Development of an empirical model for energy usage and machine maintainability: palm oil pressing

By

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22717

Dissertation submitted in partial fulfilment of

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CERTIFICATION OF ORIGINALITY

This is to certify that I am responsible for the work submitted in this project, that the original work is my own except as specified in the references and acknowledgements, and that the original work contained herein have not been undertaken or done by unspecified sources or persons.

(Aisar Amiree Bin Abdul Aziz)

CERTIFICATION OF APPROVAL

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ABSTRACT

Palm oil mill system is one of the essential production processes for producing crude palm oil. Its electricity consumption profoundly influences its cost, machine maintainability as well as its environmental impact. Hence, this research aims to develop, test and verify the relationship between the electricity consumption of the palm oil screw press machine and its maintainability as well as the environmental impact due to the machine condition. In the context of maintainability, the reliability of the palm oil screw press machine is calculated by utilizing Weibull distribution and Maximum Likelihood Estimation method. The energy consumption is measured with the measurement of the electric current in the pressing machine and the carbon emission is indirectly expressed in a norm established by the Climate Registry. Analysis of the model will show the proof that as the reduction in reliability of palm oil screw press machine, its energy consumption spikes. In addition, subsequently the usage of energy is directly proportional to carbon emission, this will also conclude that the carbon emission by the palm oil screw press machine will decrease as the energy consumption decrease. The result indicated that the energy consumption of the palm oil pressing machine dominates the machine effectiveness and environmental carbon emission. Further research is required to identify other factors that could strengthen the evaluation method of the palm oil screw press energy consumption

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INTRODUCTION

1.1 BACKGROUND OF STUDY

After Indonesia, Malaysia is the second biggest producer of palm oil which covers up to 5,849,330 hectares of land based on the field planted with oil palm trees in 2018. Crude palm oil (CPO) output registered up till June 2019, amounted to 9,785,829 tons while the palm kernel (PK) produced 2,457,874 tons [1]. For 40 years, the palm oil industry has experienced remarkable and steady global market growth, and the annual volumes of palm oil in Malaysia are projected to reach 15.4 million tons over the span 2016–2020 [1]. This shows how extensively the industry has grown in recent years. The palm oil industry's duty is extremely important for the economic growth in the countries. The sectors include oil palm mills, oil palm refineries, oleo-chemicals, and palm kernel mills. The first phase of fruit processing is oil palm mills.

Oil palm mills generally yield two output. The primary output is the crude palm oil (CPO) and palm kernel (PK), while biomass as their secondary output. In order to keep the mill self-sustaining, the oil palm mill requires multiple high calorific value of by-products, including empty fruit bunch, fibers, shells and liquid effluent with a high content of organics called the palm oil mill effluent (POME). The palm oil mill includes different unit operations such as sterilize, thresh, digest, press, clarify and depreciate. The outcome from the palm mill can be categorized as either the main product or by-product. The main products for palm mill are the CPO and PK. This original product will be transported to the refinery plant to be further processed [2].

Several items are distinguished as a by-product. They consist of EFB, POME, decanter cake, mesocarp fiber and shell. These by-products are fully utilized either in-mill usage or transported for outside mill applications. Oil palm solid waste (Figure 1.1), therefore, is readily available and a renewable energy and material resource for the country. This therefore offers the palm oil industry the opportunity to use the surplus solid waste as much as possible.

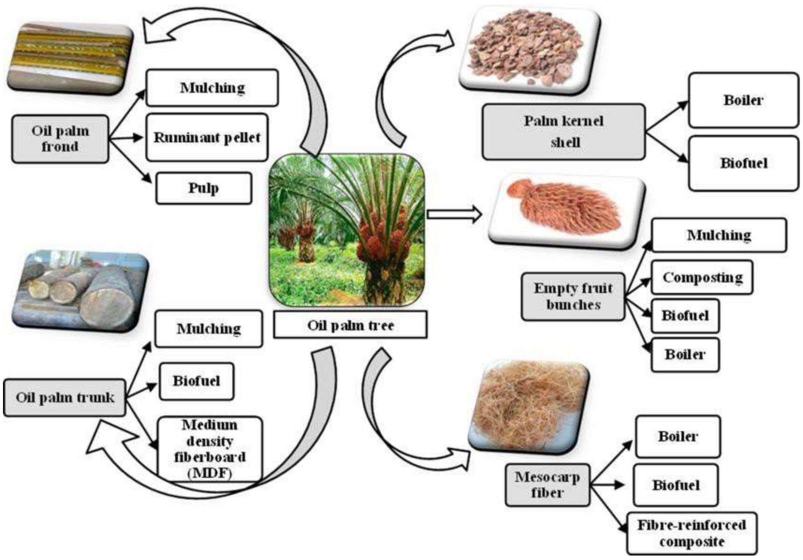

Figure 1.1 : Current usage of palm oil waste [3]

Loss of energy during the processing of palm oil not only raises production costs but also has a negative environmental impact. The energy efficiency of a plant is known to be inversely proportional to the amount of energy it loses; thus, minimizing loss by optimizing processes will result in better use of resources. It is also widely accepted that the utilization of energy can be improved with the improvement of machine performance. Most of the research on the environmental impact of associated processes has centered on trends of energy consumption, thereby reducing energy use as an important element of sustainable production processes.

1.2 PROBLEM STATEMENT

For any industrial sector, energy saving is an important issue, and can help in general to reduce energy cost and environmental effects in the processing industry. Palm oil mill system that consist of various stages of process, is one of the essential production processes for producing palm crude oil. Its electricity consumption profoundly influences the cost, machine maintainability as well as environmental impact. One of the most energy intensive sub-system found in the palm oil mill is the screw press machine. The screw machine is commonly known to be vulnerable to premature failure and to regular breakdown of its operating components due to heavy use.

However, there is not much data available in the industry to quantify the relation between the frequent breakage of the screw press machine to the electricity it consumes. Furthermore, due to insufficient existing infrastructure or lack of measuring devices, energy consumption of processes or machine is seldom recognized. In contrast, human resources and understanding of new and innovative technology were often missing. If there is experience, it is related to individual positions and does not incorporate consistently in programs or systems to enhance production processes.

Consequently, this emphasizes the need for a framework for an accurate evaluation of the energy consumption of the screw press machine. Therefore, this research aims to create a palm oil screw press machine framework to evaluate energy consumption and its relationship to the machine's maintainability, as well as the impact of the energy usage towards the environment.

