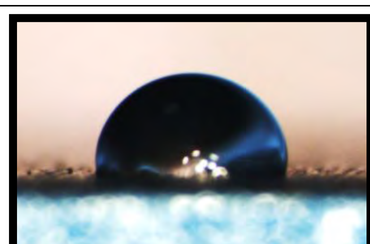
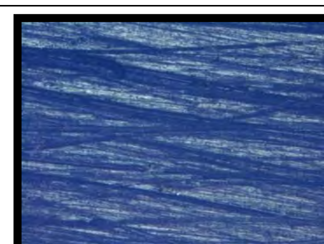
SAND PAPER GRIT	CONTACT ANGLE	SURFACE MORPHOLOGY
180 GRIT		
360 GRIT		
1200 GRIT		
2000 GRIT		

Table 4.8: Contact angle for one layer spray coating

SAND PAPER GRIT	AVERAGE CONTACT ANGLE (°)	STANDARD DEVIATION	UNCERTAINTY
2000	80.55	2. 39	0.98
1200	87.73	1.90	0.78
360	91.79	2.72	1.11
180	95.25	7.75	3.16

4.1.2.2 Two layers spray coating

Table 4.9: Images for contact angle and surface of two layers spray coating

SAND PAPER GRIT	CONTACT ANGLE	SURFACE MORPHOLOGY
180 GRIT		
360 GRIT		

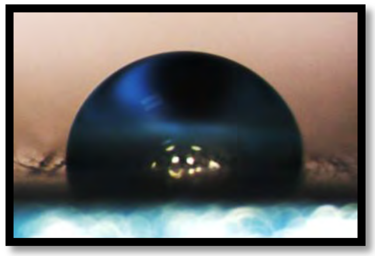
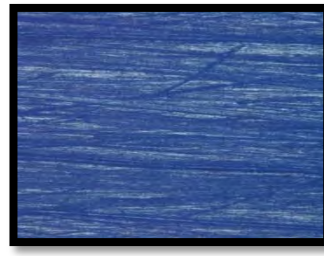
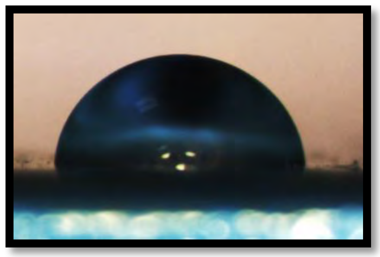
1200 GRIT		
2000 GRIT		

Table 4.10: Contact angle for two layers spray coating

SAND PAPER GRIT	**AVERAGE CONTACT ANGLE (°)**	**STANDARD DEVIATION**	**UNCERTAINTY**
2000	77.67	2. 38	0.97
1200	84.29	2.50	1.02
360	89.43	2.23	0.91
180	94.46	4.96	2.02

4.1.2.3 Stainless steel

Table 4.11: Images of contact angle and surface of stainless steel

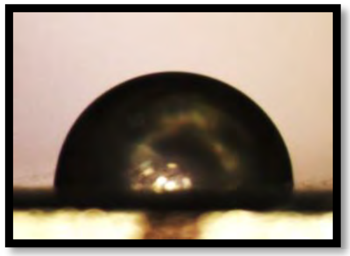
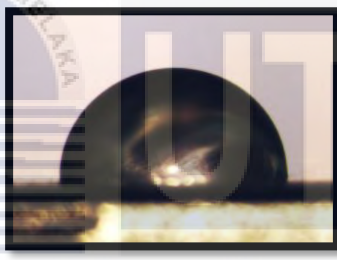
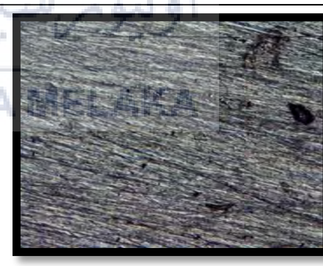
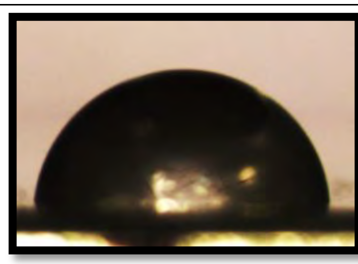
SAND PAPER GRIT	CONTACT ANGLE	SURFACE MORPHOLOGY
180 GRIT		
360 GRIT		
1200 GRIT		
2000 GRIT		

