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Pump System Optimization through Pumping System Assessment Tool (PSAT): Case studies in Johor and Sarawak Manufacturing Plants

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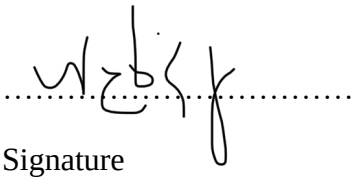
DECLARATION

I declare that the work in this thesis was carried out in accordance with the regulations of Universiti Malaysia Sarawak. Except where due acknowledgements have been made, the work is that of the author alone. The thesis has not been accepted for any degree and is not concurrently submitted in candidature of any other degree.



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ABSTRACT

Pumping System Assessment Tools (PSAT) is a tool that can be used to assess the pump system. Targeted pump in Plant A and B had been identified to apply energy savings. Through PSAT, end user can calculate electricity consumption, pump optimization rating and annual savings consumption and savings opportunities that can be done through PSAT. In this research stud, Plant A which is located in Peninsular of Malaysia, is glove manufacturing plant. Meanwhile, Plant B which is in Sarawak is cement manufacturing plant. Targeted pump for both plants has been identified to apply the PSAT. Condition of the pump, lifespan, running hours were taken into considerations before selecting the targeted pump. To optimize pump parameters, further analysis was conducted on the pump using PSAT. Annual savings potential for the existing performance of the system can be compared with the optimal condition that is suggested by the PSAT database. Annual savings potential for Plant A is found to be RM 7,500 meanwhile for Plant B, about RM 16, 500 annual savings potential that can be saved. Through this research study, pump system limitation to collect the data is the research limitation as some parameters were not available during walkthrough energy audit and data collection. The present of PSAT is great tools to be used to assist user to do preliminary assessment for each of the pump system available in the plant. Condition of the pump was varied by increasing the flow rate of the pump which will lead to higher pump efficiency, thus bring saving opportunities to the user.

Keywords: Energy savings opportunity, Pump system, Annual savings, PSAT, Walkthrough energy audit

Pengoptimuman Sistem Pam melalui PSAT: Kajian kes di Kilang Pembuatan Johor dan Sarawak

ABSTRAK

Alat Penilaian Sistem Pam (PSAT) telah digunakan untuk menentukan peluang penjimatan yang boleh dilakukan melalui sistem pam di kilang pembuatan. Pam ialah salah satu pengguna elektrik tertinggi di loji, pam sasaran di Loji A dan B telah dikenal pasti untuk menjimatkan tenaga. Melalui PSAT, pengguna boleh mengira penggunaan elektrik, penarafan pengoptimuman pam dan penggunaan penjimatan tahunan dan peluang penjimatan. Dalam kajian ini, Loji A yang terletak di Semenanjung Malaysia adalah kilang pembuatan sarung tangan. Manakala, Loji B yang berada di Sarawak ialah sebelum memilih pam yang disasarkan. Potensi penjimatan tahunan untuk prestasi sedia ada sistem boleh dibandingkan dengan keadaan optimum yang dicadangkan oleh pangkalan data PSAT. Anggaran penjimatan bagi Loji A didapati RM 7,500 manakala Loji B, kira-kira RM 16, 500 potensi penjimatan tahunan yang boleh diperolehi kerana terdapat beberapa parameter tidak tersedia semasa audit tenaga panduan dan pengumpulan data. PSAT adalah alat yang boleh digunakan untuk membantu pengguna membuat penilaian awal bagi setiap sistem pam yang terdapat di loji.

