DEVELOPMENT OF INNOVATIVE SELF-FABRICATE CONTACT ANGLE MEASUREMENT TOOLS FOR HYDROPHOBICITY ANALYSIS

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This report is submitted

In fulfilment of the requirement for the degree of

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DECLARATION

I hereby declare that this project report entitled “Development of Innovative Self-Fabricate Contact Angle Measurement Tools for Hydrophobicity Analysis” is the result of my work except as cited in the references.

Signature :

Name : MUHAMMAD SYAFIQ BIN ISKANDAR

Date :

APPROVAL

I have checked this project report that it is sufficient in term scope and quality for the award of the degree of Bachelor of Mechanical Engineering (Hons) and can be submitted to JK-PSM.

Signature :

Name of Supervisor : PROF. DR. GHAZALI BIN OMAR

Date :

DEDICATION

I would like to dedicate to my parent, my fellow friends and my supervisor, Professor Dr Ghazali Bin Omar their full support encouragement and inspired during this project.

ABSTRACT

Hydrophobicity is the physical property of a surface that avoid water. Basically, carbon and hydrogen atoms are the only molecules in the hydrophobic surface. This surface cannot interact favourably with water and repel water that make a contact with the surface. This property of the surface can be measured or classified by referring to the contact angle of the droplet on the surface. Contact angle is the most important criteria to analyse the wettability of the surface. Small contact angle is smaller than 90º it show high wettability, whereas large contact angle which exceed 90º correspond to low wettability. Contact angle can be describe as the angle formed by meeting of liquid with solid surface. The shape of the liquid drop to be measured as contact angle is determined by surface tension of the liquid. The purpose of this project is to develop an innovative contact angle measurement tools for the hydrophobicity analysis with low cost of manufacturing proses but get the high accuracy of the result. Since the previous product on market has high cost to buy it and also used advanced technology and advanced software which make users complex to handle the equipment. Furthermore the product is quiet big and stationary and only can be used in the laboratory only which is cannot be move from a place to another place. After complete the product, a few series of testing was conduct to test the accuracy of the result and compared with the previous study with high technology method. Then the result will validate using Minitab software to conduct the test for One Sample T Test and Normality Test for both samples.

ABSTRAK

Hidrofobiciti ialah keadaan fizikal suatu permukaan yang mampu menjauhi atau kalis air. Asasnya, hanya atom karbon dan hydrogen yang terdapat pada permukaan hidrofobik. Permukaan ini tidak bertindak balas dengan air dan menolak molekul air yang berada pada permukaan. Ciri permukaan ini boleh dikenal pasti dan diukur melalui cara mengira sudut titisan cecair dengan permukaan. Sudut titisan cecair ialah kriteria yang penting dalam menganalisis kadar kelembapan suatu permukaan. Jika sudut titisan cecair ialah lebih kecil daripada 90 ˚ maka ia menunjukkan kadar kelembapan yang tinggi, manakala sudut titisan cecair yang melebihi 90 ˚ menunjukkan kadar kelembapan yang rendah. Sudut titisan cecair boleh diterangkan sebagai sudut yang terbentuk apa bila cecair bertemu dengan permukaan pepejal. Bentuk cecair yang dikira sebagai sudut titisan ditentukan oleh tekanan pada permukaan cecair. Tujuan utama projek ini ialah untuk menghasilkan alat untuk mengukur sudut titisan cecair untuk tujuan hidrofobik analisis dengan mengunakan bahan yang murah dan berpatutan tetapi boleh memberikan hasil yang tepat. Disebabkan oleh produk yang berada dipasaran sekarang mempunyai harga yang mahal dan juga mengunakan teknologi yang termaju yang mampu memberikan kesusahan kepada pengguna untuk mengendalikan alat tersebut tanpa selian daripada orang yang bertanggungjawab. Selain itu alat itu juga hanya boleh digunakan didalam makmal sahaja kerana saiz yang besar dan berat untuk dialihkan dari satu tempat ke suatu tempat. Selepas menyelesaikan produk ini, beberapa siri kajian telah dijalankan untuk melihat sejauh mana ketepatan dapatan kajian daripada alat yang dihasilkan dan dibandingkan dengan kajian yang dijalankan dengan mengunakan alat yang berteknologi tinggi. Selepas itu keputusan eksperimen di sahkan dengan menggunakan Minitab software untuk menjalankan Ujian Satu Sampel T dan Ujian Normal.

ACKNOWLEDGEMENT

Alhamdulillah, all praise and thankfulness to almighty Allah S.W.T, The Most Gracious and The Most Merciful, the final prophet Muhammad S.A.W and his relatives, all his companions and those who have followed finally I have completed this Final Year Project.

