ENHANCEMENT OF COOLING SYSTEM FOR CHLORINATION DIPPING PROCESS IN RUBBER GLOVE MANUFACTURING

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DEDICATION

This project report is dedicated to my father, who taught me that the best kind of knowledge to have is that which is learned for its own sake. It is also dedicated to my mother, who taught me that even the largest task can be accomplished if it is done one step at a time.

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ABSTRACT

Since the Industrial Revolution, manufacturing industries had been too focused on outputs and neglecting other factors that might be affecting the cost of production. However, in this era, industrialist have been giving more thoughts and thinking ways to further improve their cost of production in order to maximise their profits. This is where the concept of Lean Manufacturing was used and applied in many industries especially in manufacturing industry. With that, chlorination process is an important process part in the whole powder-free rubber glove manufacturing. The main ingredient of this process is the utilisation chlorine gas to produce chlorine water for the chlorination system process. Based on journal reviews and real-time experience, it was found that chlorination system is very sensitive to temperature, in which led to a great potential of cost saving option if we are able to manipulate the temperature of the chlorine water. With the help of the journal reviews and ideology to save the consumption of chlorine gas via manipulating the temperature, the cost of chlorine gas consumption to produce chlorine water can be reduced. This can be achieved by using the suitable cooling material and cooling liquid. The savings in term of chlorine gas consumption cost and electrical energy savings in the hybrid system design were also calculated in this study. The results for the study are 15% reduction on the overall costs and reduction of energy load by 44% by implementing hybrid cooling system

ABSTRAK

Sejak Revolusi Perindustrian, industri pembuatan terlalu tertumpu pada jumlah pengeluaran dan mengabaikan faktor lain yang mungkin mempengaruhi kos pengeluaran. Walau bagaimanapun, dalam era ini, industrialis telah memberikan lebih banyak pemikiran dan cara berfikir untuk meningkatkan lagi kos pengeluaran mereka untuk memaksimumkan keuntungan mereka. Di sinilah konsep '*Lean Manufacturing*' digunakan dan diterapkan dalam banyak industri terutamanya dalam industri pembuatan. Dengan itu, proses pengklorinan merupakan sebuah proses yang penting dalam keseluruhan pembuatan sarung tangan getah bebas serbuk. Bahan utama proses ini ialah penggunaan gas klorin untuk menghasilkan air klorin untuk proses sistem pengklorinan. Berdasarkan ulasan jurnal dan pengalaman masa nyata, didapati sistem pengklorinan sangat sensitif terhadap suhu, yang membawa kepada potensi besar pilihan penjimatan kos jika kita dapat memanipulasi dan mengawal suhu air klorin. Dengan bantuan ulasan jurnal dan ideologi untuk menjimatkan penggunaan gas klorin melalui memanipulasi dan pengawalan suhu, kos penggunaan gas klorin untuk menghasilkan air klorin dapat dikurangkan. Ini boleh dicapai dengan menggunakan bahan penyejuk dan cecair penyejuk yang sesuai. Penjimatan dari segi kos penggunaan gas klorin dan penjimatan tenaga elektrik dalam reka bentuk sistem hibrid turut dikira dalam kajian ini. Keputusan untuk kajian adalah pengurangan 15% ke atas kos keseluruhan dan pengurangan beban tenaga sebanyak 44% dengan melaksanakan sistem penyejukan hibrid

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LIST OF ABBREVIATIONS

degC		Degree Celcius
kg/hr	-	kilogram per hour
kW	-	kiloWatts
kWh	-	kiloWatts per hour
pcs/hr		glove pieces per hour

LIST OF SYMBOLS

°C	-	Degree Celcius
%	-	Percentage

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CHAPTER 1

INTRODUCTION

1.1 Research Background

The biggest maker of rubber gloves in the world, Top Glove Corporation Berhad, with 50 production sites operating in countries including Malaysia, Thailand, Vietnam, and China, providing and serving more than 2,000 clients in 195 different nations. When Top Glove first began as a small local firm with just one glove production line in one plant, it had already seized 26% of the global market for rubber gloves. Tan Sri Dr. Lim Wee Chai, the creator of Top Glove, was the visionary and motivator who turned it into a resounding worldwide success when it was listed in Bursa in 2001, Singapore Exchange in 216, and Hong Kong Stock Exchange in 2021. Top Glove prioritises customer happiness above all else and keeps producing high-quality gloves at an affordable price in accordance with its tried-and-true Business Direction. Top Glove, not content to sit on its laurels, has also established next-level objectives to strive towards, such as doubling its global market share to 30% by 2020 and joining the Fortune Global 500 by 2040. Additionally, it is actively broadening the scope of its operations and searching for M&A possibilities in adjacent and congruent sectors of the economy.

