DESIGN ENHANCEMENT AND ANALYSIS OF PIGGING DEVICE FOR HEAT EXCHANGER FOULING CLEANING

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

by

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APPROVAL

This report is submitted to the Faculty of Engineering Technology of UTeM as a partial fulfillment of the requirements for the degree of Bachelor of Engineering Technology (Maintenance Technology) (Hons.). The member of the supervisory is as follow:

………………………………

(Project Supervisor)

ABSTRAK

Penukar haba adalah peralatan yang digunakan secara meluas dalam industri seperti loji kuasa , pemprosesan makanan, penapisan minyak dan gas dan penyaman udara. Fungsi penukar haba adalah untuk memudahkan pertukaran haba antara dua cecair yang berada pada suhu yang berbeza disamping mengelakkan percampuran antara satu sama lain. Masalah terbesar yang berlaku dalam semua jenis penukar haba ialah kekotoran yang boleh diklasifikasikan sebagai isu yang paling kritikal dalam aplikasi perindustrian. Kekotoran biasanya ditakrifkan sebagai pemerolehan dan pembentukan bahan-bahan yang tidak diingini pada permukaan peralatan pemprosesan . Berdasarkan masalah ini, kajian ini lebih tertumpu kepada penciptaan peranti pembersih dalam mengawal masalah kekotoran. Tujuan kajian ini ialah untuk menambahbaik rekabentuk dan menguji prestasi peranti yang dicipta. Teknik Berus dan Sistem Sangkar telah dipilih untuk mencegah masalah itu daripada menjadi lebih teruk disebabkan oleh kekotoran yang tersumbat didalam paip secara berlebihan. Bagi memenuhi objektif kajian ini, penambahbaikan reka bentuk Berus dan Sistem Sangkar telah dijalankan. Reka bentuk semasa bagi kaedah ini digunakan untuk beroperasi di dalam paip bagi membersihkan kekotoran. Bilah telah digunakan pada hujung berus untuk meningkatkan keberkesanan proses pembersihan dengan menghasilkan gerakan putaran. Paip akrilik digunakan untuk memudahkan proses pemerhatian semasa projek dijalankan. Hasil kajian menunjukkan bahawa berus dapat bergerak didalam paip kerana kapasiti pam yang mencukupi. Walau bagaimanapun, tidak ada putaran dihasilkan semasa operasi. Ini berlaku disebabkan oleh reka bentuk bilah itu sendiri yang tidak dapat mewujudkan gerakan putaran bagi berus tersebut.

ABSTRACT

Heat exchanger is an equipment that is widely used in industries such as power plant, food processing, oil and gas refinery and air conditioning. The function of heat exchanger is to facilitate exchange of heat between two fluids that are at different temperature while keeping them from mixing with each other. The biggest problem that occurs in all types of heat exchanger is fouling which can be classified as the number one critical issue in industrial application. Fouling is generally defined as the acquisition and formation of undesired materials on the surfaces of processing equipment. Due to these consequences, this study focused more on the invention of pigging device in spirit of controlling fouling problems. The main purpose of this study is to enhance the design and to test the performance ability of the device developed. The current design of the novel pigging device which known as brush and cage system, used to operate inside the pipe to clean the fouling. In order to meet the objectives of this study, the enhancement of Brush and Cage System design was conducted. Blades were applied to the tips of the brush in order to increase the effectiveness of the cleaning process by performing the rotation motion. Acrylic pipe was used to ease the observation process during the project testing. The results showed that the brush was able to flow because of sufficient pump capacity. However, no rotations were produced during the operation. This happened due to the design of the blades itself, which not able to create the rotation motion of the brush.

DEDICATION

I would like to dedicate my project to my beloved parents and to all my friends for supporting me from the beginning till the completion of this project.

ACKNOWLEDGEMENT

I have taken efforts in this project. However, it would not have been possible without the kind support and help of many individuals and organizations. I would like to extend my sincere thanks to all of them.

