ENERGY OPTIMIZATION BY USING PINCH ANALYSIS FOR CHLORINATION PROCESS IN GLOVE MANUFACTURING PLANT

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ABSTRACT

The manufacturing industry has been driven to reduce its energy use due to the rising cost of fossil fuels and their detrimental environmental impact. Energy audits are frequently used to improve energy efficiency. Most audits, on the other hand, do not include a comprehensive review of design features for optimal energy efficiency. In thermochemical industries, pinch technology analysis, which includes heat exchanger design and retrofits, is becoming more common as a way to enhance energy efficiency. Investigations into pinch analysis have been conducted in a number of industrial and processing facilities. However, no research on pinch analysis studies in the chlorination process in glove manufacturing plant has been reported. Therefore, the use of pinch technology analysis to chlorination process in a glove manufacturing plant is presented in this study. With the help of HINT software, the goal of this study is to use a model to optimize the heat exchanger network of chlorination process in the glove manufacturing plant and to estimate the minimum cost required for the heat exchanger network without compromising the energy demand by each stream. In order to increase the energy efficiency, retrofit analysis is done for the existing system in the plant and grassroot design will be created for chlorination process setup for the upcoming new glove manufacturing plants. From the study, the improved HEN in the retrofit design shows theoretical saving of energy cost by $ 278,630.17 per year and necessary capital investment is $ 175,056 with the payback period of 0.63 years. The total energy savings obtained from the retrofit design is estimated around 58.41% from the initial operating costs of old system. In addition, the grassroot HEN diagram for the new plant setup estimated to save maximum theoretical recoverable energy around 14,617,960 kW per year with the total cost of $ 475,083.70 per year. Based on the savings and investment made for the new setup, the payback period is around 1.83 years.

ABSTRAK

Industri pembuatan telah didorong untuk mengurangkan penggunaan tenaganya berikutan peningkatan kos bahan api fosil dan kesannya yang memudaratkan alam sekitar. Audit tenaga sering digunakan untuk meningkatkan kecekapan tenaga. Kebanyakan audit, sebaliknya, tidak menyertakan semakan komprehensif ciri reka bentuk untuk kecekapan tenaga yang optimum. Dalam industri termokimia, analisis ‘teknologi pinch’, yang merangkumi reka bentuk penukar haba dan pengubahsuaian, menjadi lebih biasa sebagai satu cara untuk meningkatkan kecekapan tenaga. Siasatan terhadap analisis cubitan telah dijalankan di beberapa kemudahan perindustrian dan pemprosesan. Walau bagaimanapun, tiada penyelidikan mengenai kajian analisis cubitan dalam proses pengklorinan di kilang pembuatan sarung tangan telah dilaporkan. Oleh itu, penggunaan analisis ‘teknologi pinch’ kepada proses pengklorinan di kilang pembuatan sarung tangan dibentangkan dalam kajian ini. Dengan bantuan perisian HINT, matlamat kajian ini adalah untuk menggunakan model untuk mengoptimumkan rangkaian penukar haba untuk proses pengklorinan di kilang pembuatan sarung tangan dan untuk menganggarkan kos minimum yang diperlukan untuk rangkaian penukar haba tanpa menjejaskan tenaga. permintaan oleh setiap aliran. Bagi meningkatkan kecekapan tenaga, analisis pengubahsuaian dilakukan untuk sistem sedia ada di kilang dan reka bentuk akar umbi akan diwujudkan untuk persediaan proses pengklorinan untuk kilang pembuatan sarung tangan baharu yang akan datang. Daripada kajian itu, HEN yang dipertingkatkan dalam reka bentuk pengubahsuaian menunjukkan penjimatan teori kos tenaga sebanyak $278,630.17 setahun dan pelaburan modal yang diperlukan ialah $175,056 dengan tempoh bayaran balik 0.63 tahun. Jumlah penjimatan tenaga yang diperoleh daripada reka bentuk pengubahsuaian dianggarkan sekitar 58.41% daripada kos operasi awal sistem lama. Di samping itu, rajah HEN akar umbi untuk persediaan kilang baharu dianggarkan dapat menjimatkan tenaga boleh pulih teoritikal maksimum sekitar 14,617,960 kW setahun dengan jumlah kos $ 475,083.70 setahun. Berdasarkan simpanan dan pelaburan yang dibuat untuk persediaan baharu, tempoh bayaran balik adalah sekitar 1.83 tahun.