Table 4.12: Contact angle for stainless steel

SAND PAPER GRIT	AVERAGE CONTACT ANGLE (°)	STANDARD DEVIATION	UNCERTAINTY
2000	72.09	3.46	1.41
1200	78.58	2.73	1.11
360	78.95	1.71	0.70
180	79.13	2.35	0.96

4.1.2.4 Copper

Table 4.13: Images of contact angle and surface of copper

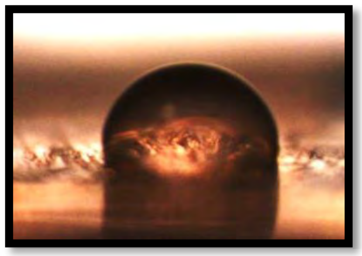
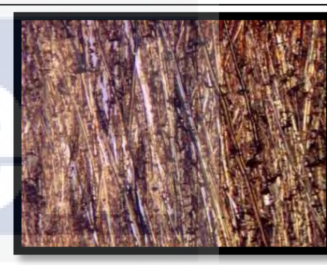
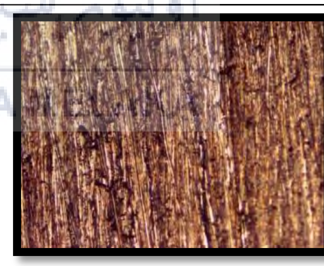
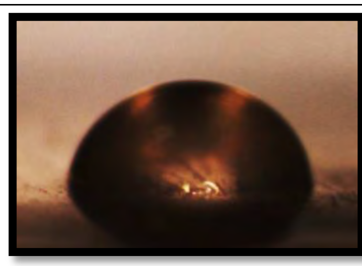
SAND PAPER GRIT	CONTACT ANGLE	SURFACE MORPHOLOGY
180 GRIT		
360 GRIT		
1200 GRIT		
2000 GRIT		

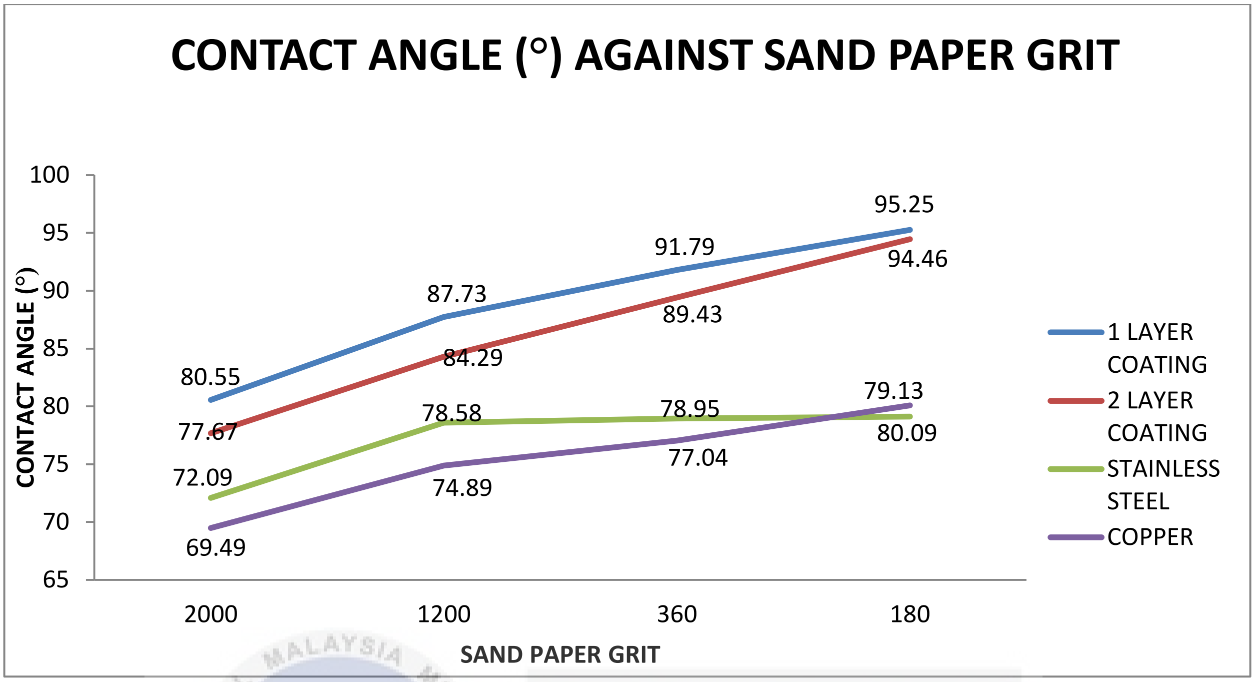
Table 4.14: Contact angle for copper

SAND PAPER GRIT	AVERAGE CONTACT ANGLE (°)	STANDARD DEVIATION	UNCERTAINTY
2000	69.49	3.45	1.41
1200	74.89	3.80	1.55
360	77.04	6.45	2.63
180	80.09	6.22	2.53