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TABLE OF CONTENT

LIST OF TABLES

LIST OF FIGURES

LIST OF ABBREVIATIONS, SYMBOLS AND NOMENCLATURE

U_o	-	Overall heat transfer coefficient for the outside tube
U_i	-	Overall heat transfer coefficient inside of the tube
di	-	Fouling coefficient for the inside
h_{do}	-	Fouling coefficient for the outside
A_i	-	Inside area of the metal tube
A_o	-	Outside area of the tube
k	-	Thermal conductivity
A A lm	-	Log mean area of the metal tube
r_i	-	Inside radius
r_o	-	Outside radius
U	-	Overall heat transfer coefficient
Q	-	Heat transfer rate
A	-	Heat transfer area
U_c	-	Overall heat transfer coefficients for clean condition
U_f	-	Overall heat transfer coefficients for fouling conditions
T_i	-	Fluid inlet temperature
T_o	-	Fluid outlet temperature
T_s	-	Surface temperature
$\Delta\theta_m$	-	Log mean temperature difference
°C	-	Degree Celcius
Psi	-	Pounds per square inch
%	-	Percent
TEMA	-	Tubular Exchangers Manufacturers Association
Mm	-	Milimeter
PVC	-	Polyvinyl chloride

LPH	-	Liter Per Hour
RPM	-	Rotation Per Minute
S	-	Second

CHAPTER 1
INTRODUCTION

1.1 Heat Exchanger

Heat exchanger is the equipment that facilitates exchange of heat between two fluids that are at different temperature while keeping them from mixing with each other. The heat transfer process accomplished by conduction from the hot fluid to the tube wall and convection from hot fluid to cold fluid (Geankoplis, 1993). Heat exchangers are usually applied in practice in a broad range of applications, from air conditioning systems and heating in a household to chemical processing and power production in large plants.

A heat exchanger consists of heat exchanging elements such as a core containing the heat transfer surface and fluid distribution elements such as manifolds, headers, tanks, inlet and outlet nozzles or pipes or seals (Sekulib, 1998). The different heat transfer applications require different types of hardware and different configurations of heat transfer equipment. In order to fulfill the requirement and the election of heat exchanger must be appropriate. There are many types of heat exchanger in industrial application such as double pipe heat exchanger, compact heat exchanger, shell and tube heat exchanger and plate and frame heat exchanger.

Double pipe heat exchanger is the simplest type of heat exchanger. In operation, one fluid through the small pipe while the other fluid flows through the annular space between the two pipes. It also consists of two types of flow arrangement which are parallel flow and counter flow (Peyman, 2013). Another type of heat exchanger is compact heat exchanger which has large heat transfer surface area per unit volume. It is commonly used in gas to gas and gas to liquid or liquid to gas heat exchanger. The flow of this type of heat exchanger is cross flow which is the two fluids move perpendicular to each other. The cross flow is also classified as unmixed flow and mixed flow (Joe, 2012).

In industrial application, the most commonly used heat exchanger is shell and tube heat exchanger where a large number of tubes are packed in a shell. The axes of the tube are parallel to the shell. On the outside of the tube, other fluid will flow through the shell. The size and weight of this heat exchange are normally large and very heavy due to its application in the industry. The classification of this type of heat exchanger is according to the number of shell and tube passes involved (Gawande et al., 2012).

The other type of heat exchanger is plate and frame heat exchanger. It consists of a series of plates with corrugated flat flow passages. The cold and hot fluids flow through the alternate passages. It is commonly used in liquid to liquid heat exchange applications and also provided that the hot and cold fluid streams at the same pressure (Wang, 2007). These heat exchangers are also having the common problem that can interrupt the efficiency of the operation. The biggest problem of all types of heat exchanger is fouling which can classify as the number one critical issue in industrial application.