1.3 OBJECTIVE

The aim of this project is to develop a framework for the palm oil pressing machine in which to evaluate its energy consumption and relationship with the machine's maintainability and also the environmental impact.

Therefore, the objective for the above aim are:

1) To identify the components of a pressing machine and its energy consumption in any related industry.
2) To analyze the relationship between the consumption of energy by pressing machine towards the machine maintainability and environmental impact.
3) To development an empirical model for energy consumption of palm oil pressing machine.

1.4 SCOPE OF STUDY

Due to the vast scope in the palm oil industry which compromising of the palm oil plantation, palm oil mill and refinery, this project was aimed to solely focus on the pressing process in particularly the palm oil screw press machine (POSP) in the palm oil mill sector. The POSP consists of the worm shaft, cylindrical barrel, feeding hopper, electric motor, pulley, cake outlet, oil outlet and the mainframe. This research will specifically cover the energy consumption context and machine maintenance with the addition of the impact of these both parameter towards the environment. Furthermore, this project aims to develop a framework in which to evaluate the empirical relationship between the POSP energy consumption and machine maintainability as well as the impact of energy usage towards the environment.

CHAPTER 2

LITERATURE REVIEW

2.1 OVERVIEW

This chapter will cover the research and studies that is related to the palm oil industry, which is the current status of the palm oil, palm oil mill and also palm oil screw press machine. It will also include the detail study of the energy consumption in relation to the palm oil screw press with its maintainability and also the effect of this machine towards the environment.

2.2 PALM OIL – MILL

Palm oil is an organic vegetable oil derived from the reddish pulp of the fruit, and it is now cultivated mostly in South East Asia, Africa, and Latin America. After Indonesia, Malaysia is the second biggest source for palm oil. In 2018 it was announced that Malaysia has planted up to 5,849,330 hectares of palm oil crops. Average crude palm oil (CPO) output and palm kernel production for the period up to June 2019 was 9,785,829 and 2,447,874 tons, respectively [1]. It is estimated that, by the year 2020, global demand for palm oil will double and triple by 2050, according to the United Nations Food and Agriculture Organization [4]. All of this palm oil trees were cultivated and then taken to a large number of palm oil mills required for processing in the country for its fresh fruit bunch (FFB).

The palm oil mill is made up of a number of processes, including sterilization, threshing, digestion, pressing, clarifying, purification and drying. The crude palm oil (CPO) and palm kernel (PK) is the main product of this processes, while the secondary product is biomass.

The processing of palm oil starts with the sterilization of the fresh fruit bunch (FFB). Once the steam cooks the fruit bunch, it will pass through the threshing process where the fruitlet and calyx leaves are separated from the bunch. In order to allow the pericarp to loosen from the nut and be prepared for oil extraction in a screw press machine, it must be reheated. The digester is usually mounted on the top of the presser so that the digested fruit can be directly fed to the presser. In horizontal configuration, the screw press mechanism is fitted with a cylindrical perforated cage in which a pressure screw is rotated [5,6].

The design of screw's pitch is decreasing manner that results in the increase of pressure applied to the fruitlet and oil is extracted. The expelled oil will flow through the cage holes, and crude oil is produced. The by-product of the important process is the cake which consists of the nut and fiber of the fruit pericarp. The cake is further processed through a subsequent process to retrieve the kernel from the fibers by cracking the shell of the kernel. This process is called nut cracking. The separated kernel and fiber are then stored in the silos. In practical application, the fibers and shell is used to sustain the boiler in the mill for its energy usage to process the palm oil [6].

The extracted crude oil obtained by pressing of the palm fruits includes various quantities of water and impurities of vegetables in which some are insoluble, and some are dissolved in water. Water and impurities in the crude palm oil must be separated to create a pure and stable product with an appropriate appearance. This process is called oil clarification. The overall process of the palm oil mill can be mapped out based on Figure 2.1.

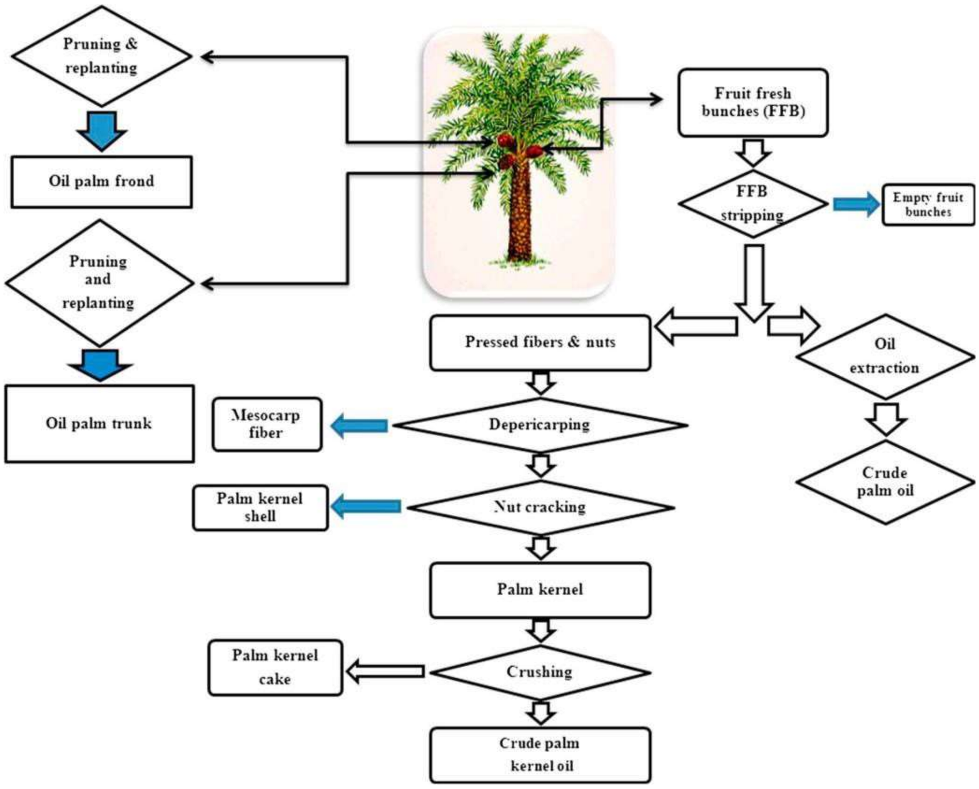

Figure 2.1: Overall palm oil processing flow [3]

2.3 PALM OIL SCREW PRESS

Physically, the screw press consists of a worm shaft, cylindrical barrel, feeding hopper, electric motor, pulley, cake outlet, oil outlet and mainframe. There is a variety of screw configuration with regards to its screw flight, position and the direction of the flight rotation. Initially, the type of screw is divided into 2 type; which is a single and double screw. The position of the double screw breakdown further into four different types of position which is staggered, matched, intermeshing and non-intermeshing. Next, the direction of rotation for the double screw is categorized into two types which is co-rotating and counter-rotating, as shown in Figure 2.2. All of this configuration of the screw press varies according to the application also the capacity of the production.