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LIST OF ABBREVIATIONS

UTM	-	Universiti Teknologi Malaysia
kW	-	kiloWatts
HEN	-	Heat Exchanger Network
HINT	-	Heat Integration
EAC	-	Equivalent Annual Cost
NPV	-	Net Present Value
PTA	-	Problem Table Algorithm
GCC	-	Grand Composite Curve
MER	-	Maximum Energy Recovery
CW	-	Cooling Water
Ts	-	Supply temperature
Tr	-	Return temperature

LIST OF SYMBOLS

ΔT	-	Temperature difference
Cp	-	Specific heat
°C	-	Degree celcius
lb	-	Base year Cost Index
lc	-	Current year Cost Index
%	-	percentage
in.	-	inch
ft	-	feet
m	-	meter

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CHAPTER 1

INTRODUCTION

1.1 Background of Study

Rubber industry and rubber products are one of the most important industries in parts of the country's economy, such as Malaysia and Thailand, because they are the primary source of revenue. Furthermore, the increasing demand for product consumption from the rubber industry and rubber products causes both the utilization and exportation patterns to endure. At that point, the rubber industry and its products are capable of competing in the global market with other countries, since it is still the most important industry that the government should confirm to encourage and assist. According to Potential Energy Saving of Malaysia Manufacturing (2014), rubber industry and rubber products are thought to be businesses that consume a lot of energy and will continue to do so as the economy develops. When considering the energy component, it is vital to establish a means to encourage and support efficient energy consumption. If not, the influence on energy conservation increases the country's competitiveness with other countries on the worldwide market.

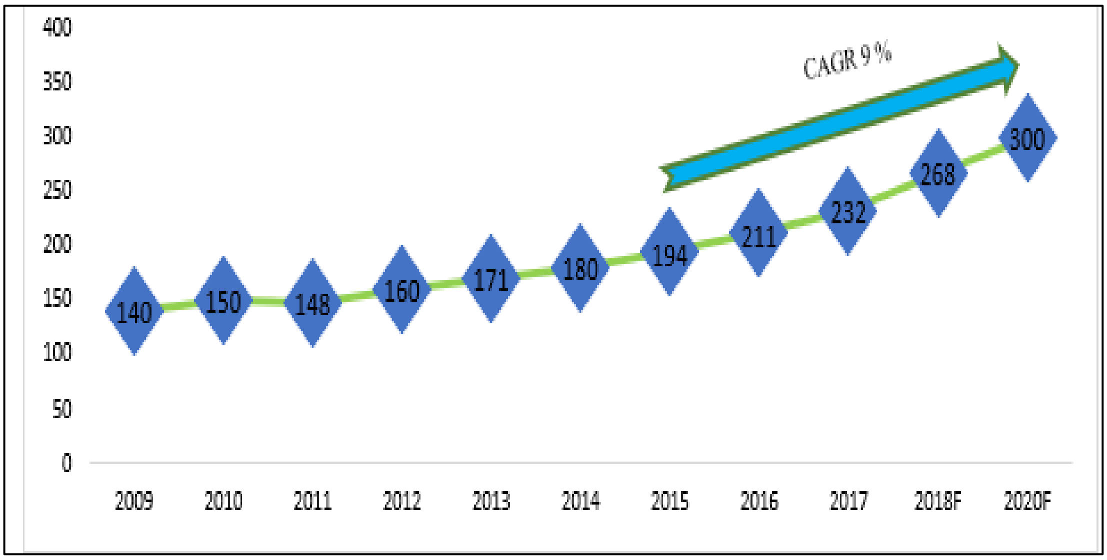

Figure 1.1 Global demand of rubber gloves (Televisory's Research and Malaysian Rubber Glove Manufacturers Association, 2018)