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LED	=	Light emitting diode
DIY	=	Do It Yourself
CATIA	=	Computer aided three-dimensional interactive application
PC	=	Personal Computer

CHAPTER 1

INTRODUCTION

1.1 Background

The contact angle is the angle which is conventionally measured through the fluid, where the liquid-vapour interphase meets a solid surface. It quantifies the wettability of a solid surface by a liquid via the Young equation. A given system of solid, liquid, and vapour at a given temperature and pressure has a unique equilibrium contact angle. However, in practice contact angle hysteresis is minimal contact angle. The equilibrium contact is within those values and can be calculated from them. The equilibrium contact angle reflects the relative strength of the liquid, solid and vapour molecular interaction.

The hydrophobic coating is the earlier stage of water repellent coating before achieve a superhydrophobic coating. (Bhushan & Jung, 2011) states that hydrophobic is usually used to define the contact of a solid surface with any liquid. The surface will have low energy and build of non-polar molecules. The properties of hydrophobic coating can be improved to become a superhydrophobic are by increasing the surface roughness and lower the surface energy. The contact angle of hydrophobic coating is greater than 90º and lower than 150º so that make this coating have a good wettability properties (Kubiak & Mathia, 2014)

Superhydrophobic coating is inspired by the unique structure of the Lotus leaf refers to self-cleaning mechanism. The lotus effect is occurred only due to low energy surface topography with hierarchical morphology. A hierarchical morphology allows the formation of air pocket that reduced the contact area between an applied water droplet and the surface

(Mahadik,et al 2013). A superhydrophobic surface are water repellent with large water static contact angle above 150º and low sliding angle lower 10º .The superhydrophobic provides the surface with various used in many application such as self-cleaning, anti-biofouling, anti-icing, drag-reducing, and corrosion resistance.

There are many strategies that have been develop for coating technologies to aluminium and glass material to prevent it's from harmful effect of water and moisture in the environment. Aluminium is widely used in many industrial fields as a basic material because it's good properties in excellent thermal and electrical conductivity but poor in corrosion resistance. So that the aluminium with hydrophobic coating can improved the corrosion performance for the material.

The properties of hydrophobic and superhydrophobic coating such as contact angle, surface morphology and its oxidation can be analysed on the substrates temperature of the thin film hydrophobic coating. The main criteria for hydrophobic coating to protect the coating from undergoes oxidation and resistance to the corrosive is high temperature resistance.

The ideas come out after a few testing done by manually drop by hand is quite tough and take a few time for the next drop let can be put. With the automatic tools we can run the test just by pressing the on off button and it is reduces time wasting. The measurement tools sure can be functional like the advanced technology tools but we just make it as portable and easy to used but the result will be same.

1.2 Problem Statement

Superhydrophobic and hydrophobic coating has the application of water proofing, self-cleaning, anti-corrosion and anti-icing. These hydrophobicity concepts have been applied in textiles, paints, electric devices, automotive industry and car glass. In order to check the hydrophobicity we need to measure the contact angle of the specimen. For liquid moving quickly on the surface, the contact angle can be altered from its value at rest.

Contact angle measurements are often used to estimate surface and liquid cleanliness and the effects of surface treatment developed as a part of fundamental research in surface science as well as for industrial applications. The advancing contact angle will increase with speed, and the receding contact angle decrease. In industry there are many method that have been develop but all of those method using expensive and high cost of testing tools. The product also stationary and complex to handle by the beginner. So we need to develop the measurement tools which is using the low cost but have high efficiency in order to measure the contact angle.

1.3 Objective

The objectives of this project are as follow;

i. To develop an innovative and portable contact angle measurement equipment tools for hydrophobicity analysis with low-cost manufacturing process and easy to handle.
ii. To verify and validate the measurement data accuracy of the contact angle using Minitab Software.

1.4 Scope

The scope of the study is the development in order to measure the contact angle with lower cost of equipment. The development on tools is made by low cost of material but the result is efficient for the measurement and also self-fabricate manufacturing process. The specimen is based on the type of surface which in different roughness which is lotus leaf and silica carbide.

1.5 General methodology

The working procedures that need to be done to achieve the objectives are listed below

1. Problem statement

The problem will be analysed and investigated to find the best solution in the project to get the better result and finding.

2. Literature review

Review the article, journal, finding on internet and older experiment to get the information about the project

3. Design product

The stage and box for the measuring equipment of contact angle will be design in a few type of design to get the good result.

4. Fabrication product

After get the design actual product will be fabricated and prepared for the experiment of testing.