4.1.2.5 Comparison between all materials

Table 4.15: Comparison of contact angle for all materials

SAND PAPER GRIT	CONTACT ANGLE (°)			
	1 LAYER COATING (ALUMINUM)	TWO LAYER COATING (ALUMINUM)	STAINLESS STEEL	COPPER
2000	80.55	77.67	72.09	69.49
1200	87.73	84.29	78.58	74.89
360	91.79	89.43	78.95	77.04
180	95.25	94.46	79.13	80.09



Graph 4.3: Comparison of contact angle for all materials

From the second method, it showed that the trend of surface roughness increase will increase the contact angle followed by all the material. All of the results for the materials show that the higher surface roughness increased the contact angle. The materials of substrate are not affecting the trend of contact angle against surface roughness. But, the uncoated materials show that the contact angle not achieved hydrophobicity. Aluminum with coating shows the higher results of contact angle compared to uncoated stainless steel and copper.

4.2 Discussion

4.2.1 Effect of surface roughness

As the liquid or water spread on a solid surface which was the sample, the contact angle can be defined. When the equilibrium state reached when the water deposited on the sample surface, the water will be spread under gravity until the internal forces (cohesion) of the liquid, the gravity forces and the surface tension forces are in balance. After it balanced and achieved the equilibrium, the contact angle between the solid and liquid can be measured.

For the effect of surface roughness on the contact angle of hydrophobic coating, it shows from the entire table above that as the surface of the sample becomes rougher, the contact angle becomes higher. In this experiment, the sand paper grit represented the roughness of the surface of sample where the lower grit of sand paper grit, the coarser the surface. So, from the tables above, it shows that as the sand paper grit decreased, the contact angle increased. The roughness of the surface was calculated by using profilometer. The results showed that the higher value of R_a represented the higher of surface roughness. It also showed on the tables above for images of the contact angle that the contact angle between sample surfaces and the liquid increased as the sand paper grit decreased.

Compared to the surfaces which have flat surface which is without be grinding by using sand paper, the water contact angle was the lowest that was below than 75°, the rougher surfaces can achieved higher hydrophobicity. But, for the first method, as water used when the grinding process take place where the sand paper had been wet by water before the sample grinded, the contact angle was not achieved the hydrophobicity. This is because, the water presented make the roughness of the sand paper reduced. For the second method, the sand paper was not wet with water, and it can be seen that the contact angle for the aluminum with coating increased as the surface roughness increased and the surfaces grinded with sand paper grit of 180 grit achieved the contact angle of hydrophobicity for both aluminum with one layer coating and two layers coating. The comparison between the methods can be seen by using the example of the sample from 1 layer of coating for both method from table 1 and table 6 where the highest contact angle for the first method is only 86.14° while the highest contact angle for the second method achieved hydrophobicity which was 95.25°.

The rougher surface has higher contact angle because of the air trapped in the microstructures forms and additional barrier against water penetration. As the surface becomes rougher, the contact area between the particles and sample surface will becomes lesser and the contact area between particle and water drop increased which minimizes the adhesion forces. The rougher surface roughness also maximize the hydrophobicity because of the decreased of surface energy. It also makes the surfaces have the poor wetting which was high contact angle when the surface energy lowers. When the droplets of water drops on the rougher surface, there was numerous three-phase intersection lines the acted as the boundaries of wetted caps on the top of the roughness in the wetting area and there was coexist with the trapped air pocket. As there are air pockets trapped in between the peak to peak in rougher surface, the droplets of water were not absorbed in the space between the peaks that make the contact angle higher. Compared to the smoother surface, there will be less or no presence of air trapped that make the water droplets absorbed to the surface of the specimen then decrease the contact angle.

