OPTIMIZATION OF CHLORINATION COOLING SYSTEMS IN GLOVE MANUFACTURING INDUSTRY FOR MAXIMUM ENERGY RECOVERY

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A project report submitted in fulfillment of
the requirements for the award of the degree
of Master of Science in Energy Management

School of Chemical and Energy Engineering
Faculty of Engineering
Universiti Teknologi Malaysia

JULY 2022

ACKNOWLEDGEMENT

In preparing this project report, I was in contact with many people, researchers, academicians, and practitioners. They have contributed towards my understanding and thoughts. In particular, I wish to express my sincere appreciation to my main thesis supervisor, Ts.Dr.Azizul Azri Mustaffa, for encouragement, guidance, advice, motivation, critics and friendship. Without his continued support and interest, this thesis would not have been the same as presented here.

I would also like to express my gratitude to Top Glove Sdn.Bhd, including my manager and my fellow colleagues for granting me the permission and their providing their extensive support for me to conduct this research on the facility.

Last but not least, I am extremely grateful to have received tremendous support from my family who have forever been the pillar of my strength, while not forgetting to mention my wonderful husband for his patience, faith and love.

ABSTRACT

The Chlorination process in a glove manufacturing industry aid as a surface treatment on the latex surface by improving the surface frictions allowing the donning of the glove. A cooling system in chlorination process functions to replace and displace the heat from hot chlorine water and thus lowering the temperature by returning the colder water back to the chlorine water tank. Current chlorination cooling system used in Top Glove factories proven inefficient to achieve the desired chlorine water temperature in the chlorination process due to several factors such as high utility rate and energy consumption, cooling tower design and production processes. Energy losses are one of the major concerns especially in process where equipment and heat integration system design are outdated. In this paper, the optimization of the current chlorination cooling system in glove manufacturing industry was assessed by two methods; the heat integration analysis and direct integration of lithium bromide heat pump. Although there are not many applications of heat pump scenarios in engineering practices, studies have shown that heat pumps are effective in improving low-quality heat energy in energy conversion systems. The main goal is to determine the savings that can be generated through retrofitting the current design of the overall system as well as identifying the optimum cooling system suitable to be implemented in chlorination process in glove manufacturing industry based on thorough economic analysis. The energy saving and the cost savings obtained from both methods are evaluated and compared to determine the feasibility of its implementation to the existing system, which results at 99.59% for the retrofit of the existing system and 35% for the direct approach design. However, for combined design for the grassroot design was up to 135 % in terms of cost saving for the both utilities and chemical savings.

ABSTRAK

Proses klorinasi pada sarung tangan getah membantu untuk rawatan permukaan latex atau susu getah yang diprocess. Ia juga membantu mengurangkan geresan pada permukaan sarung tangan gedah untuk memudahkan pemakaiannya. Sistem penyejukkan amat penting untuk proses klorinasi dalam industri pembuatan sarung tangan getah kerana ia akan merunkan suhu panas tanki klorin. Sistem semasa yang digunapakai di kilang Top Glove tidak effektif untuk mencapai suhu yang rendah di proses klorinasi disebabkan beberapa factor seperti reka bentuk sistem penyejuk, pengunaan tenaga dan bahan kimia yang tinggi dan proses produksi itu sendiri. Pembaziran tenaga juga adalah masalah utama dalam proses ini. Kajian ini dilakukan untuk mengoptimumkan penyejukkan proses klorinasi di Top Glove dengan mencadangkana dua kaedah iaitu *Pinch analysis,* dan mengunakan *lithium bromide adsorption heat pump* sebagai system pra-penyejukkan untuk menara penyejuk yang sedia ada. Walaubagaimanapun, kaedah ini belum diterokai oleh penyelidik secara menyeluruh dalam sistem penyejukkan di semua industri. Matlamat utama kajian ini adalah untuk mencapai and tentukan system penyejuk yang paling efektif bagi digunapakai dalam industri pembuatan sarung tangan getah. Penjimatan tenaga sebanyak 99.59% boleh dicapai melalui kaedah *Pinch analysis*, sementara, Penjimatan tenaga sebanyak 35% dicapai bagi kaedah *lithium bromide adsorption heat pump*. Tambahan pula, kombinasi kedua-dua kaedah akan memberi kita penjimatan tenaga dan bahan kimia secara menyeluruh sebanyak 135%