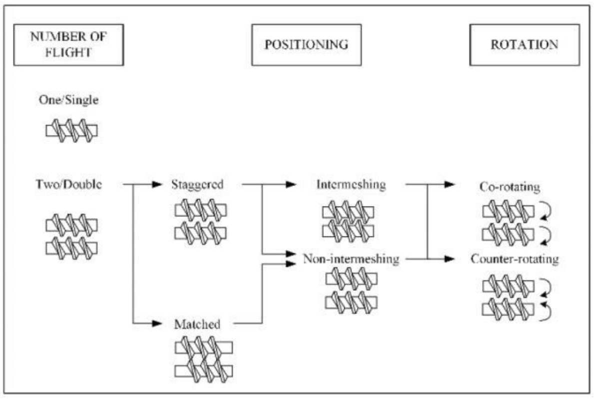

Figure 2.2: Setup of screw press flight in proportion to number, position, and direction of rotation. [8]

Generally, a straight screw shaft with constant pitch and root diameter is commonly used in the screw press machine due to sole purpose of which it is easy to manufacture and is used in the oil extraction industry for a long time. In addition, the screw configuration is not restricted to only of this of configuration. There is another screw configuration (Figure 2.3) that are available in the industry depending on the gradient of pressure it requires, which is:

1) Tapered shaft and constant pitch screw:
2) Variable pitch screw
3) Tapered shaft and variable pitch screw

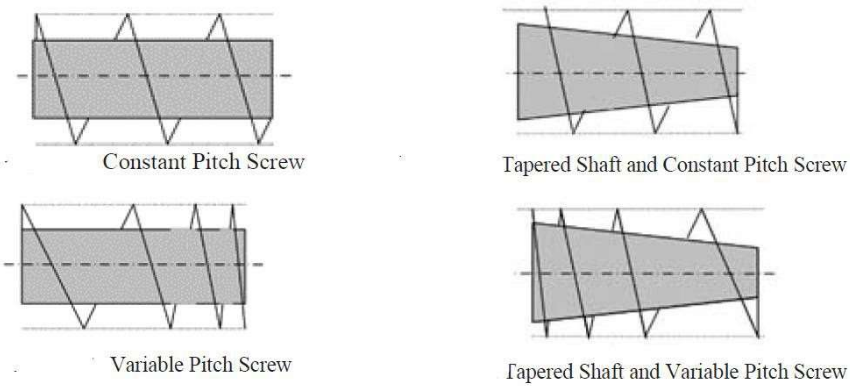

Figure 2.3: Screw configuration with difference in annular area and pitch [9]

An investigation was made in regard to the palm oil screw press in Malaysia because of its well-known reputation for frequent failure (Figure 2.4). The results show that the best screw configuration to be used in the pressing process is a tapered shaft with the constant pitch because it has the highest lifespan of 5948 hours before failure compared to other screw configuration and also a higher range in terms of Von Misses stress. Consequently, it will reduce the maintenance cost and reduce the frequency of maintenance work. The typical material used to produce the screw shaft of the palm oil pressing machine is cast carbon steel and mild steel [9,10].

Malfunction	Reported cause	Valid response		Single press	Double press
1. Screw press unit					
(a) Total operation halt	i. Mechanical breakdown	102	Yes	21	36
	ii. Moving parts jammed		No	12	33
	iii. Clogging due to overfeed		min h[a]	52	81
2. Main parts (press cage, screw flight, adjusting cone)					
(a) Broken drive shaft	i. Fatigue	102	Yes	20	39
	ii. Corrosion		No	13	30
	iii. Hydraulic pressure overload		min h	1000	173
	iv. Presence of foreign object				
(b) Wear and tear	i. Corrosion	91	Yes	27	58
	ii. Poor maintenance		No	2	4
	iii. Quality of material		min h	400	139
(c) Leakage at joints	i. Corrosion	102	Yes	17	34
	ii. Poor welding		No	16	35
			min h	130	97.5
3. Auxiliary parts (driving motor, gear box, hydraulic module)					
(a) Low hydraulic pressure	i. Leak	35	Yes	1	29
			No	0	5
			min h	69	173
(b) Broken coupling module	i. Pressure overload	37	Yes	2	23
			No	0	12
			min h	208	260

Figure 2.4: Malfunction case of palm oil screw press in Malaysia [7]

Operationally, the working principle of the palm oil screw press has almost the same principle with extruder or kneader in other industry with some significant difference. The screw press usually has a single or double screw depending on the mill's capacity. The barrel of the screw press is perforated and usually referred to as press cage. The pressing process of the fruitlet composed of the feed, compression and monitoring section [8,11]. During the feed section, the screw press machine would receive a direct feed from the digester once the fruitlet had passed through some other process which is sterilizing and threshing. With the addition of more cooked fruitlet, the residing fruitlet in the screw press will rearrange in the screw flight cavity. Next, in the compression section, the force applied to the fruitlet is due to the turning of the screw. The velocity of the screw turning is a component of radial and axial direction, and the velocity of it has a high relation to the speed of the motor and screw configuration as discussed earlier. During this phase, water absorbed during the cooking process of the fruit and oil started to dislodge from the fruit and pass through the holes of the press cage. The oil-water mixture will accumulate at the bottom of the press cage.

Additionally, the cake residue will discharge at the cake outlet for further processes with the specification of maintaining 6 to 7 per cent of the nut to free shell ratio. Finally, for a specific period, the pressure on the fruitlet applied by the screw and the hydraulic press will be applied to allow maximum oil extraction (7% w / w residue in press cake). The discharge cone will now be removed to free the fruit mash from the press cage after the oil extraction has been completed [8].