Other than that, the stability of hydrophobicity can also be one of the reason that affect the relationship between the roughness of the surface and contact angle. There were a few cases involve in hydrophobicity stability. In Cassie-Baxter state, the wetting condition was one of the requirements for achieving hydrophobicity as the lower the wetting, the higher the contact angle that make the hydrophobicity also increase. Firstly was the structural instability where when the surface had larger roughness, the pillar height (or slenderness) also increased. Then, as the larger slenderness increasing the structural instability, the wettability will also decrease. Other than that, there was the stability of hydrophobicity against pressure where in this condition; the scale of roughness was affecting the wet area faction then it the maximum pressure that can be withstand to maintain the droplets of water which were required for water repellency. So, as the contact angle increase, the wet area decreased that make the better hydrophobicity.

By conducting the experiment, it can be determined from the method 2 that the different of materials also were not affecting the trend of the increasing the surface roughness will increased the contact angle. It can be seen from the Table 4.7, Table 4.9, Table 4.11 and Table 4.13 where different materials were used which were aluminum with coating, stainless steel and copper. Even though the trend was followed, but copper and stainless shows that the contact angle of hydrophobicity cannot be achieved. The uncoated surfaces of copper and stainless steel shows poor results of contact angle compared to the coating surface of the aluminum where the contact angle for the 180 grit sand paper for each sample which were aluminum with one layer coating, aluminum with two layers coating, stainless steel and copper are 95.45°, 94.46°, 79.13° and 80.09° respectively.

4.2.2 Effect of coating thickness

For the effect of coating thickness, the comparison between the contact angle between the surface with one layer coating and two layers coating shown in Table 4.5 and Graph 4.3 where it can be seen that the contact angle for one layer coating was higher than the contact angle for two layers coating. For example, when the sand paper grit used was 180 grit, the contact angle for the one layer coating and two layers coating were 86.14° and 83.35° respectively. But, before the surface grinding with sand paper where the surface is flat, the thickness of the coating will not affect the contact angle where the contact angle for one layer coating and two layers coating were 71.67° and 71.27° respectively. From Graph 4.3, also, it showed that the copper and stainless steel without coating had lower contact angle compared to the aluminum with coating which had higher contact angle. The coating also was one of the reason that make the aluminum achieved the contact angle of hydrophobicity.

The results from the profilometer also shown that the R_a for the 1 layer coating thickness was higher than the R_a for the 2 layers coating thickness. As the value of R_a represented roughness of the surface, it can be concluded that the thickness of the coating was related to the roughness of the surface. The thicker the coating will decrease the roughness of the surface. The thickness of the coating also affects the ripple height. Ripple height also can be determined as the surface roughness. As the coating thickness increased, the value of ripple height will decrease which makes the contact angle decreased and increased the wettability. The reduction of coating thickness also reduced the water droplets from sample surfaces makes the contact angle higher which correlates with a higher surface roughness.

CHAPTER 5

CONCLUSION AND RECOMMENDATION

5.1 Conclusion

For conclusion, this project generally is about the preliminary study on effect of spray coating parameter on hydrophobic coating effect. The parameters studied in this project were thickness of coating and surface roughness of coating. The thicknesses of coating for this project were a layer of spray coating and two layer of spray coating thickness. Then, for surface roughness, four different grit of sand paper used to differentiate between smooth, medium and coarse. The effect of surface roughness on the different material also observed. From the researched, as the thickness of coating increase, the contact angle of the hydrophobic decreased. Then, the rougher the coating surface, the higher the contact angle of hydrophobic. Even though different materials used to study the effect of surface roughness, the results shows that the materials did not affect the trend of increasing the surface roughness will increase the contact angle of hydrophobicity. For the effect of thickness of coating that was studied on the aluminum plat, it shows that the thicker the thickness of coating will decrease the contact angle of hydrophobicity. The materials without coating showed the results of lower contact angle compared to the aluminum with spray coating which they are not achieving the hydrophobicity.

5.2 Recommendation

As in this research, the parameter that studied was only the effect of surface roughness and thickness of coating, for future research, there are many mechanical testing that can be studied and observed more in order to find the best experiment that can provide higher contact angle of hydrophobicity. Other than that, the influenced of different materials should be studied more details to be able to choose the best materials that can be used as the best hydrophobic material. The effect of hydrophobicity on the different material without coating also can be studied further in order to reduce the cost of coating the materials that need to undergo the testing.

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