Kata kunci: *Peluang penjimatan tenaga, Sistem pam, Penjimatan tahunan, PSAT, Audit tenaga*

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LIST OF ABBREVIATIONS

ac	Alternating current
ANSI	American National Standard Institute
BEP	Best efficiency point
BEMS	Building Energy Management System
CO	Carbon Monoxide
CO_2	Carbon Dioxide
cP	Centipoise
dc	Direct current
EMS	Energy Management System
FLA	Full Load Amps
HL	Head Losses
Hs	Static Head
HVAC	Heating, Ventilation and Air-conditioning
I/C/F/EMS	Industrial, Company, and Factor Energy Management System
NO_X	Nitrogen Oxide
NPV	Net positive suction head
Ns	Specific Speed
Nss	Suction Specific Speed
PSAT	Pumping System Assessment Tool
SDGs	Sustainable Development Goals
SO_2	Sulphur Dioxide
UNIDO	United Nations Industrial Development Organization

CHAPTER 1

INTRODUCTION

1.1 Study Background

Energy is a main need for different purposes in industrial facilities around the world. For economic competitiveness and employment, energy has become a crucial factor in current faster economic growth. With the recent global population, with rapidly increasing energy needs, this scenario must be addressed to avoid shortage of energy in the future. In addition, it is important to raise awareness of its adverse impact on the environment. In rational use of energy concept, main aims are reduction of how the energy has been used and optimum usage of the limited resources.

This project was conducted in two manufacturing plants, Plant A is an Examination Nitril Powder Free Glove Plant which is in the southern coast of Malaysia, Johor and Plant B is producing cement product which is in Sarawak. These two manufacturing plants are consuming energy the whole year, running all machines 24 hours in 365 days a year. Thus, energy savings is crucial to survive between production and profit.

In this thesis, both factories have been chosen. An energy audit and collection of data throughout the whole plant were conducted to see any potential machine for energy savings opportunities. Survey, questionnaire to the person in charge of the machines has been conducted to understand further how the machines are operated.

The United Nations Industrial Development Organization (UNIDO) has provided free tools called PSAT which are Pumping System Assessment Tools to be used for manufacturers or organizations. The pump system operations can be analysed through

PSAT. Potential savings in energy and cost can be calculated with the data obtained from Hydraulic Institute Standard and the motor performance can be obtained from Motor Master. Based on field-measured data, the application is allowing users to calculate savings opportunities in their pumping system. Annual energy usage and their costs for existing and optimal equipment also can be provided through PSAT.

Many benefits can be obtained by using PSAT, one of them is the efficiency of the system can be established and potential in energy savings can be quantified. Through these, our economics can be examined, and the effect of energy can be observed at different operating cases.

Benefits of PSAT include establishing system efficiency, quantifying potential energy savings, examining the economics and impacts of energy at different operating scenarios. Although PSAT will not provide users how to improve the systems, it does allow users to identify the pumping systems for further investigation. In pump systems, there are few symptoms that can be observed by using PSAT pre-screening, for example throttle-valve control for the system, damage or cavitation noise in the system, and continuous operation to support the process. It is challenging to stop the production to meet the production demand as some of the pump is working non-stop and no preventive maintenance being taken.

In most industries, pumps are used to by transferring fluids for processes. It also provides motive forces in hydraulic systems, which pump used to provide cooling to all machineries.

In the glove manufacturing industry, which is Plant A in this study, the pump is very important for the plant. Pumps are working to supply chilled water into all tanks in the production area. Pumps are also used to supply back used water to the chiller system.

Cooling process is important to produce the glove as it may cause defects in the production goods. In the glove industry, the temperature of the tank is crucial as the whole process depends on the temperature given by the tank. Plant B which is CMS Cement Plant Industries Sdn.Bhd, targeted pump is located at water cooling pump house. Pump is running 24 hours in for the whole year and is being used to provide chilled water to all of the tanks in production.

Energy walkabout through the plant has been conducted to assess the pump type, specification, function, and details in both plants. Each specification, process and user needs has been studied to collect all the data needed by the PSAT.

PSAT is a tool that can help to monitor and analyse the pump performance across the plant despite the type of pump. As a result, efficiency of pump and motor, annual energy usage, cost for both existing and optimal condition, annual savings and rating pump optimization can be estimated.