5. Sample preparation

Each sample will be prepared in specific properties which is different type of surface.

6. Testing of sample

All the sample will be tested to get the image of the contact angle of the droplet

7. Analysis and result

After get the result will be analysed on the different type of surface and the contact angle measurement.

8. Suggestion and recommendation

Suggestion will be proposed based on the result and analysis

9. Report writing

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

The methodology of this project is summarized in the flow chart as shown in the figure below

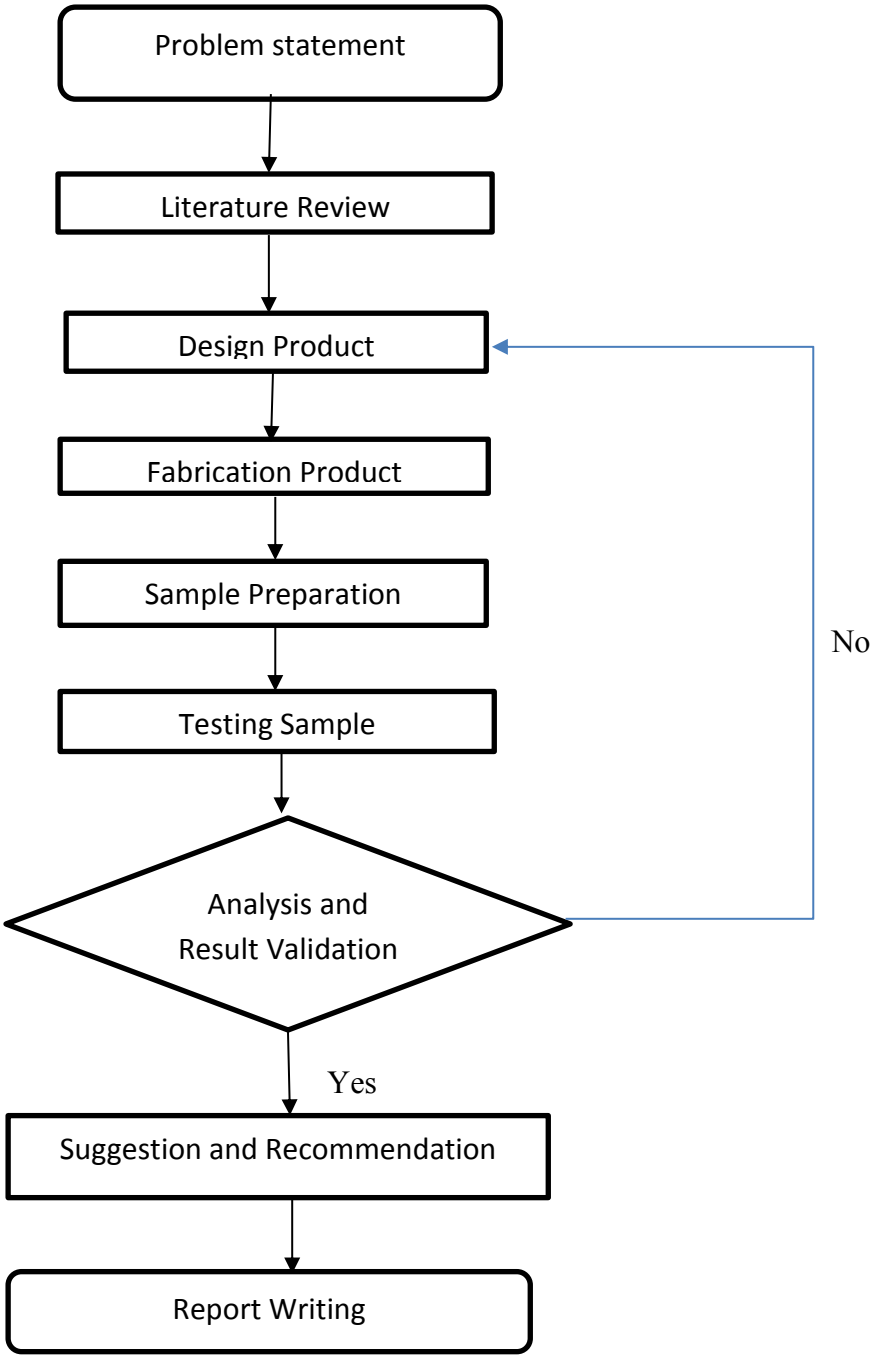

Figure 1.1: Flow chart of General Methodology

CHAPTER 2

LITERATURE REVIEW

2.1 Overview

This chapter present the review cases study of the development tool in order to measure the contact angle. It includes the hydrophobicity properties which is super hydrophobic and hydrophobic and also contact angle properties.

