UNIVERSITI TEKNIKAL MALAYSIA MELAKA

DESIGN AND FABRICATION OF OIL-WATER SEPARATION SYSTEM WITH HYDROPHOBIC COATING WIRE MESH FILTER FOR GREASE TRAP

This report is submitted in accordance with the requirement of the Universiti Teknikal Malaysia Melaka (UTeM) for the Bachelor of Mechanical Engineering Technology (Maintenance Technology) with Honours.

by

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APPROVAL

This report is submitted to the Faculty of Mechanical and Manufacturing Engineering Technology of Universiti Teknikal Malaysia Melaka (UTeM) as a partial fulfilment of the requirements for the degree of Bachelor of Mechanical Engineering Technology (Maintenance Management) with Honours. The member of the supervisory is as follow:

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ABSTRAK

Lemak, minyak dan gris (FOG) adalah sisa yang dilupuskan terus ke dalam sistem saliran dan sisa *FOG* akan terkumpul dan tersumbat sekitar sistem paip air kumbahan. Bagi objektif projek ini adalah untuk reka bentuk dan membina sistem pemisahan air dan minyak dengan menggunkan penapis dawai di saluti hidrofobik. Sistem pemisahan air minyak direka berdasarkan kaedah reka bentuk kejuruteraan seperti pembentukan Rumah Kualiti (HOQ), carta Morfologi, dan kaedah Pugh. Penapis dawai keluli tahan karat telah diuji untuk menolak air dan mendapati mempunyai ciri-ciri penyerapan minyak yang baik. Ciri-ciri pembasahan menggunakan salutan berasaskan seramik boleh melindungi permukaan dari degradasi dan kelembapan penyerapan kerana keadaan permukaan tersebut dalam hidrofobisiti. Projek ini menunjukkan ciri-ciri dan pemahaman kesan perbezaan saiz pori dawai pada pembasahan terhadap prestasi jejaring penapis dengan salutan dan tanpa salutan seramik. Lapisan seramik yang digunakan ialah Titanium Dioksida (TiO2). Persentuhan titisan sudut dan peranan permukaan morfologi dinilai dengan menggunakan alat pengukur sudut persentuhan dan mikroskop elektron pengimbas (SEM). Hasilnya menunjukkan, hidrofobisiti jejaring dawai keluli tahan karat yang tidak bersalut akan meningkat jika saiz liang dawai semakin kecil. Bilangan terhadap lapisan TiO_2 juga dikaji iaitu tanpa salutan, 7 kali salutan dan 14 kali salutan. Ia mendapati bahawa, lapisan TiO_2 yang lebih banyak dapat meningkatkan hidrofobisiti jejaring dawai dengan kenaikan sentuhan sudut melebihi dari 100º. Manakala bagi titisan minyak masak pula, ia dapat meresap cepat pada permukaan jejaring dawai tersebut kurang dari 1 saat, ia menunjukkan mempunyai sifat oleophilic. Hasil gambar *SEM* pula menunjukkan permukaan jejaring dawai semakin kasar disebabkan oleh lapisan TiO_2. Kekasaran pada permukaan ini adalah salah satu faktor yang mempengaruhi permukaan hidrofobisiti disebabkan mempunyai perangkap udara diantara cecair dan permukaan seperti dinyatakan dalam teori Wenzel dan Cassie-Baxter.

ABSTRACT

Fat, oil and grease (FOG) is a waste disposed directly into the drainage system that may build up around the plumbing system of the wastewater system facility. The objective of this project is to design and development oil water separation system with hydrophobic coating wire mesh filter. The oil water separation system is designed based on engineering design methods such as House of Quality (HOQ), Morphological chart, and Pugh method. Stainless steel wire mesh filter has been tested for water repellent and oil absorption characteristics. Wetting characteristics using ceramic-based coating may protect the surface from degradation and moisture absorption due to the hydrophobicity behavior of the surface after coating. This project showed the characterization and understanding the effect of the difference in pore size of wire mesh on the wetting characteristics performance of the filter mesh with and without a ceramic coating. The ceramic coating used was Titanium Dioxide (TiO_2). Contact angle of droplet and morphology surface characterization were evaluated by using contact angle measurement tools and scanning electron microscope (SEM). The result showed, hydrophobicity of uncoated stainless steel of wire mesh will increase if the pore size of wire mesh is decreasing in size. The number of TiO_2 coatings was also studied, uncoated, 7 times coating and 14 times coating. It was found that, the more layers of coating increases the hydrophobicity of the wire mesh in increments with contact angle more than 100º. For the cooking oil droplet to expeditiously spread over the mesh surface and rapidly permeate through the mesh within < 1 second, showed the oleophilic nature of the mesh. The *SEM* shows that the roughness of the surface is cause by TiO_2 coating. This is one of the factors affecting the hydrophobicity of the surface due to liquid-air interfaces under the droplet (air trap) as stated in Wenzel and Cassie-Baxter theory.