The figure 1.1 shows the global demand for gloves has grown at an annual rate of 9%, with initial projections from the MARGMA (Malaysian Rubber Glove Manufacturers Association) putting global demand for rubber gloves at 268 billion pieces in 2018. Malaysian rubber glove suppliers provided 168.8 billion pieces in 2018, meeting 63 percent of global demand and earning MYR18.8 billion (Source: MARGMA). Furthermore, rubber gloves account for more than 70% of Malaysia's total rubber exports.

Malaysia's rubber producing industries, which include around 510 manufacturers, include latex products, tires and tire-related products, and industrial and general rubber products. As a result of their rapid development, Malaysia has become the world's largest buyer of natural rubber latex. General rubber manufacturing plants typically have production lines ranging in length from 800 to 1200 meters and are spread out over several levels or buildings. Mastication, mixing (mills, internal mixers, cooling mills), further processing (pre-warming, processing in extruders, processing on calendars), and vulcanization are the basic processing processes for rubber products.

1.1.1 Rubber glove manufacturing cycle

Karunaratne, (2007) stated that the product forming by dipping method, such as rubber glove, is the forming production process; the dipping process is illustrated in the accompanying figure 1.2. This procedure involves dipping the former in chemical cleaning agents, a pick-up agent, and a solvent that forms a thin film around the former, followed by leaching, breading, curing, and ultimately stripping.

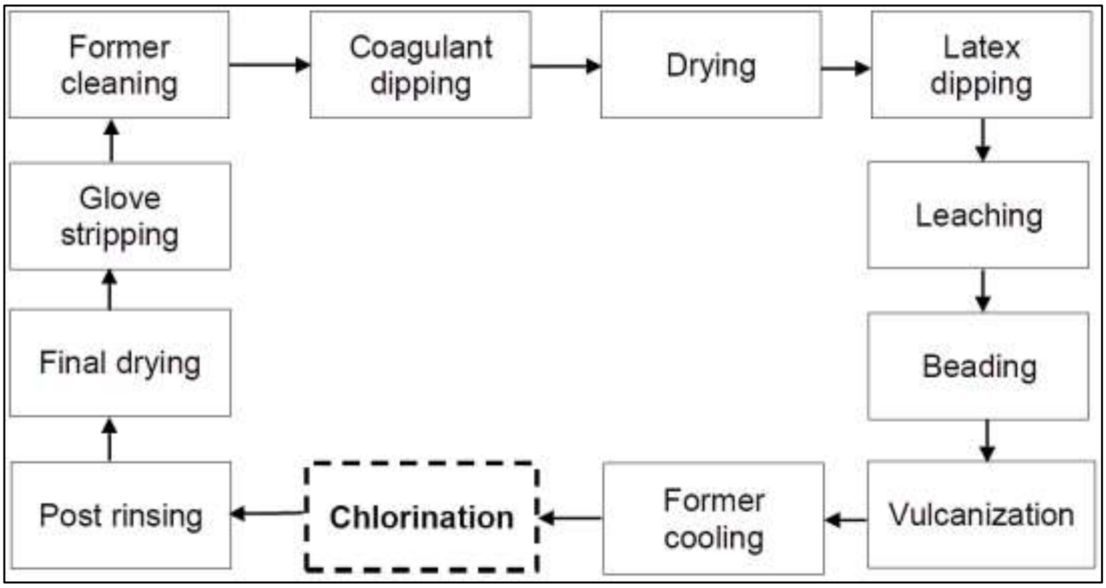

Figure 1. 2 General Manufacturing process of rubber glove

1.1.2 Chlorination process in glove manufacturing industry

The primary purpose of chlorination process (dipping in chlorine water) is to reduce the tackiness, which is a characteristic of the rubber gloves. This also reduces the friction between the rubber film and other surfaces with which it comes into contact. The chlorination process is commonly used in latex dipped glove industries because it gives a smooth surface of pleasing feel by considerably reducing the friction between the glove and the hand. Therefore, the user can easily remove the chlorinated glove. During the chlorination process, certain unevenness on the surface of the rubber particles can be created and this phenomenon has been described as Micro Textured. This can weaken the latex film surface. Therefore, the products, which are extremely thin, are required to be subjected to chlorination under special care. Preece et al., (2021) also specified that failure to do so would result in high reject rates.

