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Analysis of Energy Consumption and Electrical Power Efficiency on Conventional and CNC Lathes at CV Wakinara Teknik

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This research is motivated by the high consumption of electrical energy in the machining process that has not been balanced with an analysis of power usage efficiency, especially on conventional lathes and CNC machines at CV Wakinara Teknik. The lack of monitoring and evaluation of energy consumption leads to potential electricity waste and suboptimal machine utilization in production activities. Therefore, this study aims to analyze the energy consumption and level of electrical power efficiency on both types of machines to determine the comparison of energy performance and potential savings opportunities. The research method used includes direct measurement of electrical parameters such as voltage, current, power, and power factor during the machine operation process. The data obtained are then analyzed to calculate energy consumption and power usage efficiency on each machine. In addition, a comparison of energy consumption characteristics between conventional and CNC lathes is conducted under similar workload conditions. The results show that CNC machines tend to have more stable energy consumption and higher power efficiency than conventional lathes, although under certain conditions their power consumption is greater due to the use of an automatic control system. Meanwhile, conventional lathes have higher fluctuations in energy consumption and relatively lower efficiency. These findings indicate that the application of CNC machines can improve energy efficiency in production processes, as well as provide a basis for developing more optimal energy management strategies in industrial environments.

Keywords: energy consumption, electrical power efficiency, conventional lathe, CNC machine, energy analysis.

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1. Introduction

The increasingly rapid development of the manufacturing industry demands the efficient use of electrical energy to support productivity, maintain operational sustainability, and increase company competitiveness amidst rising energy costs and increasingly fierce industrial competition. Electrical energy is a key component in the production process, particularly in the metal processing industry, which relies heavily on machine tools, such as conventional lathes and Computer Numerical Control (CNC) lathes. Conventional lathes are still widely used in small and medium-sized industries due to their simple construction, relatively low investment costs, and ease of operation and maintenance. However, conventional lathes generally rely on mechanical systems and manual controls, so their electrical energy consumption tends to be unstable, especially when there are changes in workload, variations in rotational speed, or inaccurate operating parameter settings. This condition has the potential to cause energy waste, increased electricity costs, reduced lifespan of electrical and mechanical components, and low power efficiency.

On the other hand, CNC lathes come with a computer-based automatic control system that allows for more precise, consistent, and programmed operating parameter settings, so that theoretically they are able to produce more optimal performance and better energy efficiency compared to conventional machines. However, CNC machines also have the characteristic of relatively large power consumption, mainly due to the use of servo motors, electronic control systems, and other supporting devices that require a continuous electrical power supply. If the operation of CNC machines is not managed properly, the potential for energy waste can still occur, so that energy efficiency goals are not optimally achieved. A problem often faced by small and medium industries, including CV Wakinara Teknik, is the lack of analysis and evaluation of electrical energy consumption in the production machines used. CV Wakinara Teknik as a company that operates conventional lathes and CNC lathes, to date, does not have quantitative and comparative data that shows the amount of electrical energy consumption, the level of power efficiency, and the differences in energy use characteristics between the two types of machines.

This condition causes decision-making regarding machine maintenance, operational optimization, equipment replacement, and energy management implementation to not be fully based on measurable technical and economic considerations. In fact, amidst rising electricity rates and demands for production cost efficiency, effective electricity management is a strategic factor in improving operational efficiency and business sustainability. Therefore, a study is needed that specifically analyzes electrical energy consumption and power efficiency on conventional lathes and CNC lathes used at CV Wakinara Teknik, so that a real picture can be obtained regarding the amount of electrical energy consumption (kWh), electrical power used (Watt/kW), power factor, and the level of power usage efficiency during the turning process. This study focuses only on two main objects, namely conventional lathes and CNC lathes operating in the production area of CV Wakinara Teknik, with the analysis of electrical energy consumption carried out only when the machines are operating in the normal production process and does not include idle, stand-by, or machine maintenance conditions. The parameters analyzed in this study are limited to electrical aspects, including electrical power, energy consumption, power factor, and power usage efficiency, without discussing aspects of machine investment costs, maintenance costs, or mechanical efficiency that are not directly related to electrical energy consumption. The type of load tested is also limited to the turning process commonly carried out in the company's daily production activities, so that the analysis results reflect real operational conditions in the field. Energy consumption measurements are carried out using available measuring instruments and in accordance with field conditions at CV Wakinara Teknik, with the scope of the study limited to one work location, namely the company's production area, and does not emphasize aspects of work safety, the environment, and ergonomics, except those directly related to the use of electrical energy.

Based on the description, this study was designed with the aim of determining the amount of electrical energy consumption on conventional lathes and CNC lathes used at CV Wakinara Teknik, analyzing and comparing the level of electrical power efficiency between the two types of machines, and identifying differences in energy consumption and efficiency characteristics that occur during the production process. In addition, this study also aims to provide recommendations for appropriate and applicable electrical energy saving strategies based on the results of the analysis of energy consumption and power efficiency, so that they can be implemented by companies in order to optimize the use of electrical energy. The results of this study are expected to provide benefits both academically and practically, including adding scientific references regarding the analysis of energy consumption and power efficiency on production machines in the manufacturing sector, contributing to the development of electrical engineering science, especially in the field of industrial electricity and energy management, and becoming a reference for further research that discusses the comparison of conventional and CNC machine performance from the perspective of energy use. From a practical perspective, this research is expected to provide accurate information to CV Wakinara Teknik regarding the actual electrical energy consumption of the lathe used, as a basis for consideration in decision making related to machine operational optimization, energy savings, and electricity cost efficiency, assisting companies in identifying more energy-efficient machines

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without sacrificing productivity, and supporting the implementation of better energy management in small and medium industrial environments. In addition, the results of this research can also be used as reference material for students and industrial practitioners who conduct similar studies, as well as encourage increased industrial awareness of the importance of efficient energy management in order to reduce electricity waste, reduce operational costs, and improve business sustainability.