2.2 Contact angle

Contact angle is the most important criteria to analyse the wettability of the surface. Small contact angle is smaller than 90º it show high wettability, whereas large contact angle which exceed 90º correspond to low wettability. Contact angle can be described as the angle formed by meeting of liquid with solid surface. The shape of the liquid drop to be measured as contact angle is determined by surface tension of the liquid.

In liquid state the net force is zero because each of the molecules in the bulk is pulled equally in every direction by neighbouring liquid molecules. The molecule that exposed at the surface does not have neighbouring molecules and creating an internal pressure. Therefore the liquid will contract its surface area to maintain the lowest surface free energy (Yuehua Yuan and T. Randall Lee, n.d.).

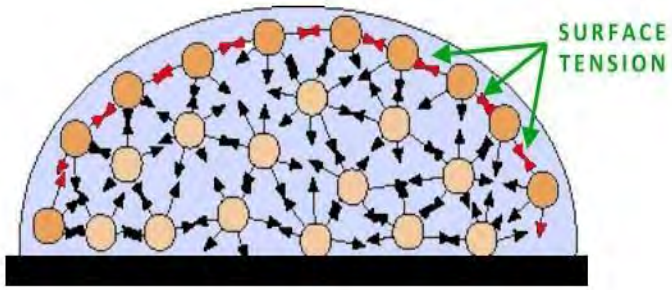

Figure 2.1: Surface Tension in water droplet

Based on the past study by Thomas Young(1804), he were proposed treating the contact angle of a liquid with a surface as the mechanical equilibrium of a drop resting on a plane solid surface under the restrains at three condition of surface tension. From the study it form "Young Equation", where the angle formed by the solid surface and the tangent of the drop is called as a "contact angle". Each combination of a solid and a liquid, there is an appropriate angle of contact between both surfaces that exposed to the air and to the solid

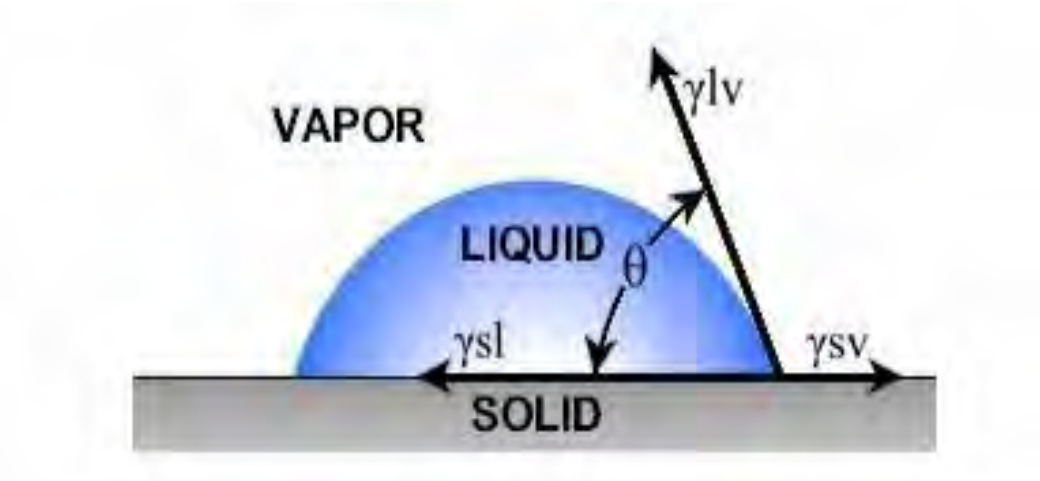

Figure 2.2: Contact angle according to Young Equation (Mittal and Robert, 2014)

$$\gamma SV=\gamma Sl+\gamma lV cos\theta \qquad \text{Eq. (2.1)}$$

Where: γlV - Liquid-vapour, γSV - Solid-vapour, γSl - Solid-liquid, θ – Contact angle

Equation 2.1 is relates to the contact angle to the surface free energy of a system containing solid(S), liquid (L), and vapor (V) phases, it referred as Young's equation. (Lamour et al., 2010)

The contact angle hysteresis played an important role in the system is get when Young's equation applied to a specific liquid-solid system, three parameters, γSV,γSl and γlV determine a single and unique contact angle θ. The phenomenon of wetting is more than just a static state. The liquid moves to expose its fresh surface and to wet the fresh surface of the solid in turn. The measurement of a single static contact angle to characterize wetting behaviour is no longer adequate. When in actual motion, the contact angle produced is called a "dynamic" contact angle (Young, 1804).