1.2 Problem Statement

In plant manufacturing, high electricity consumption is due to inefficient machinery usage, improper planning, and preventive maintenance. Lack of proper machinery maintenance causes reduction of their lifespan. Improper planning of the machine usage also causes high consumption of electricity. There are many various ways to reduce electricity consumption and one of them is through pump system optimization. By improving efficiency of the pump and to extend the lifespan of the pump, it is important to achieve optimal performance for the pump. Preventive maintenance and monitoring the condition of the pump is crucial to mitigate any potential impact that might cause a drop in pump performance. As an extension of our research, we are motivated to apply a pumping system

assessment tool (PSAT) to targeted pumps to obtain reduction in energy consumption in manufacturing plants. Reduce energy consumption in industrial plant will contribute to achieve one of the Sustainable Development Goals (SDGs) for UNIDO which is climate action. UNIDO has promotes to reduce carbon dioxide emission in industrial sector and other greenhouse gas emissions. This is including sustainable energy solutions, uptake of resource-efficient technologies and practices and cleaner production in industrial processes. Thus, the study to reduce energy consumption through pump system optimization is important as a part in climate action.

1.3 Research Hypothesis

In this study, PSAT tool application will be giving a positive impact to the pump system as energy opportunities can be obtained. If the machineries are being used in optimum condition, the energy consumption will be reduced. If the pump system is not running in its optimum condition, the lifespan of the pump will also be decreased and consuming power. Total amount of greenhouses gases, primarily carbon dioxide, CO2 and other carbon compounds was emitted direct or indirectly by individual, organization and also mostly by any industrial activities. In return, this will cause global warming potentials. There is statistically significant reduction in carbon footprint resulting from energy-saving initiative.

1.4 Objectives of Research

The objectives of this study are:

i. To analyse and evaluate performance of selected two (2) pumps in Johor and Sarawak by using Pumping System Assessment Tool (PSAT).

ii. To investigate the impact of varied flow rate on the pump performance.

iii. To propose system optimization for energy savings opportunities for the pumps

1.5 Scope of Research

To comply with the objectives, there are several considerations and constraints that needto be considered. They are:

i. Pump was selected based on condition of all pumps available in the plant. Only two (2) pumps were selected in this research after assessment had been done. These pumps were selected as both pumps are the oldest pump and were running with highest voltage among the other pumps exist in respective plant. Older pumps have been in operation for a long time and are often part of legacy systems. They might not have been replaced or upgraded due to budget constraints or because they were considered reliable. Older pumps may be less energy-efficient due to outdated technology and wear and tear. Identifying and upgrading these pumps can lead to significant energy savings. Replacing all pumps in a plant can be expensive and cost consuming for the end user. Studying and upgrading older pumps can provide a cost-effective way to improve energy efficiency without a complete overhaul. Older pumps may offer the most immediate and substantial energy-saving opportunities since newer equipment is often designed to be more efficient from the start. Since the management are trying to adopt sustainability goals and commitments, thus by upgrading the older pump within the plant, make less efficient equipment aligns with these goals by reducing energy consumption and greenhouse gas emissions.

ii. Downtime of machineries that may affect the production line. Since the production output demand is important to the operation, it is difficult to have machine downtime. Thus, this study was carried out when the pump is running, and no downtime is allowed.

iii. The flow rate of the pump needs to be measured manually. During energy walkabout, we observed that some of the flow meter was not installed properly. This has caused some delay to assess the condition of the pump and we need to install portable flow meter to the pump to know the flow rate running.