2.4 ENERGY CONSUMPTION

Energy is defined by the ability to do work. It can exist in many forms depending on its association. The word energy is used in industries as a synonym for energy sources referring to fuels, petroleum products and electricity in general, since a large proportion of the energy in such resources can be easily extracted to serve a useful purpose. The energy input in these processes (mainly from electricity) is transformed into useful work, including in the form and composition of products and waste and waste heat. Therefore, the amount of energy and the amount of power used to produce work can be described directly. A research on the use of energy in the manufacturing industry for machines indicates that the machine itself provided a large proportion of the energy consumed [12].

The energy indexes of the screw press can be improved through parameter optimization [13,14,15]. The energy-related parameter obtained from various literature is the screw shaft speed and length, opening area for cake removal, the outer and inner diameter of the shaft, the screw flight configuration [11].

According to a few works of literature, an increase in the screw shaft speed will lead to an increase in processing rate (also known as throughput) can lead to a significant amount of energy saving. The processing rate is defined as the amount of time required to produce a finished product after passing through all the process required. It is said that with an increase in the processing rate, the amount of time required to produce a finished product will be much lower. Furthermore, it is found that the processing rate has a high correlation with the amount of energy consumed to produce a product. An empirical study was conducted in the injection molding industry to identify the amount of energy consumed during the process. The result shows that a higher throughput produces lower specific energy consumption (SEC) which is defined as the energy required to produce one cubic meter product [13]. Also, an energy consumption study was conducted in the various manufacturing industry to evaluate the same parameter and resulted in the same deduction as the study above [12,13,14].

Nevertheless, there is an unclear relationship between motor energy consumption with regards to the screw speed. Theoretically, as the speed of the screw shaft increase so that the throughput increase, the motor energy consumption should also increase to accommodate this demand. However, in a study conducted [16], the result shows that as the speed of the screw shaft is inversely proportional to the specific energy consumption of the motor. However, in another study [17,18], the result obtained contradicts with the result of the experiment mentioned previously [16], where it shows an opposite trend of the specific energy consumption of the motor is lower as the screw speed increase. Hence, further study needed to be conducted to get the conclusion of this issue.

Furthermore, the size of the choke (press nozzle) for oil extraction also plays a role in the energy usage of screw press as it was highlighted in a few studies as one of the energy components in the screw press [8,11]. When the size of the choke is reduced, the amount of pressure in the pressing chamber increases to overcome the restriction. This resulted in more energy is required. During the experiment conducted to evaluate the separation efficiency and energy consumption of oil expression using a screw-press [19], in any given scenario of seed preparation whether it is cooked, crushed or even feed as raw seed, result shows that there is a substantial change in the mechanical energy required to extract the oil when the size of choke is configured to tight compared to an open choke. Consequently, a high pressure resulted in more demand in the mechanical energy to overcome the restriction.

Aside from the energy consumption has a mass effect in the manufacturing cost, it also has a major role in the overall sustainability strategy and most research on the environmental impacts of manufacturing processes and technologies centered on trends of energy consumption and was important to reduce energy use in sustainable production. To measure the environment effect of the machine tool, a standard was implemented by the Climate Registry. From this standard, there is a series of step should be taken in order to have a measurement of carbon emission that is due to the energy consumed by the machine. This standard was applied to a case study in which concluded that the amount of electrical energy used from a facility is directly proportional to the amount of carbon emission to the environment [20].

2.5 MAINTAINABILITY

Maintenance is defined as a probability of restoring the failed item to operational efficiency in a period of time when repair is carried out according to the prescribed procedures. It can also be defined as' the probability of compensation in a given time' and often corresponds to' percentile downtime.'

It is usually associated with mean time between maintenance (MTBM), mean time between failure (MTBF), mean time between repair (MTBR), maintenance downtime (MDT), turnaround time (TAT), product operating hour (OH) and maintenance cost per system/product operating hour (Cost/OH) [21]. All related factors listed are just a snapshot of the overall maintenance context. Any system or product such as a big or small system, commercial product, defense products, production systems, communication systems, transport system and even software-intensive systems are subject to the principle of maintainability. In terms of start-up production and continuous maintenance and support, an easily maintained system / product is less costly. In any case, incorporating maintenance features in a design leads to a decrease in the total cost of the life cycle. In turn, this has a positive impact on the marketplace, an increase in customer satisfaction, future contracts and sales and an improvement in profits for a given industrial company.

One of the main criteria in the design of a system for maintainability is reliability. It is possible to determine the likelihood that a system or product will perform satisfactorily during a specified timeframe [21]. Maintenance shall include all necessary measures to retain or restore a desired operational state a system or product. Maintenance can be categorized as follows:

1) Corrective maintenance

It is usually known as unscheduled maintenance actions performed due to system failure in order to restore the condition of the system to its satisfactory state.

2) Preventative maintenance

It is the scheduled maintenance action for retaining a system to a specified operational state.

3) Predictive maintenance

Often known as a condition-monitoring preventive-maintenance program where the monitoring method is used to evaluate the current status of equipment, to predict possible degradation and identification of crucial maintenance area.

4) Maintenance prevention

Primarily used in the context of 'Total Productive Maintenance (TPM)', which refers to the effort towards a 'maintenance-free design'. The main objective of this method is to minimize maintenance downtime and the requirement for support resources, improving productivity and reduce overall life-cycle cost.

Notably, maintenance plays a vital role in ensuring the performance and effectiveness in any system. For example, a knife that is brand new and is freshly produced allow a lesser cutting effort when it is used compared to the one that is frequently used. This analogy is similar to any system or machine when performing work. When a machine is at its optimal condition, it can perform the desired task easily without any problem. However, as the life cycle of the machine continues, the machine started to degrade, and its reliability will decrease. It is because a continuous cyclic loading in the long run will result in possible problems and will impact the system and its reliability in the future. [20]. Therefore, this gives the need to carry out preventative maintenance so that machine breakdown is avoided.

2.6 OUTCOME OF LITERATURE REVIEW

In this project, after considering multiple study cases and literature related to screw press machine, it shows that the machine maintenance has a high connection with energy-saving as well as the impact towards the environment as stated in the problem statement. One of the factors that shows this relation is the relationship between a machine's reliability and its energy consumption by vibration monitoring. It shows that a longer life cycle could degrade a machine performance due to continuous loading given upon it, which is known as material fatigue. Consequently, a degraded machine started to use more energy to do the required work before failure occurs [13, 20]. Another factor also demonstrates the importance of optimizing maintenance activity to increase the performance of a system, and it shows that it is possible to quantify the impact of maintenance in terms of energy-saving or effectiveness. By demonstrating maintenance optimization such as upgrades or using new technologies, the performance of a system can increases, and this ultimately led to potential energy saving [22,23].