According to (Bhushan & Jung, 2011), Wenzel was formulating a simple model predicting that the contact angle of a liquid with a rough surface is different with smooth surface. Cassie and Baxter present that water vapor which is normally called as "air" in gaseous phase in the literature, may be trapped in the cavities of a rough surface. Therefore, it form solid-liquid-air interface, it opposed to the homogeneous solid-liquid interface. These two theories explain two condition wetting regimes or state: the homogeneous (Wenzel) and the composite (Cassie-Baxter) regimes.

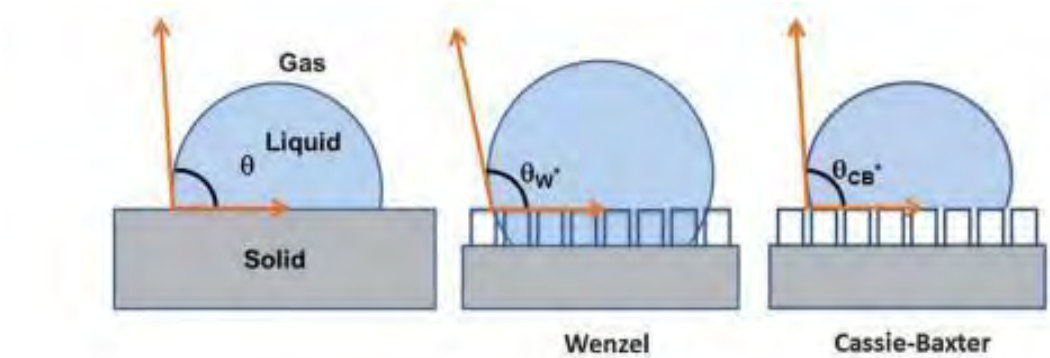

Figure 2.3: Water droplet in Wenzel state and Cassie-Baxter states (Nuraje,et al 2013)

This two equation are explained about contact angle of liquid with rough surface. The Wenzel Equation, Eq (2.2) states that the water droplet is in full contact with the surface and is amplified by a roughness parameter. Hydrophobic can be obtained when is larger than 90º, with Hysteresis, H and sliding angle, due to the increase in the solid-liquid interface. It show that the value of contact angle of a rough surface is depend on the value of the contact angle.

$$\cos\theta = r\cos\theta Y \qquad \text{Eq. (2.2)}$$

The Cassie-Baxter equation, Eq (2.3), indicate the water droplet is suspended on a composite interface made of solid and air trapped between the droplet and the surface. Hydrophobic can be assumed when H is low and is low due to the increase in the solid-vapor interface. It describe the superhydrophobic surface with contact angle is not dependent to the roughness where is the fraction in the contact liquid or solid. Wetting in the Cassie Baxter state is more suitable to be considered for achieving superhydrophobic rather than Wenzel state (Zheng & Lü, 2014)

$$\cos\theta = \varphi s(\cos\theta y + 1) - 1 \qquad \text{Eq. (2.3)}$$

2.3 Hydrophobicity properties

Hydrophobicity is the physical property of a surface that avoid water. Basically, carbon and hydrogen atoms are the only molecules in the hydrophobic surface. This surface cannot interact favourably with water and repel water that make a contact with the surface (Law, 2014)

2.3.1 Definition

The term hydrophobic is from word "hydro-"means water and "-phobia" means fearing or hating in Greek. It refer to fearing condition and used to define the contact of solid surface with any liquid (Bhushan & Jung, 2011). Hydrophobicity is a tendency of water molecules to minimize their contact with hydrophobic molecules. In other word is a nonpolar substance that does not combine with water molecules. Hydrophobic molecules tend to be nonpolar and, thus, prefer other neutral molecules and nonpolar solvents. Hydrophobes do not dissolve well in the water molecules are polar. Hydrophobic molecules in water often to group up together, forming micelles and show a high contact angle.

Superhydrophobic is described by materials that having surfaces that are very difficult to wet, and the surface with contact angle between 150º to 180º. Figure 2.4 show the differences between super hydrophilic, hydrophilic, hydrophobic and superhydrophobic. It exhibit very low water contact angle, smaller than 10º. This causes the water droplet rolling and bouncing from the surfaces. It also will remove contaminants on the surface due to self-cleaning properties of superhydrophobic coating. Water drop are able to capture the dust and dirt particle, while moving on the surface, and can easily remove particle contaminants from the solid surface (Bernagozzi, Antonini, Fabio, & Marengo, 2014).

Superhydrophobic coating is a coating that exhibits the extremely high water repellence. The degree to which a solid repels a liquid depends on two factors which is surface energy and surface morphology. Once the surface energy is lowered, hydrophobicity