1.6 Chapter Summary

This thesis is divided into five chapters. Chapter 1 describes the overall intention of the study. In this chapter, background of study, research objectives including scope of research are included. Chapter 2 is the literature review revolving on the study that is gathered from confided thoughts research, publications and reports worldwide. This chapter also discusses about energy savings opportunity, pumping system, the main components of the centrifugal pump, best efficiency point (BEP) in pump system, PSAT software including its layout and overview regarding the tool. Chapter 3 explains about the methodology used in completing this project. The main activities in this project include walk-through energy audit at targeted industry and experimental process at industry. Chapter 4 will be discussing on the results and findings of the project. The result gained from the preliminary data collection, taking parameters of the current process pump and from PSAT Software. Discussion on the results will also be reported in this chapter. In the last chapter, Chapter 5, the conclusion will be made based on the data analysis from Chapter 4. Some recommendations on further works will also be provided in Chapter 5.

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CHAPTER 2

LITERATURE REVIEW

2.1 Energy Savings Opportunity

It is about a 33% increase in world marketed energy consumption projected from 2010 to 2030. Total world energy is expected to rise from 82,919 Zettawatt (ZW) in 1980 to 116,614 ZW in 2000, about 198,654 ZW (Abdelaziz et al., 2011) as shown in Figure 2.1.

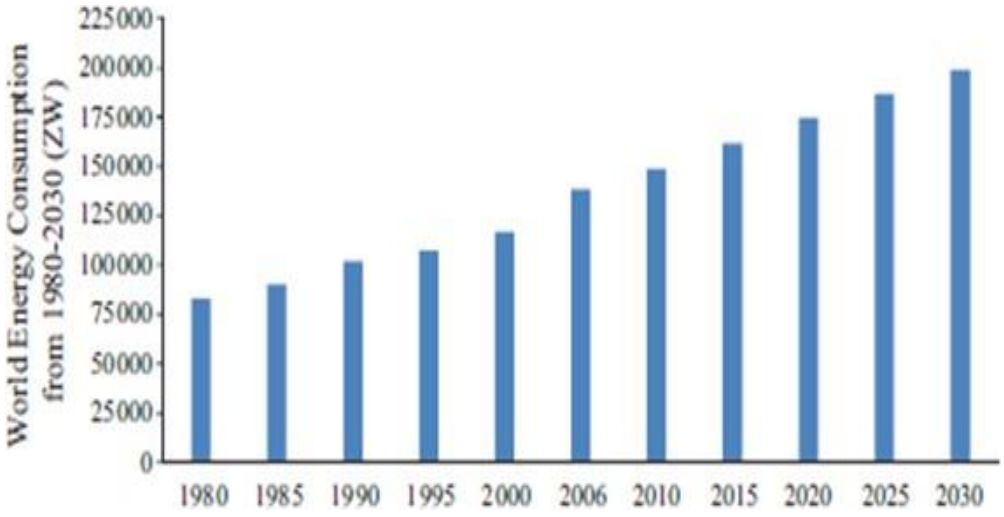

Figure 2.1: World Marketed Energy Consumption from 1980 to 2030 (ZW) (Abdelaziz et al., 2011)

Many industries like manufacturing, agriculture, mining, and construction are consuming energy for bigger range activities like processing and assembly, space conditioning, and lighting (Abdelaziz et al., 2011).

In the next 25 years, worldwide industrial energy consumption is projected to grow from 51,275ZW in 2006 to 71,961ZW in 2030 by an average of 1.4% per year (Abdelaziz et al., 2011) as shown in Figure 2.2.