DEDICATION

I dedicate my work to my family and other friends. Realize that every of challenging work is needed self-efforts as well as helps and guidance from elders and friends. Also, special feeling of gratitude to my beloved parent whose words of encouragement and prayers of the day and night. I also dedicate my work to my supervisor who have guided me to do the real of work-self until finish. From this supporter, I can handle the work even the challenger that very hard to face. Encouragement and advice from them, I am able to get such a success. Thank you for all the support and ideas.

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LIST OF ABBREVIATIONS

2D	–	2 Dimension
3D	–	3 Dimension
AGRU	–	Automatic Grease Removal Unit
CA	–	Contact Angle
CNC	–	Computer Numeric Control
FOG	–	Fat, Oil, and Grease
HOQ	–	House of Quality
MSDS	–	Material Safety Data Sheet
OCA	–	Oil Contact Angle
OSHA	–	Occupational Safety and Health Administration
SEM	–	Scanning Electron Microscope
TiO_2	–	Titanium Oxide
VPSEM	–	Variable Pressure Scanning Electron Microscopy
WCA	–	Water Contact Angle

CHAPTER 1

INTRODUCTION

1.1 Background of Study

Fat, oil and grease (FOG) are found in food products like butter, vegetable oil, animal fat, meat, sauce and dairy products. Usually, these are found in the kitchen of food service such as restaurants and cafes where the food are prepared, cooked and served. If the *FOG* is handled in the wrong way, it can caused problems of blocked sewer and unpleasant odour (Husain *et al.*, 2014). Filtering process of separating oil and water is needed by using absorbent materials. These materials have pores absorbent properties like wire mesh, PU sponge, carbon based sponge, and aerogels. They are able to absorb oil from water by opposite wetting behavior (Y. Yu *et al.*, 2016). Despite this process, oil spillage clearance is still an issue. Porous hydrophobic material normally used as filter, letting oil through it and block the water because the oil can wet and penetrate it. This is because the former is normally employed as an adsorbent to separate oil from water surface (Yang *et al.*, 2019). There are differences between the filter process and absorption process. Unlike the absorption process, the filter eliminates regeneration phase by desorption, cleaning, or squeezing the oil material. Many studies had been carried out regarding the separation of oil water using metal wire mesh as filter that only allows oil flow through the pores and repel the water from going through the pores (Lu *et al.*, 2018). Fabricate of metal meshes with specific wettability has been extensively investigated with

various methods such as layer by layer, chemical etching, and electrodeposition (Y. Yu *et al.*, 2016). Nevertheless, few studies are to be found compared to other materials, metal meshes are recognized as a better choice because they can separate large quantities of mixed oil water. They have better mechanical behavior, cost-effective fabrication procedures (X. Yue *et al*, 2018), and low pressure is required to drive liquid through metal meshes because gravity alone can be used to drive the flow (R.K. Gupta *et al*, 2017). Stainless steel is commonly used for fabricating hydrophobic materials. It is used in oil water separation because it has adjustable pore sizes, good thermal stability and anti-corrosion (Jiarou Wang *et al.*, 2019). Pore size of mesh plays an important factor by shrinking the pore size the maximum water pressure that the separation mesh can sustain (intrusion pressure) for water will increase but at the same time the oil penetrate through (oil flux) the mesh is reduced. The delicate balance between the intrusion pressure and oil flux can determine the optimal size of the hydrophobic meshes (Singh *et al.*, 2018).

1.2 Problem Statement

Following the process of oil water separation using skimmer method by using rotating disc from the previous product of grease trap project, the main problem is that it cannot completely separate the oil from the water because the skimmed mixture still contains a large quantity of water. The capability for the disc to collect the oil was not very effective because the surface of the disc was made of oleophilic which are not adhesion enough compare to superoleophilic sobert surface. After oil have been dragged out from the skimmer, the oil need to be placed into the container for further recycling process. In order to remove the water from the oil, the products require a filter before the oil is transfer to a container. In this

study a filter concept must be designed using wire mesh to separate oil water after the mixture has gone through the oil skimmer process. So that the water content collected from the oil can be minimized. Therefore it can improve the percentage of the removal water. This oil water separation system using hydrophobic wire mesh design is simple and does not consume any power source to perform the oil water separation process. In addition, it has two separate drainages, one drains out oil and the other one drains out filtered water into respective containers.