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LIST OF ABBREVIATIONS

NR	Natural Rubber
NBR	Nitrile Based or Synthetic Rubber
PHE	Plate Heat Exchanger
EP	Extractable Protein
HVAC	Heating, Ventilating and Air Conditioning
NDDCT	Natural Draft Dry Cooling Tower
EDR	Aspen Exchanger Design and Rating
NDWCT	Natural Draft Wet Cooling Tower
CFD	Computational Fluid Dynamics
HE	Heat Engine
HEN	Heat Exchanger Network
OAT	Optimal Approach Temperature
RPACT	Randomly Packed Air-Cooling Tower
GDS	Greedy Diffusion Search
CCWS	Circulating Cooling Water Systems
MINLP	Mixed Integer Non-Linear Programming Field
Cl2	Chlorine gas
PTA	Problem Table Algorithm
CC	Composite Curve
GCC	Grand Composite Curve
MER	Maximum Energy Recovery

LIST OF SYMBOLS

%	Percentage
ºC	Degree Celsius
º F	Degree Fahrenheit
3D	Three Dimensional
Pa	Pascals
kcal/kg.°C	Heat Capacity
FCP	Flowrate of Heat Capacity
DH	Enthalpy
Ts	Supply Temperature
Tt	Target Temperature
Ts'	Shifted Supply Temperature
Tt'	Shifted Target Temperature
Tmin	Smallest temperature difference
Tpinch,hot	Hot Pinch Temperature
Tpinch,cold	Cold Pinch Temperature
QHInitial	Initial Hot Utility
QCInitial	Initial Cold Utility
QHmin	Mininum Hot Utility
QCmin	Mininum Cold Utility
Qrec	Recovered Energy
kW	Kilowatt
TLM	Logarithmic Mean Temperature Difference
kg/hr	kilogram per hour

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CHAPTER 1

INTRODUCTION

1.1 Problem Background

Top Glove Corporation Bhd is the world's
operations spanning across Malaysia, Thailand, China, US and Europe. Top Glove success story began a quarter of a century ago in 1991, as a local business enterprise with a single factory and 1 glove production line. Today, it has captured 25% of the world market share and offers a comprehensive product range, fulfilling demand in both the healthcare and non-healthcare segment. Top Glove serves a network of over 2,000 satisfied customers in more than 195 countries, and these numbers are still growing. Its outstanding achievements and global recognition are credited largely to its founder Tan Sri Dr Lim Wee Chai, the visionary and driving force, who within a short span of time has built the Malaysian-based company into a resounding global success. With customer satisfaction as a key priority, Top Glove continues to produce high quality gloves at an efficient low cost in line with its time-tested Business Direction. Not content to rest on its laurels, Top Glove has also set next-level goals to aspire towards, which include increasing its world market share to 30% by 2025 and becoming a Forbes and Fortune Global 500 Company by 2030. It is also aggressively expanding its business scope and on the lookout for M&A opportunities in similar and related industries.

Gloves are used vastly around the globes as it proven to provide a protection layer against microorganisms. Rubber gloves are divided into two main types, which are Natural Rubber (NR) and Nitrile Based or Synthetic Rubber (NBR). NR gloves are preferred globally due to it ablility to provide protective barriers against bacteria and viruses (Yip *et al*., 2002). Various studies have shown that there are different methods for producing powdered and powder-free gloves. Top Glove produces its top quality rubber gloves through a series of dipping process, whereby the hand mould known as formers are dipped into various types of chemicals inclusive of latex, coagulants and chlorine water. Figure 1 below shows the schematic flow diagram of glove manufacturing process. The glove manufacturing process begins with former cleaning process, followed by coagulant, latex, hot water and series of oven for drying purposes and ends at stripping and packing. All these tanks have functions of their own in order to produce high quality glove. These processes require a specific operating condition and parameters to be maintained in order to ensure high quality end-product.