2.7 SUMMARY

From the literature review study, the parameter obtained to alter the energy consumption of the palm oil screw press machine is the screw speed, amount of throughput, area of choke of the screw press and also the screw geometry. Next, to relate the energy consumption towards the maintainability part, the vibration of machine, lifecycle and reliability will be observe to obtain the energy consumption pattern of the screw press machine.

CHAPTER 3

METHODOLOGY

3.1 PROJECT METHODOLOGY

This chapter will give details of described methods for the modeling the palm oil pressing machine energy usage towards its maintainability. In the beginning of the project, the issue regarding the lack of framework to evaluate the palm oil pressing machine energy usage towards the machine maintainability is highlighted. Based on this matter, a critical literature review is carried out to determine the extent of the gap between the mentioned knowledge. The literature review covers the study of a general machine energy consumption pattern which has the same major working principle as the palm oil screw press machine. Next, the energy usage data is linked to the machine maintainability through the common energy component of the pressing machine. The outcome of this literature study shows that the machine condition highly affects its energy usage.

3.2 RELIABILITY MODELLING

A series of time to fail data from a population of similar equipment should be available for modeling the reliability of a pressing system. By fitting the mean time to failure (MTTF) data of the screw press machine to Weibull distribution, a reliability model is created. Weibull distribution is generally a powerful tool used in reliability engineering. Weibull distribution can take on the characteristics of other types of distributions, based on the value of the shape parameter, β and scale, η. These two parameters are then estimated using Maximum Likelihood Estimation method. Maximum Likelihood Estimation is a method that determines values for the parameters of a model that resulted in a curve that best fit the data collected. By referring to the known bathtub curve in Figure 3.1, the value of beta that is lower than one shows an infant mortality or burn-in period, while beta value that is equal to one shows a random failure and beta value lower than one gives the indication of wear out failure.

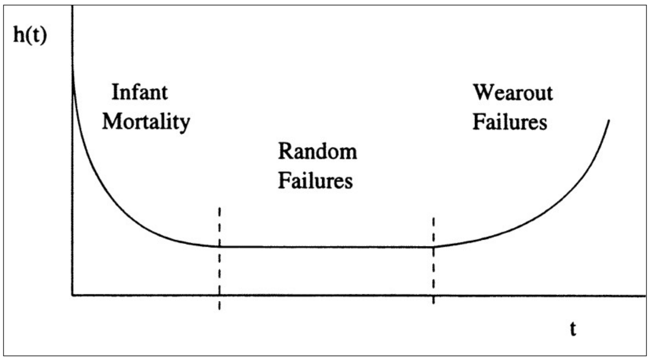

Figure 3.1 : Bathtub Curve [24]

By considering the time as the lifetime of the machine or component, the general formula utilizing Weibull distribution to estimate the reliability is given by

$$R(t) = \exp\left[-\left(\frac{t}{\eta}\right)^{\beta}\right] \tag{1}$$

3.3 MOTOR ELECTRIC CONSUMPTION MODELLING

For the assessment of the electric consumption of the screw press machine, generally, the energy consumption increases as its machine condition worsens, which directly shows that the reliability of the machine is decreasing. The measurement of energy use, including electricity usage, is complicated since the press is rather non-linear in nature. Considering the complexity, in this research, without the aid of any sensors to monitor the energy consumption of the pressing process, a general formula for power requirement to drive the screw press is adapted to simulate the electricity consumption of machine and the power required is converted into electrical energy consumption with respect to time (3). In this research, for simplicity purposes, when the energy consumption of the electric motor reached its maximum value, the reliability of screw press machine is set to be zero, and when it is at lowest value, the reliability is at one hundred percent in performance.

$$P_{Motor} = \frac{4.5\ Q_v I_s \rho g F}{\eta} \tag{2}$$

Where,

$Q_v = volumetric\ capacity\ of\ the\ screw\ shaft$

$I_s = length\ of\ the\ worm\ shaft$

$g = acceleration\ due\ to\ gravity$

$F = material\ factor$

$$Electricity\ energy\ consumption,\ E = P_{motor}t \quad (3)$$

Once the energy consumption by the motor to drive the screw press over time are calculated, an evaluation on the effect of the screw press speed to the theoretical capacity of the screw press machine was carried out as in equation (4). This is to determine the best amount of energy utilization with respect to amount of input processed. This term is also known as specific energy consumption (SEC). SEC is calculated as a ratio ofenergy used for producing a product as shown in equation (5).

$$Q_e = 60\ \frac{\pi}{4}(D_s^2 - d_s^2)P_sN_s\varphi\rho \quad (4)$$

Where,

$D_s = diameter\ of\ screw\ thread$

$d_s = base\ diameter\ of\ screw\ shaft$

$P_s = screw\ pitch$

$N_s = rotational\ speed\ of\ screw\ shaft$

$\varphi = filling\ factor$

$\rho = bulk\ density$

$$SEC = \frac{Energy\ used}{Product's\ Amount} \quad (5)$$

3.4 CARBON EMISSION ASSESSMENT

The energy usage can be translated to carbon emissions to calculate the environmental impact of machine tools, which are applied in compliance with the criteria defined in the Climate Registry. Based on the General Reporting Protocol (GRP), the indirect production of carbon from machine tool energy will be measured after conducting three significant phases [20].

Step 1 : Determine the machine's energy use in use.

Step 2 : Identify or pick relevant emission factors.

Step 3 : Determine emission of gas with the emission factor and using equation (6)

$$E_{CO_2} = E_C \times F_{CO_2} \quad (6)$$

Where E_{CO_2} are emission of CO_2, F_{CO_2} are emission factors of CO_2, and E_C is energy usage of the machine tool. The volume of green home gas released to the atmosphere is quantified by an emissions factor which can be calculated directly and analyzed in laboratories or by standardized default factor to be generated per unit of electricity. This is typically measured per kilowatt hour or megawatt hour in pounds of greenhouse gas.

3.5 EMISSION FACTOR ASSESSMENT

There are two ways in determining the emission factors; which is by calculation procedure or just simply refer to the default factors that is available in the GRP table.