1.2 Fouling

Fouling is generally defined as the acquisition and formation of undesired materials on the surfaces of processing equipment. It can have a significant, negative impact on the operational efficiency of the unit (Bell & Mueller, 2001). Fouling in heat exchangers is a grave problem. In fact, fouling has been existed for a long time. Analysis on heat exchanger fouling was managed as early as 1910 and the first practical application of this research was implemented in the 1920. Technological progress in the prevention, reduction and elimination methods in industrial fouling were investigated in a study managed at the Battelle Pacific Northwest Laboratories for the U.S. Department of Energy (Ibrahim, 2012).

In industry, fouling of heat transfer surfaces has always been an identified phenomenon, although terribly understood. Fouling of heat transfer surfaces occurs in most chemical and process industries, including pulp, oil refineries and paper manufacturing, fiber production and polymer, food processing, desalination, power generation, dairy industries and energy restoration. Fouling can occur as a result of the fluids being handled and their constituents in combination with the operating conditions such as temperature and velocity (Awad, 2011). Heat exchanger foulant mostly come from solid or semi solid material, but some materials that are predominantly encountered in industrial operations as foulants.

Major harmful consequences of fouling include loss of heat transfer as indicated by charge outlet temperature decrease and pressure drop increase. Other undesirable effects of fouling may also include blocked process pipes, under-deposit corrosion and pollution. Where the heat flux is high, as in steam generators, fouling can lead to local hot spots resulting eventually in mechanical failure of the heat transfer surface. Such aftermaths lead in most cases to production losses and increased maintenance costs (Ibrahim, 2012).

1.3 Problem Statement

Fouling is the most serious problem in heat exchanger. It starts building up on the unmixed material between fluids which increasing the resistance of heat transfer and reduce the efficiency of heat exchanger when the heat exchanger has been operated in a period time. The problem of fouling on the inside and outside the tube can be worse to the heat exchanger because the fouling layer can close off the flow through the tube.

There are many methods used to control the fouling problem which is classified to two techniques. These techniques are online and offline respectively (Garrett-Price et al., 1989). The example of online techniques is sponge ball techniques with rough surface which are circulated through the heat exchanger (Müller-Steinhagen, 2000). Brush method is only used for softer fouling condition (Müller-Steinhagen, 2000). Thermal shock method is only carried out when the thermal expansion differences form between the fouling deposits and the temperature changes on a metal surface (Bott, 1995). Soot blowers are one of the methods used to clean the fouling which is popular for gas side use (Müller-Steinhagen, 2000). For offline techniques, it is all about the manual techniques such as air jet, manual cleaning and mechanical cleaning such as scrapers and drills (Bott, 1995).

Chemical additives are also used to reduce the fouling problem by choosing the selected chemicals. In previous work, the example of chemical additives method are sequestering which is forms a chemical complex with foulant, threshold which retard precipitation, chelating which forms a strong chemical complex with the foulant, crystal modifier which changes crystal habit preventing the formation of large crystalline structure assists removal, biocide which kills or disable microorganism, biostats which inhibits microorganism activity and corrosion inhibitors which separates surface from corrosive agent (Bott, 2007).

This study will focus on constructing a new method for cleaning the tube of the heat exchanger. It is also focuses on the design specification developmental that is suitable to reduce any condition regarding fouling defects.

1.4 Objective of Studies

Based on the problem statement stated above, the objectives of this study are stated below:

1. To design and develop a device used for inner tube fouling cleaning.
2. To test the performance ability of the device developed

1.5 Scope of Studies

In order to reach the objectives, a few scopes have been drawn:

1. Designing a tube fouling cleaning device and piping system using SOLID WORK software.
2. Developing a tube fouling cleaning device with ability to flow along the acrylic pipe.

Testing the developed device with two different sizes of brush and two different capacities of submersible pump.

CHAPTER 2

LITERATURE REVIEW

2.1 Heat Exchanger

Heat exchanger is a device that transfers heat between two fluids using hot and the cold fluid. The heat transfer process accomplished by conduction from the hot fluid to the tube wall and convection from hot fluid to cold fluid (Geankoplis, 1993). There are many types of heat exchanger in industrial application such as double pipe heat exchanger, compact heat exchanger, shell and tube heat exchanger and plate and frame heat exchanger.