1.3 Aims and Objective of Research

This project aims to investigate of oil water separation using hydrophobic coating wire mesh. The system is expected to separate the oil water mixed from the grease trap. There are several objectives to achieve the aims;

1. To design the concept of oil water separation with hydrophobic coating of wire mesh.
2. To fabricate prototype of oil water separation system with hydrophobic coating of wire mesh.
3. To investigate the effect of pore size wire mesh and coating towards wettability characteristic.

1.4 Scope of Research

The scopes of this study are:

1. The concept of this study is designed by using House of Quality (HOQ), Morphological chart, and Pugh method.
2. The development of oil water separation system with hydrophobic wire mesh.
3. The investigation based on oil water separation by different pore size of stainless steel wire mesh with and without ceramic coating Titanium Dioxide ($TiO_{2)}$.

CHAPTER 2

LITERATURE REVIEW

2.1 Grease Trap

Grease trap is a plumbing component used to block some of solids or oils before them through a wastewater enter disposal system. This trap is a container into which wastewater having *FOG* flows through before entering a drainage system. The container is designed to trap the *FOG* while allowing clear water to discharge. Regular wastewater contains small measures of oils which enter into septic tanks and treatment offices to outline a floating scum layer. This scum layer is very gradually digested and produced by microorganisms in the anaerobic digestion process. This trap can be installed over or below the ground, inside the kitchen or outside the building.

2.1.1 Passive Grease Trap

Passive grease trap usually is installed under the sink or around the kitchen area. It has an inlet that received wastewater drained from the sink and an outlet which discharge treated water from the grease trap. Passive grease trap is divided into three chambers separated by buffers. Each chambers are important in separating the amount of *FOG* from water. *FOG* with low density float on the surface of water. Solid particle with high density will sink in water. Amount of grease and oil will decrease as they pass through from first chamber to the last chamber. The first chamber will collect the most waste compared to

next chamber. For cleaning process, each chamber is clean individually by using special equipment done manually. It is tedious because involving more manpower and regular frequent supervision periodically. In terms of price, passive grease trap is cheaper than other types of grease trap. However, maintenance cost is higher. Maintenance is to prevent *FOG* from over flowing in the chambers.

2.1.2 Active Grease Trap

Active grease trap is made of metal or plastic material. It is installed and used in food services industry restaurants and cafeterias. Active grease trap it also known as bioremediation grease trap because it uses bioremediation technique. This technique is good because it is a greed technology not damaging eco-system. Active grease trap uses live organism such as bacteria, cyanobacteria, fungus, and alga to deactivate microorganism and to remove waste like wastewater and toxin in water and change it into soluble liquid (Oya, 2007). This treated soluble liquid is drained out of the tank into the drainage system safely. Bioremediation digestion process take along time of two to five hours. With right combination of temperature, nutrition and food are important factors to fasten the process of waste digestion.

2.1.3 Automatic Grease Trap

Automatic grease trap also known as Automatic Grease Removal Unit (AGRU). This type of grease trap uses mechanical and electrical components as energy source using motor timer which will rotate skimmer wheels for separating fat, oil and grease layer from

the water surface. This grease trap has high efficiency because it is able to separated *FOG* layers from water surface almost 99% efficient. Furthermore, it has different sizer to cater different purposes, smaller size it can be place under the sink and for the bigger size, it can be used in larger food service industry. Separation of *FOG* layer from water surface is done by skimmer wheels that is rotated by motor timer and *FOG* surface it adhere to the wheel and scraped off into discharge external container. Therefore it needs low maintenance cost. The disadvantage is it cost a lot to acquire it compared to other different types of grease trap.

2.1.4 Efficiency Performance between Automatic and Passive Grease Trap

The amount of grease collected in this trap system determine the efficiency of separating grease from water. The more grease trapped in the tank, the less efficient is the separation grease from water. Therefore, automatic grease trap is more efficient than passive grease trap because the automatic grease trap can remove the *FOG* into the external container periodically. This system can maintain efficiency at consistent maximum level compared to passive grease trap. Passive grease trap is less efficient because removal of *FOG* is done manually. According to an investigation by Aqua Cure, overall performance of the passive trap drops quickly once the amount of grease gets to a certain level, while the automatic trap maintains consistent performance.