By carrying out these procedures as shown in Figure 3.2, we are able to model the relationship between the screw press energy consumption and its maintainability.

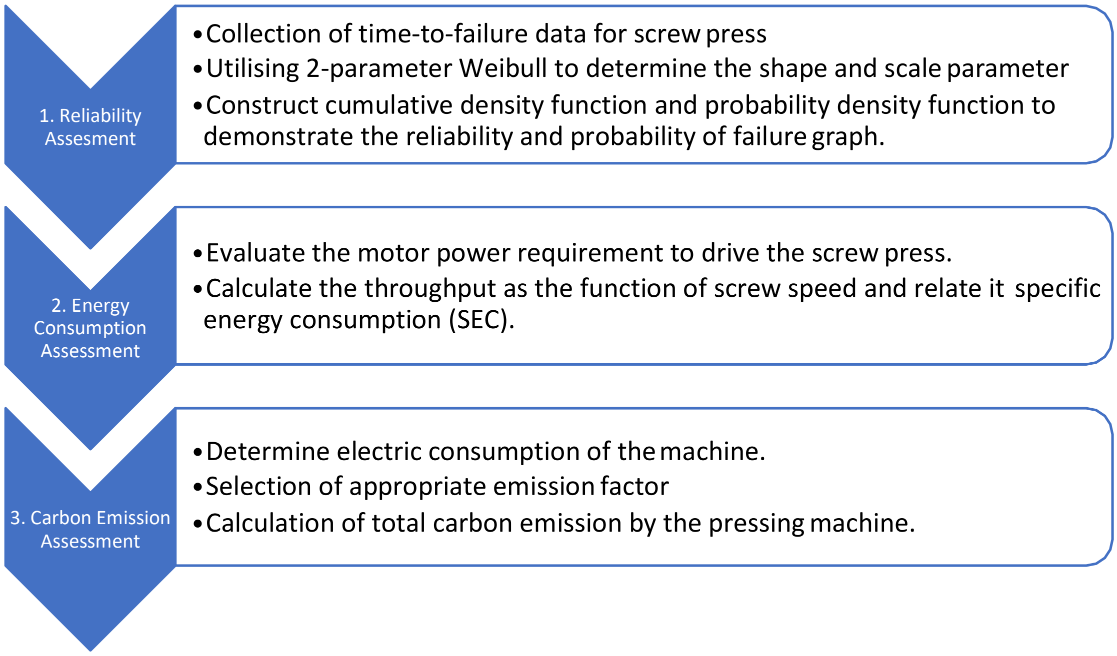

Figure 3.2 : Framework to evaluate the relationship between screw press energy consumption and its maintainability.

Hence, once the time to failure data of the screw press machine is obtained, it can be used to evaluate the reliability of the machine with the utilization of Weibull distribution and Maximum Likelihood Estimation method. Then, the relationship of the machine's energy consumption and its maintainability can be observed by comparing the energy consumption of the motor and the reliability of the screw press machine. Additionally, to better illustrate the significance of the capacity utilization of the screw press machine with the energy consumption, an analysis on the screw speed parameter with the increase in throughput was conducted. Finally, the environmental impact of the machine was evaluated as a function of the motor energy consumption.

CHAPTER 4

RESULTS AND DISCUSSION

A test was carried out on the pressing machine from the IOI Palm Oil Mill. One sets of twenty life cycle data reflecting the screw press deteriorating process were created with the aid of Weibull++ software and a variability of 10% was included in the data to simulate the degradation of machine tool. Additionally, since the electricity data of the machine is only evaluated through formula, there is only one set of data to illustrate the use of the model and verify that the current simulation approach is feasible.

4.1 RELIABILITY ASSESSMENT

By fitting the failure data of the machine tool to Weibull distribution, the reliability of machine tool is calculated. The estimated parameters of the distribution is $\eta = 828.695831$ and $\beta = 19.693725$ by using Maximum Likelihood Estimation (MLE) method. Figure 4.1 shows the assumed time to failure (TTF) data by taking the basis of failure limit of 800 hours. By applying 2 parameter Weibull distribution method with the estimation of the parameter using Maximum Likelihood Estimation, the reliability of the pressing machine can be monitored as shown in Figure 4.3 with the aid of Reliasoft Weibull++ software.

State	Time to Failure (Hours)
Fail	822
Fail	826
Fail	722
Fail	833
Fail	772
Fail	817
Fail	758
Fail	818
Fail	873
Fail	836
Fail	751
Fail	765
Fail	868
Fail	854
Fail	874
Fail	726
Fail	827
Fail	773
Fail	867
Fail	768

Figure 4.1 : Time-to-failure (TTF) data of pressing machine

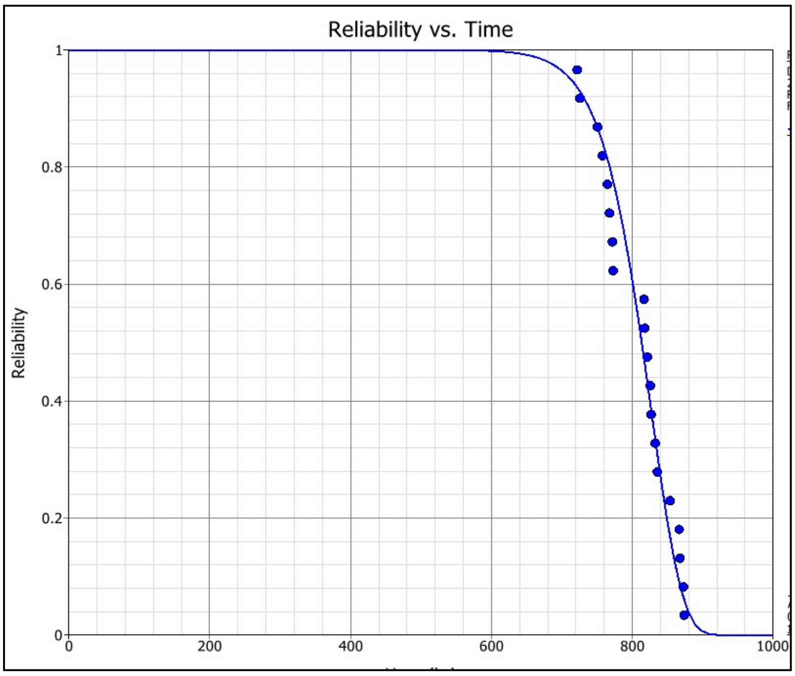

Figure 4.2 : Reliability vs Time of pressing machine

With the plotting of the reliability of the system using Weibull distribution method, the probability of failure for the equipment to fail graph can be plotted as in Figure 4.4.