The operations of Online Chlorination Process throughout the daily glove manufacturing would possess an inherent danger to the environment, which is deemed as the main concern to the top management of the factory. Meanwhile, the chlorine solution is the main agent used for the entire glove dipping process, which may possibly be causing tangible chlorine fumes emission occurrence within the atmosphere of surrounding areas. In addition, this will cause serious air pollution or contamination to the environment and becomes a hazard to operational personnel, if these emissions are remained unchecked. Therefore, the chlorine fumes will also accelerate heavy corrosion on the machineries and steel structures, indirectly contributing unnecessary intangible losses to the factory. In the light of this, an appropriate utilization of a well-designed Chlorine Fume Scrubber System that possesses with appropriate volume metric flow allocation and uniformed distributions will be fully utilized to overcome the aforementioned problems.

1.1.3 The cooling system in chlorination process

The chlorination system in the glove manufacturing requires the dipping of hand –shaped molds/formers fully in chlorine water in order to ease the donning process of gloves. The dipping of those formers actually heats up the water chlorine water to a certain temperature as it a continuous process. Chlorine fumes are easily vaporized if the water temperature is high and the tank temperature is best to maintain to certain range of temperature. Therefore, the heated chlorine water needed to be cooled down continuously as the dipping process occurs simultaneously. The simple diagram below shows the cooling system for the chlorination process in a glove manufacturing plant.

1.2 Problem Statement

The rising expense of fossil fuels, as well as their negative environmental impact, has forced the manufacturing industry to lower its energy consumption. To increase energy efficiency, energy audits are routinely utilized. Generally, an energy audit is a review of the equipment or system's energy consumption to ensure that it is being used efficiently. However, most audits do not include a thorough examination of design aspects for maximum energy efficiency. Pinch technology analysis, which includes heat exchanger design and retrofits, is becoming more popular in thermochemical businesses to improve energy efficiency. Investigations into pinch analysis have been conducted in a number of industrial and processing facilities. However, there is no published literature about pinch analysis studies in the chlorination process for glove manufacturing plants.

1.3 Objective of Study

There are three objectives in this study:

1. To evaluate current HEN performance for the existing system of chlorination process.
2. To retrofit the system's HEN by focusing on becoming most-energy efficient and most cost-efficient.
3. To perform a pinch analysis of energy by using HINT software for the system and its grassroot design in order to be implemented in the upcoming new glove manufacturing plant.

1.4 Significance of study

To optimize the heat exchanger network for of chlorination process in the glove manufacturing factory, as well as to estimate the least cost required for the heat exchanger network without compromising the energy demand of each stream. To improve energy efficiency, a retrofit analysis of the existing system in the plant will be performed, and a grassroot design for the chlorination process setup for the planned new glove production plants will be established. In the long run, there will be a reduction in the amount of process utilities required, as well as the associated environmental effects.

1.5 Scope of Study

The study will be done in one of the glove manufacturing plant and the study period is limited to roughly around 4 months. The study only focuses on the chlorination process segment from the overall glove manufacturing process because it is the most important part in glove manufacturing process. It helps in donning and without donning of gloves; the gloves are difficult to be stripped from the formers. Other than that, intangible cost will occur in order to replace the damaged gloves. Finally, chlorination deals with hazardous chlorine gas and chlorine department have to ensure that all are in good running condition and parameters. In addition, the study only prioritizes on the energy optimization of process. Finally, yet importantly, this case study of retrofit pinch analysis and grassroot analysis will be a pioneer study for chlorination process in glove manufacturing plant as there are no other references related especially to this type of industry.

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