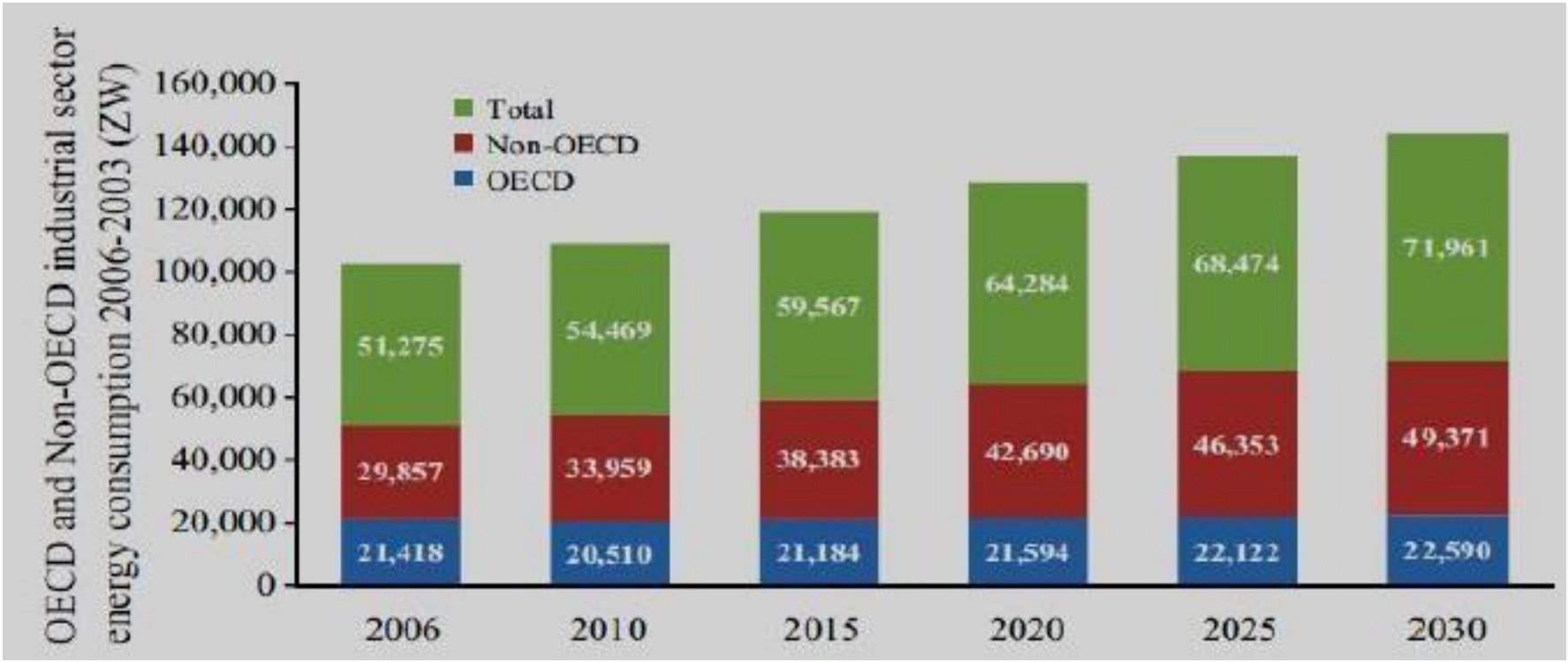

Figure 2.2: OECD and non-OECD industrial sector energy consumption from 2006 to 2030 (Abdelaziz et al., 2011)

From the figure, it can be seen that, from the year 2006 to 2030, shows there is an increasing in energy demand proposed for nations outside the Organization for Economic Cooperation and Development (non-OECD). Greenhouse gas emission, GHG, has been contributed by all various industries. It has been proved in a previous study, 10-30% of GHG emissions can be reduced either with implementation of a few energy savings options with less or zero cost to the industrial sector (Ghaddar & Mezher, 1999). In any building or manufacturing plant, energy savings on major equipment or installed drive can decrease the usage of energy consumption. In 2006, worldwide industrial energy consumption was projected to grow. By an average of 1.4% per year from 51,275 ZW to 71,961 ZW in 2030 for over the next 25 years (Abdelaziz et al., 2011).