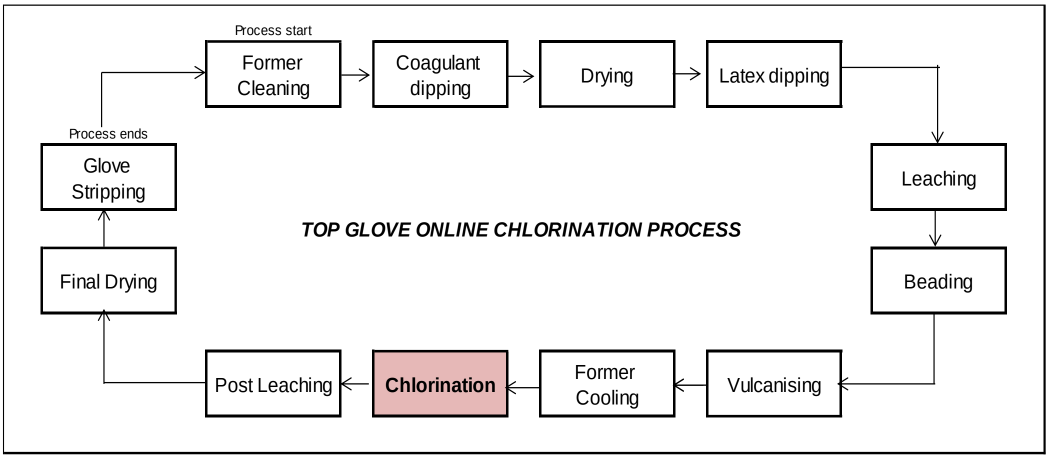

Figure 1.1: Schematic flow diagram of glove manufacturing process

The chlorination process in the manufacturing of rubber gloves is conducted in the chlorinator either by way of online or offline chlorination. Gloves are dipped into tank filled with diluted chlorine water up to required concentrations as it enters the production process. Chlorination processes improves donning of gloves by reducing the friction on gloves' surface. During th water, the hot former reacts with chlorine water, to release chlorine fume. In order to combat higher evaporation rate of chlorine fume, it is very crucial to maintain the temperature of the dipping tank at least below 30^{o}C. Therefore, the most efficient and effective cooling system need to be introduced for maintaining and controlling the desired temperature of the chlorine water in the dipping tank.

A cooling system in chlorination process functions to replace and displace the heat from hot chlorine water and thus lowering the temperature by returning the colder water back to the chlorine water tank. The cooling system used in Top Glove for chlorination’s cooling processes are cooli pumps coupled with plate heat exchanger (PHE) for each individual production line. Currently, in the market, the equipment that are able to provide cold water for industrial processes are cooling towers, chillers, refrigerant and other, meanwhile, heat exchanger equipment ranges from plate heat exchanger, shell-and-tube heat exchanger, double pipe heat exchanger, condenser and evaporators. The cooling systems used in industrial process require high energy consumption and water consumption unless its usage is optimized. In order to achieve this, extensive study need to be conducted and implemented to identify the optimum cooling equipment and system for chlorination process in glove manufacturing industries.

1.2 Problem Statement

Current chlorination cooling system used in Top Glove factories has proven inefficient to achieve the desired chlorine water temperature in the chlorination process due to several factors such as high utility rate, high energy consumption, cooling tower design and production process parameters as to name a few.