2.1.1 Double Pipe Heat Exchanger

Double pipe heat exchangers are the simplest exchangers used in industries. On one hand, these heat exchangers are a great choice for small industries because the cost needed for both design and maintenance is low. But on the other hand, the efficiency of these exchangers is low beside the space occupied is high for such exchangers in large scales, has forced modern industries to use more efficient heat exchanger like shell and tube or other modern heat exchangers. But, since double pipe heat exchangers are simple, it is profitable on learning process for those who want to know about the design concept for modern and normal heat exchanger as the basic rules are the same and much easier to understand the design techniques (Peyman, 2013).

Double pipe heat exchanger includes two concentric pipes. As explained by Peyman (2013), the inner pipe is generally called the tube and the outer one is pronounced as annulus which produced in standard sizes. In most situations, there are only a few pipe sizes available and also the choice of the pipe size is limited. By considering the operating conditions, it is feasible to decide the fit pipe size for design. Furthermore, there are two main flow arrangements, concurrent flow and countercurrent flow. In concurrent flow, both cold and hot fluids will enter the heat exchanger at the same head. Therefore, the cold fluid temperature will increase while the hot fluid temperature decrease and as a result the temperature difference between two flows reduces through the exchanger (Bartlett, 1996). This will conduct to gradual reduction of thermal driving force along the exchanger and the efficiency and heat transfer rate of heat exchanger will decrease.

In countercurrent flow arrangement, both cold and hot fluids will not enter the heat exchanger at the same head. One of the fluids will enter the heat exchanger at one head and the cold flow enters at the other end. In this flow arrangement, between the two flows, the temperature is different. The driving force will remain almost persistent along the heat exchanger (Peyman, 2013).

2.1.2 Compact Heat Exchanger

Compact heat exchangers are actually known by a large heat transfer surface area per unit volume of the exchanger, weight, resulting in a reduced space, support structure and footprint, reduced energy requirement and cost, improved process design, plant layout and processing conditions and low fluid inventory compared to conventional designs such as shell-and-tube exchangers (Shah and Sekulib, 1998). Remarkably high heat transfer coefficients are attainable with small hydraulic diameter flow passages with gases, liquids, and two-phase flows.

As stated by Shah and Sekulib (1998), the heat transfer coefficient or overall heat transfer coefficient of a standard plate heat exchanger has about two times more than a shell-and-tube exchanger for water applications. Basic constructions of gas to gas compact heat exchangers are plate-fin, tube-fin, and all prime surface recuperators including polymer film and laminar flow exchangers and compact regenerators. Basic flow arrangements of two fluids are single-pass cross flow, counter flow and multipass cross counter flow. The exchanger effectiveness can be produced very high by the last two flow arrangements. It also yields very small temperature differences between fluid streams and pressure drops compared to shell and tube exchangers.

Liquid to liquid and liquid to phase change fluid compact exchangers basic constructions are gasketed and welded plate-and-frame, welded stacked plate without frames, spiral plate, printed circuit and dimple plate heat exchangers (Kreith, 2000). For gas to fluid exchangers, as compared with the conventional shell and tube exchangers, the unique characteristics of compact extended which are plate fin and tube fin surface exchangers, there are lots of surfaces provided by various orders of magnitude of surface area density, flexibility in circulating surface area on the hot and cold sides as justified by design considerations and generally substantial cost, weight, or volume savings (Shah and Sekulib, 1998).

2.1.3 Shell and Tube Heat Exchanger

Shell and tube type heat exchangers are assembled of tubes which round or rectangular in general, mounted in cylindrical, rectangular or arbitrary shell shape. Many variations of this basic type are available. Normally, the dissimilarities depend on the detailed features of construction and provisions for differential thermal expansion between the tubes and the shell (Gawande et al., 2012). The standards defining how shell and tube exchangers should be built are governed by Tubular Exchangers Manufacturers Association (TEMA). It also describes a naming system that is regularly used.