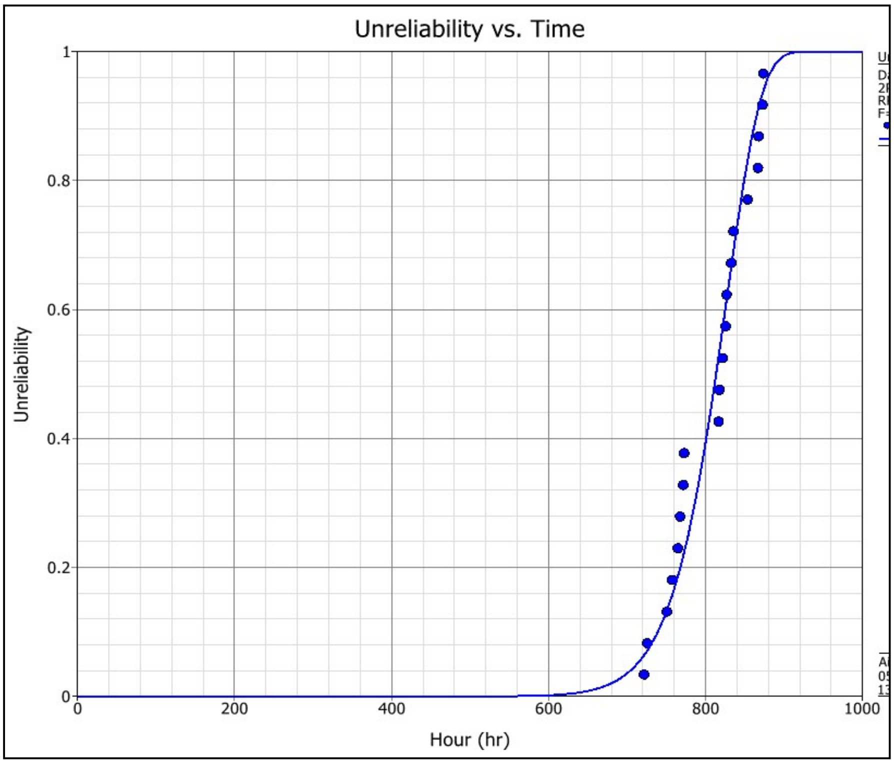

Figure 4.3 : Failure rate vs Time graph of pressing machine

4.2 ELECTRIC CONSUMPTION ASSESSMENT

The electrical energy consumption per unit of time is obtained through the use of formula (2) with the parameter setting of $Q_v = 0.4\ m^3/h$, $I_s = 0.44\ m$, $g = 9.81\ m/s^2$, $F = 0.4$ and an efficiency of $\eta = 75\ \%$. The obtained power requirement to drive the screw press is equivalent to a 5 hp electric motor and it is factored by time to obtain the power consumption graph as shown in Figure 4.4 and Figure 4.5.

Time (h)	Energy Consumption per unit time (kWh)
0	0
100	375
200	750
300	1125
400	1500
500	1875
600	2250
700	2625
800	3000
900	3375
1000	3750

Figure 4.4 : Energy Consumption Table per unit time

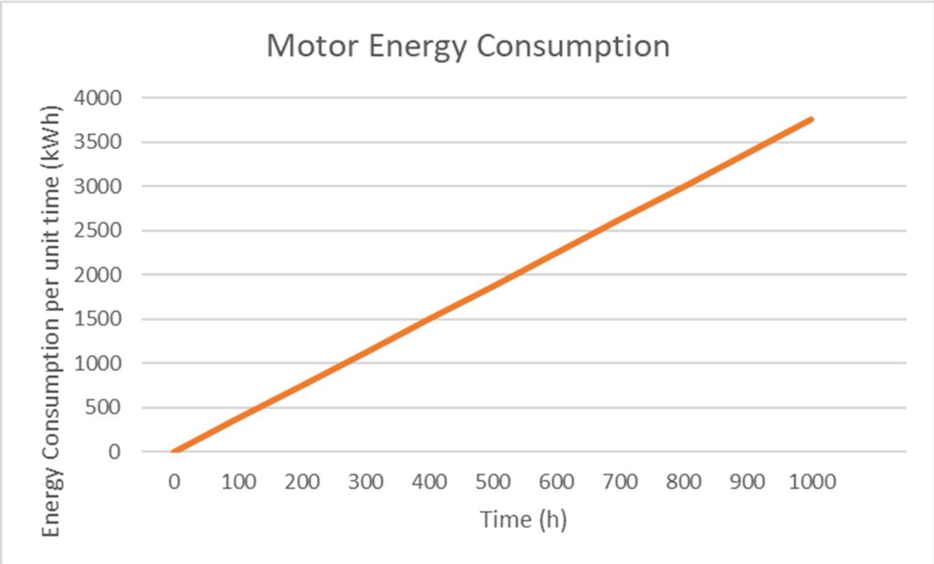

Figure 4.5 : Motor Energy Consumption graph as per unit of time

Since the graph in Figure 4.5 does not actually reflect the actual energy consumption pattern of the screw press machine but theoretically it is able to show that as assumed before, once the energy consumption is at its maximum value at maximum observation time of 1000 hours, the reliability of the machine is considered to be zero. This is because as the reliability of the machine is low and it will continue to degrade as time continues, the ability of the machine to perform its specified task will be more difficult and this shows the reason why the energy consumption is increasing with time.

Moreover, to better utilize the screw press speed to obtain optimal energy usage and further justify the relationship between the energy consumption and machine's maintainability, the throughput of the model is altered as shown in Figure 4.6; to identify which point is suited for optimal energy consumption according to the screw press speed. By utilizing the formula in (4) and relating with the data obtained in Figure 4.4, the table below (Figure 4.7) was developed.