As mentioned above, one of the major factors is high utility rate. This is majorly caused by the high-water consumption that leads to water wastages in cooling tower system. Cooling towers design has a large and exposed water holding tank. Evaporation of water occurs at the exposed water surfaces. Furthermore, the water level of the cooling tower holding tank needs to be frequently checked and maintained with a mechanical float valve. Any failure in the mechanical device will result in discharge of water from the holding tank. Both situations mentioned above will cause water wastages as well as increase in water consumption. An average water usage for cooling tower is approximately 15m3/hr.

The selections of the most effective cooling system for industrial processes are largely affected by the energy consumption rate as well. Electrical energy consumption plays a crucial role as there are limitations in terms of costs and budgeting during designing and purchasing a cooling system. Water cooled chiller and air-cooled chiller have higher energy consumption rate compared to cooling tower due to using larger motor sizes and the use or evaporator. Cooling tower on the other hand, only requires small sized motors and pumps to operate (Cutillas et al., 2017). Besides, poorly maintained equipment will result in high power consumption due to higher load on the system and equipment.

Apart from that, another issue that arise from the existing cooling system design in Top Glove where the equipment either is oversized and undersized cooling tower. An oversized cooling tower has a higher capacity, workload and electrical load and vice versa. Few older factories in Top Glove have undersized cooling towers for several reasons, such as changes in production parameters overtime and increased in number of production lines to cater for heat reduction. When parameters such as line speed, oven temperatures and wet tanks temperature is increased, the heat load at chlorine tank will also increase. Therefore, the under-capacity cooling tower will not be able to effectively reject the entire heat load and achieve the desired chlorine water temperature. To combat these unexpected parameters changes in future, cooling towers are designed for larger capacity. This oversized design however is not an optimum design for cooling purposes as more wastage tend to take place. The objective to reach the low chorine water temperature is still not efficiently achieved through cooling tower systems for chlorination process.

Abovementioned problem also arises due to the inconsistency of production processes and parameters. Troubleshooting the production processes will often lead to changes in parameters, especially increase in oven and wet tank temperatures and production line speed. When oven temperature is increased, the heat energy from the oven will be transferred to the former and glove in which relatively spends about 7 to 10 minutes in the main oven zone area. The temperature ranges from 400 to 500 °C. Throughout this process, the ceramic former mainly absorbs the large amount heat energy provided by main oven, due to its nature of having specific heat capacity of 1.0883 kg/kcal.

1.3 Objectives of Study

The main objectives of this study will be as follows;

1. To evaluate existing chlorination cooli
2. To perform systematic optimization of the chlorination cooling system by utilizing heat integration analysis
3. To retrofit the current chlorination cooling system by optimizing it in achieving the most energy efficient process design.
4. To compare and identify the most energy efficient chlorination cooling system based current industrial setup and requirement.

1.4 Scope of Study

In order to implement this research, a careful consideration of the scope of study are identified and defined as below;

1. Perform state of the art analysis on different types of cooling systems for chlorination process in glove industry.
2. Performing data collection from actual chlorination cooling system process in Top Glove factory.
3. Perform heat integration analysis and retrofit analysis of the current design to obtain the Maximum Energy Recovery (MER) based on existing data.
4. Perform detailed cost analysis on energy recovery and utility savings.
5. Compare and analyse results of different approaches of chlorination cooling systems in order to identify the most effective cooling system based on low cost, energy saving obtained for chlorination process in glove industry.
6. Identifying the optimum cooling system which is suitable for chlorination process in glove industry.

1.5 Significance of Study

Through this research, we can contribute positively to the company based on the output that we obtain. This benefit is described as below;

1. This study shall be able to help glove manufacturing industries to improve on its chlorination cooling system and process.
2. An improved Chlorination cooling system and process will be economical in terms of cost, electricity consumption and water consumption.
3. This research benefits to reduce chemical wastages in terms of losses of Chlorine gas from the chlorination process.
4. The research finding will lead to an optimized Chlorination process with reduced energy wastages as well as increased productivity rate.

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