There are now several types of raw materials available on the market that are used to make rubber gloves, but there are primarily two sorts. To make Natural Rubber (NR) gloves, one uses natural latex, while to make Acrylonitrile Butadiene Rubber (NBR) gloves, one uses synthetic latex.

Hevea brasiliensis latex, a milky liquid produced by tapping Hevea tree bark, is the raw material for NR goods. Proteins, carbohydrates, and other organic and inorganic components are present in latex, as they are in all plant materials. The elastic component sought after in all NR products, the rubber hydrocarbon particles, make from 25 to 45 percent of the latex cooling system (Yip and Cacioli 2002).

Natural rubber latex (NRL) disposable gloves are "sticky" or "tacky" by nature since they are manufactured. If not coated during production with some sort of powder or lubricant, a glove will:

(a) remain attached to the hand-shaped mould from which it was made, frequently ripping when released;

(b) stick to itself within the glove as it is being packed and stored, making forced donning nearly difficult and making the glove vulnerable to ripping;

(c) stick to the gloves on above and below them, making it challenging to remove them from one another (bricking);

(d) be difficult to put on when trying to put the glove on because they stick to the hand (the negative effect is accentuated when hands are wet);

(e) be overly sticky, which makes it challenging to accomplish tiny tasks (remove tape and labels, let go of small things);

(f) get moist on the inside when worn because there may not be enough absorbency to lessen the build-up of sweat (Truscott 2002)

There are several ways to improve the donning and reduce tackiness of rubber glove (Truscott 2002) & (Preece et al. 2021)

1) Powder slurry coated glove using corn starch
2) Polymer coated
3) Chlorinated

1.1.1 Glove Manufacturing Process

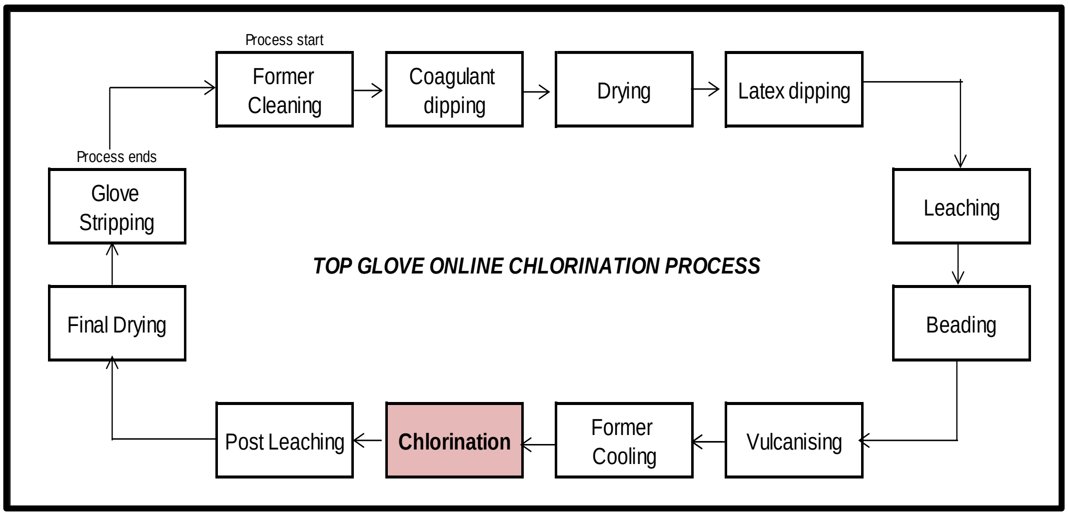
As personal protective equipment (PPE), rubber gloves are worn to prevent contact with potentially harmful, infectious, irritating, or sensitising substances (Geier et al. 2003). Rubber gloves provide defence not only against physical and chemical harm but also against viral and bacterial infection (Akabane 2016).

Natural rubber (NR), polyisoprene rubber (IR), acrylonitrile butadiene rubber (NBR), and chloroprene rubber are the latices that are nearly primarily employed in the dipping process (CR). When the rubber tree's bark sustains damage, it secretes NR latex, an opaque, sticky liquid. It is an emulsion of rubber particles distributed in an aqueous solution as a colloid (particle size: 0.3-2.0 mm); in addition to 35–50% rubber, it also contains trace quantities of protein, resin, carbohydrates, and other substances.