In the literature of energy consumption, economic growth and environment are getting attention from the past few decades. The Environmental Kuznets Theory (EKC) is the first theory which reveals a relationship between economic growth and environment. The theory postulates that with the increase in economic growth, the environmental degradation increases till it crosses the peak level (Ang, 2007; Banday et al., 2014; Banday and Ismail, 2017; Saboori et al., 2012). Increase in global temperature is due to increase of consumption of fossil fuels. Previous study output can be seen as being conducted for Asian economies (Qingquan et al., 2020); China (Ahmad et al., 2018); OECD (Ahmad et al., 2020); Pakistan (Chandia et al., 2018); Finland (Kunnas & Myllintaus, 2017); Malaysia (Saboori et al., 2016); BRICS (Danish et al., 2019) and also developing coutries (Sapkota & Bastola, 2017). To cope with deteriorating environment, all these G7 nations have been adopting different eco-innovation strategies. The relationship between the economic growth and carbon emission has been testifies in few researches (Shafik, 1994; Heil and Selden, 1999; Friedl

and Getzner, 2003; Dinda and Coondoo, 2006; Coondoo and Dinda, 2008; Managi and Jena, 2008).

At rate of three to four percent, the global economic growth keep on rising. In an excessive use of fossil fuel gives impact on CO2 emission arising thus result in higher risk to environment (Bennet & James, 2017). In the context of the pollution, from an academic perspective, scholars have examined the international trade-CO2 nexus. In recent years, there are debate from association between international trade and CO2 emission (Ding et al., 2020). In 1960, percentage of gross domestic product (GDP) is only twenty-three percent, which compared to year 2017 which GDP has reached fifty-eight percent, as reported by the World Bank (2019). The cause of rising international trade to the world might increase economic opportunities, but this is also an impact to the ecological damage for example release of CO2 emission (Hasanov et al., 2018).

Current amount of energy and emission in China's cement industry has been also analysed for cement production in various levels from year 2011 to year 2030. Potential for cumulative final energy savings of 27.1 to 37.5 Exajoules, EJ was calculated under the best practice scenarios, which also give reductions by 1.2 Gigatonnes of CO2 for the energy emissions (Ke et al., 2012). Similarly, for the cement industry in Taiwan, under the technical diffusion scenario, around 25% savings for electricity and 9% savings for fuels by year 2035 were estimated in eighteen energy efficient technologies adopted over there (Ke et al., 2012).

Cement industry is observed as the second most energy-intensive user in european country. It is important to understand its promising potential for energy efficiency improvements. In the European market, Levelized Cost of Energy (LCOE) has analysed the energy savings used by modified split pumps and this energy solution has shown promising

results. The calculated LCOE is ranging from 0.440 USD/kWh up to 0.194 USD/kWh depending on the considered hybrid energy solution (Ke et al., 2012). Either petroleum or chemical plants already made a commitment to reduce consumption of energy or usage in terms of thermal, electrical, and mechanical energy.

There are so many ways that can be done to reduce the energy consumption either in plants or in buildings. For example, energy management system (EMS), or building energy management system (BEMS), for building that uses refrigerating, lighting systems, and motors. These are the tools used to study energy saving effects in an industrial plant. Study has conducted and shows that, in a year, about 11.39% to 16.22% savings effects of BEMS can be increased. For effective energy savings, these key EMS functions can be identified (Lee & Cheng, 2016). Negative impact of the trade and economic growth on the environmental quality environment can be reduced by applying cleaner production technologies (Zhang et al., 2017).

In this world, the cement industry has become one of the most intensive industries for energy consumption. It is that estimated at about 2% energy consumption by the cement industry contributes to global primary energy consumption. Processes for cement manufacturing either wet or dry processes cost a large amount in energy cost because high thermal energy is needed for the wet and dry process and electrical energy for operation of motors. Grinding machines, fans system, conveyors of the machine, and equipment used motor driven has caused high energy cost. Cement industry has operated at about 50% of thermal efficiency. High amount of carbon dioxide released by cement manufacturer. Around all man-made CO2 emissions which are about 20% and 10% of global warming