Qe (kg/hr)	Ns (rpm)	Time (hr)	Total Produced (Ton)	Energy Consumption per unit time (kWh)	SEC
942	90	0	0	0	0.00
1046	100	100	105	375	3.58
1151	110	200	230	750	3.26
1255	120	300	377	1125	2.99
1360	130	400	544	1500	2.76
1465	140	500	732	1875	2.56
1569	150	600	942	2250	2.39
1674	160	700	1172	2625	2.24
1778	170	800	1423	3000	2.11
1883	180	900	1695	3375	1.99
1988	190	1000	1988	3750	1.89

Figure 4.6 : Specific energy consumption (SEC) evaluation

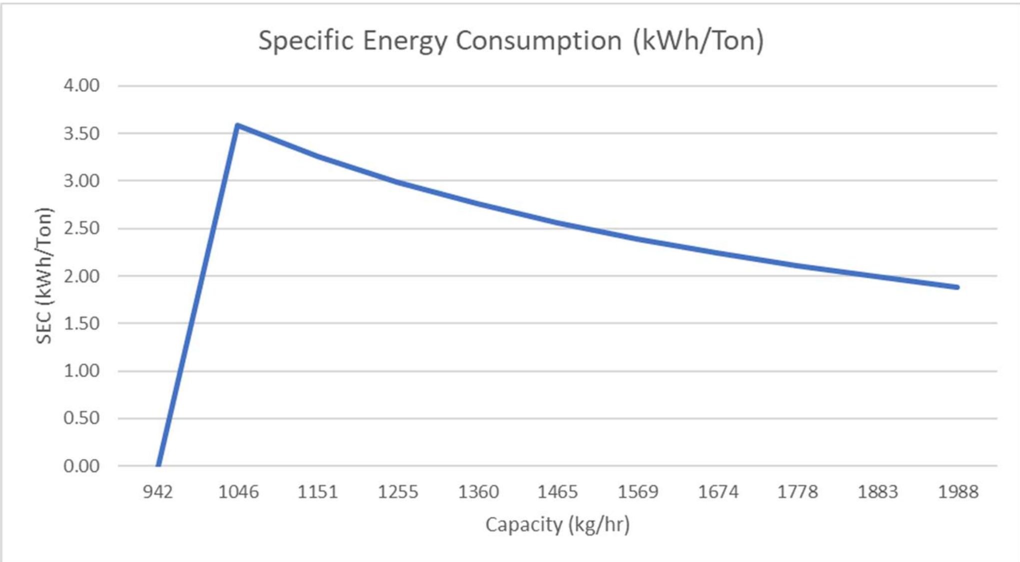

Figure 4.7 : Specific energy consumption vs capacity graph

As observed from Figure 4.7, it is observed that as the screw speed increases, the throughput the machine can carry also increase. Furthermore, as shown in Figure 4.8, with higher throughput, the trend of energy utilization is getting better. Hence, a higher processing rate of the fruit bunch can lead to a better energy optimization.

4.3 CARBON EMISSION ASSESSMENT

By referring the 2018 Climate Registry for Malaysia for emission factor which are 688 g CO_2 /kWh, the electric consumption data was utilized to calculate the carbon emission. Since it is proportional to electricity consumption, the energy consumption of the motor is factored by the carbon emission for Malaysia and the result is shown in Figure 4.9 and Figure 4.10. On top of that, since the table in the Climate Registry only provides the emission rate for CO_2, we should assume that the emission rate for other gases can be neglected or already converted to CO_2 for simplicity purpose in terms of the model analysis.

Energy Consumption per unit time (kWh)	Carbon Emission (kg CO2)
0	0
375	258
750	516
1125	774
1500	1032
1875	1290
2250	1548
2625	1806
3000	2064
3375	2322
3750	2580

Figure 4.8 : Total Carbon Emission in kilogram

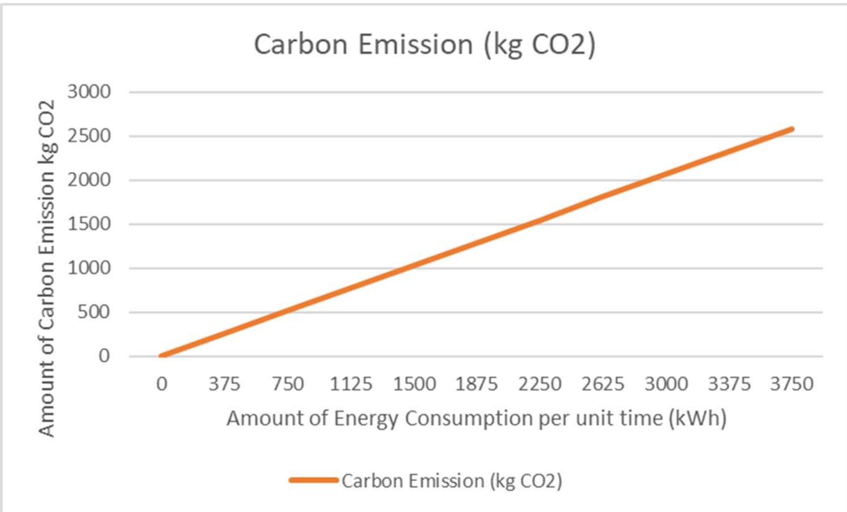

Figure 4.9 : Carbon Emission vs Energy Consumption

In addition, the energy consumption of the machine tool increases as seen on Figure 4.2 and 4.5, but compared to the other way around, the reliability of the machine tool declines. Therefore, the rise in carbon dioxide with a higher energy consumption is clearly seen in the case of Figures 4.9 and 4.10. Hence, it is best to evaluate which capacity would provide a better specific energy consumption for the screw press machine and also better reduction in the carbon emission towards the environment.

CHAPTER 5

CONCLUSION

A method of modelling energy usage is proposed for the palm oil screw press. The correlation between the energy consumption and the maintenance of the system can be formed by connecting the system tool's efficiency to its energy consumption. The power consumption of machine tools can be easily accomplished during operation by referring to the reliability determined by integrating life data into the Weibull distribution and formulating a power requirement for electric motors that operate the screw press. In order to assess the environmental effect of the machine, energy consumption is converted into carbon discharge. It is also the case that no integrated energy consumption sensor is installed in most old models of machine tool. Furthermore, in order to get a more accurate result, a sensor must be integrated to the system to accurately reflect the reliability of the machine and energy usage pattern. This method of simulation will then be used in use by manufacturer to determine the energy use and effect of their machine tools on the environment, given that the right electric current equation is obtained to actually reflect the energy consumption pattern of the screw press. In future works, modeling for evaluating more energy parameter of the screw press can be implemented.

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