The dispersion phase is positively charged whereas the rubber particles are negatively charged. On the other hand, IR, NBR, and CR latices, together referred to as synthetic rubber latices, are made up of 0.1–1.0 mm polymer particles that are disseminated in water thanks to a protective surfactant layer, etc. By emulsion polymerization or polymer emulsification by mechanical shearing, synthetic latex is produced. The method, which can be batch, semi-batch, or seed polymerization, controls the polymer content as well as the particle size, shape, and size distribution. Other methods include two-stage seed swelling polymerization, in which a seed latex is pre-swelled with an organic third component, thereby increasing the monomer content of the particles, and soap-free polymerisation, which makes use of the surfactant capacity of oligomer lightly polymerised with initiator present in the aqueous phase.(Akabane 2016)

Manufacturing rubber gloves is a continuous operation that uses moving and rotating machine elements, such as conveyor chain and sprockets. The earlier cleaning process is the first step in the rubber glove manufacture process. Formers, often called moulds, are objects that mimic the shape of the human hand, including its fingers, palm, and arm. Then the former enters the coagulant tank for a dip. Coagulant tanks are made of chemicals that adhere to the surface of the former to help latex adhere to it more effectively. Additionally, the former goes into the oven for drying after coagulant dipping, and then it goes into the latex tank for dipping.

The former will be dipped into a tank of hot water for the leaching process after being covered in a latex coating. The surplus chemicals will be removed throughout this procedure. The formers then proceeded on to a sequence of carpet beading, where the top portion of the glove film would be rolled to a specific thickness to produce the round beading. In order to successfully complete the vulcanizing process that results in the glove, the formers will then spend a considerable period of time in the hot oven. After leaving the oven, the hot formers are dipped into a cooling tank filled with room temperature water to bring the formers' temperature down before they are dipped into the chlorination tank. Gloves on formers are dipped in the chlorination tank for a long period of time in order to smoothen the surface of the glove, a process known as donning, which makes wearing the glove easier. The cycle continues when the glove moves on to the post-leaching tank and final drying oven following the chlorination process.



1.

Figure 1.1 Schematic flow diagram of glove manufacturing process

1.1.2 Glove and Former Cooling Process

Formers and wet latex film are placed in a succession of ovens before gloves and formers are added to the cooling process. 200 pieces of double former with interloping and folded conveyor chain are planned to be accommodated by one oven unit. Depending on the area that is available during plant design and line configuration, a series of ovens may have 4 or 5 oven units. Zone 1, Zone 2, Zone 3, and so on are labels for each oven. For NBR gloves, the sequence of oven zones will be maintained at temperatures between 100°C and 180°C, and for NR gloves, between 120°C and 200°C. To finish the vulcanization process in the latex that transforms latex film into gloves on the former, gloves are placed into ovens.

Gloves and formers are dipped into a series of tanks known as the cooling tank after the main oven, before the gloves are dipped into the chlorine tank. A series of cooling tanks is made up of three to four stainless steel tanks that are each filled with water that is room temperature and comes from a water pipe. The cooling tank's purpose is to lower the temperature of the gloves and formers when they depart the high-degree oven and enter the chlorine tank.

It is very pertinent for the temperature of gloves and formers to be as low as possible as chlorine ions in the chlorine water tends to evaporate to fume easily upon the introduction of the heat. Evaporation of chlorine ion from the chlorine water affects the concentration of chlorine water. By controlling the concentration of chlorine water within the specified standard ensures the donning process of the glove completes successfully.

Reduction of chlorine water concentration means high consumption of chlorine gas is required. 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 cooling tower, which includes a cooling tower, pumps coupled with plate heat exchanger (PHE) for individual production line. The cooling process of the chlorination water starts at the chlorine storage tank, whereby the overflow of the chlorine water from dipping tank goes into the storage tank, the water latter will be pumped to PHE. In the PHE, the heat from the chlorine water will be displaced by the cold cooling tower water, thus reducing the temperature of the chlorine water lower by 5 to 6^{o}C.

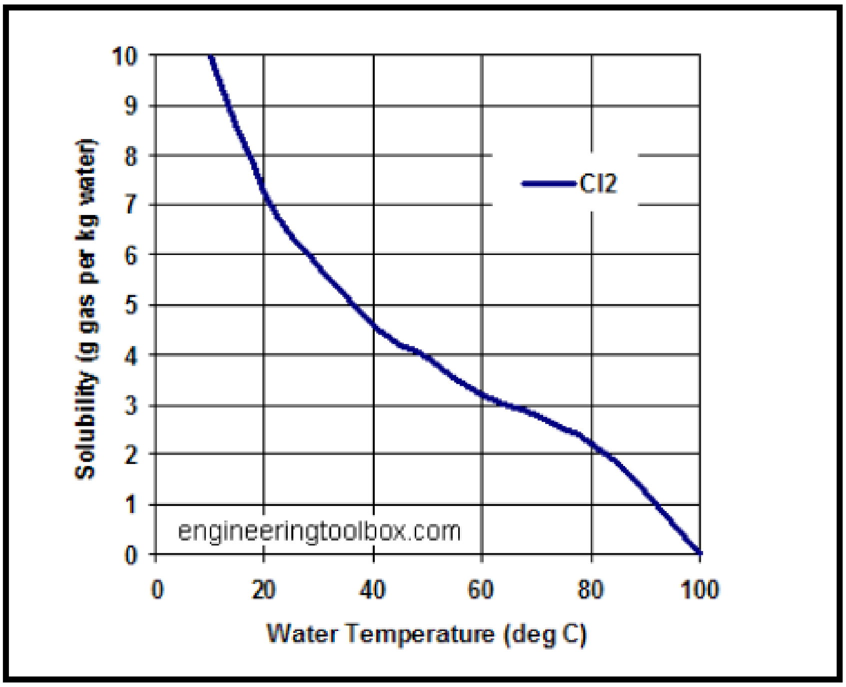


Figure 1.2 Graph of Solubility of Chlorine gas in water

In general, chlorine water is an unstable substance because the electrons may readily separate, creating free chlorine ions. According to Figure 1.2 above, chlorine molecules are not very soluble in chlorine water. The chlorine molecule's link will break under the influence of high heat and agitation, releasing a fume. High chlorine water temperature will be produced in the chlorine tank as a result of continuous production dipping. More heat will be transferred into the chlorine tanks as a result of the high oven temperatures and ineffective cooling water tanks. The heat load on the current cooling tower for heat reduction will rise as a result. Despite having a boiling point of 108 °C, chlorine water will ultimately get agitated by frequent and rapid hot currents, which will trigger the discharge of chlorine fume. More pure chlorine gas had to be pumped into the cooling system since more chlorine fumes were being lost through evaporation and continual manufacturing. This will eventually result in higher monthly chemical use. ***Sen et al. (2001)***.

Due to the high solubility of chlorine gas in water and the high concentration of chlorine water produced during dosing at low flowrate, it is important to maintain a lower water temperature.

1.2 Problem Statement

The chlorination process in Top Gloves uses pure chlorine gas. The optimum concentration of chlorine water required for the rubber glove manufacturing process is being prepared by controlling the flowrate of the chlorine gas let to pass in the ejector. However, there are other factors responsible to ensure the prepared chlorine water is in optimum concentration and one of it is temperature being the biggest factor of all. Based on chlorine gas solubility curve, the lower the liquid temperature, the lower the flowrate required to achieve optimum concentration of chlorine water.

However, in current operation in Top Glove, due to insufficient heat being rejected in the chlorine water, higher flowrate is required to dose, in order to attain optimum required concentration. Due to this, the management had allocated some budget to the chlorination team to conduct a R&D study in lowering temperature of chlorine water to lower down the cost of consumption of chlorine gas.

1.3 Objective of Study

The main objective of this study will be as follows;

1. To compare between two types of heat exchanger and two types cooling unit utility that can contribute for better cooling of chlorine water
2. To evaluate the most appropriate cooling system in chlorination process that can:
   i) reduce the consumption of chlorine gas in daily operation and the cost saving
   ii) consume least amount of electricity.

3) To find the most appropriate cooling system that can balance both reduction in chlorine gas consumption while minimising electricity usage.

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. Preforming analysis on the types of cooling utility water required for chlorination cooling system
2. Performing analysis on the types of cooling equipment required for chlorination cooling system
3. Identifying parameters for cooling system in chlorination cooling system in Top Glove Sdn.Bhd.
4. Performing data collection & comparison analysis from previous cooling system and newly R&D cooling system.
5. Comparing and analysing results of different cooling systems in order to identify the most effective cooling system based on optimum cost, energy consumption and water consumption while reducing high consumption of chlorine gas for
6. Identifying the optimum cooling system coupled with cooling equipment on the most suitable for chlorination process in glove industry.

1.5 Significance of Study

1. To contribute to the company by saving the cost in chlorination cooling system in rubber glove making production process
2. To contribute to the company in energy saving in chlorination system process.

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