2. Literature Review

Electrical Energy

The definition of electrical energy is the energy used for electrical equipment for lighting, cooling, heating, driving motors or re-driving mechanical equipment. The most frequently used energy in the needs of today's society is electrical energy. (Khairul Anwar, 2018). Electrical energy is also energy that cannot be created and cannot be destroyed. Electrical energy is also a very flexible energy. However, electrical energy can also be converted into other energy with the help of equipment that uses electricity, an example of a frequently used tool is a rice cooker or commonly called a Rice Cooker. Rice cookers can convert thermal energy from electrical energy. Rice cookers are also electrical devices that have resistance. If used, they will require voltage, electric current and usage time. Electrical energy is also often used for heating (for example: Rice Cookers, Irons, Soldiers, and Ovens), sound energy (TV, Tape, Radio), kinetic energy (Fans, and Water Pumps), light energy (Incandescent Lamps and TV). (Kazimierczuk, MK (2015). The equation written in the amount of electrical energy can be written in the following equation;

$$W=Q.V \tag{2.1}$$

Q = Charge transferred (Coulomb)
V = Potential Difference (Volts)

If the potential difference is written as "V", the time interval is written as "t", and the current strength is written as "I", then the energy released by the device and converted into heat is;

$$W = V. I . t \tag{2.2}$$

Where:
W = Electrical Energy (Joules)
V = Electric Voltage (Volts)
t = Time Interval (Seconds)
I = Current (Amperes)
If in Ohm's law it is formulated as
V = I . R,
This equation can be reduced to the following equation

$$W = I. R . t \tag{2.3}$$

or

$$W = I2. R . t \tag{2.4}$$

A flow of a certain electric charge that moves from one point to another point in a circuit in each unit of time, this term can be said to be an electric current. The event that causes the movement of electric current is due to the presence of electrons that move according to a predetermined current. (MH Jamil, et

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al, 2020) Electric current can flow through a conductor whose conductive media comes from certain hardware only, for example: steel, brass, copper, silver, tin, iron and lead. A conductor is a medium or object that can or is easy to conduct electricity. An insulator is a medium that cannot conduct electric current, for example: rubber, dry wood, cardboard, styrofoam, plastic, and glass. The strength of the electric current can be written in the following equation:

$$I=V/R \qquad (2.5)$$

Where:
I = Electric current (Ampere)
V = Voltage (Volts)
R = Resistance (Ohm)

CNC Machine

The use of CNC (computer numerical control) machine tools is now quite popular and widely applied to various machining processes. Manual machining has largely shifted to CNC machining to achieve high productivity and desired geometric accuracy. Consequently, energy consumption in the manufacturing industry has increased. Therefore, comprehensive energy management measures are needed in the process and manufacturing industries.

Machine tool energy consumption in the process and manufacturing industry can reach 68% of a company's total energy needs (Anisah, S., et al., 2022). Production processes such as milling, turning, drilling, etc., require significant electrical energy. Therefore, implementing energy efficiency in the process and manufacturing industry is essential for the sustainability of the process and manufacturing sector, which is related to energy costs and environmental factors (Rahmaniar et al., 2023).

CNC machines, such as CNC lathes and CNC milling machines, are widely used by large companies and small and medium-sized industries and consume a lot of electrical energy (Rahmaniar et al., 2022). Each CNC machine consists of various components that consume electrical energy. These components are either primary components that have a significant impact on the machining process or secondary components that support the machining process. Therefore, knowledge is needed to map the primary components in a CNC machine as specific energy users. The specific energy users of each CNC machine vary, but mapping each energy-using component can help in energy savings. With the widespread use of CNC machines in various manufacturing sectors, savings in energy use in CNC machines can have a significant impact on total energy consumption (Hu et al., 2017). For example, making a slight change in the settings of the spindle motor acceleration in a machine tool can save electrical energy. The acceleration speed of the spindle motor in a lathe will affect the pattern of electrical energy consumption (Lv, Tang, Tang, Liu, & Zhang, 2017).

In the planning stage, the machine selection must be adjusted to the process. production to avoid unnecessary component/feature functions of the machine so that it can reduce energy use. In the process of selecting machine tools that are adjusted to the production process, the key performance index can be used (Hamdani, H. (2024). To determine the characteristics of energy consumption in machine tools, bench marking can be carried out on several similar machine tools to investigate energy use to obtain data on energy consumption patterns from each machine (Wirtz, Meißner, Wiederkehr, & Myrzik, 2018). The process of collecting energy consumption data can be done by conducting cutting tests on each machine with the same operating parameters and the same workpiece material, so that variations in energy consumption data from each CNC machining center are obtained. Figure 1 shows a schematic of a CNC machining center machine that depicts the components/sub-assemblies that influence energy consumption.

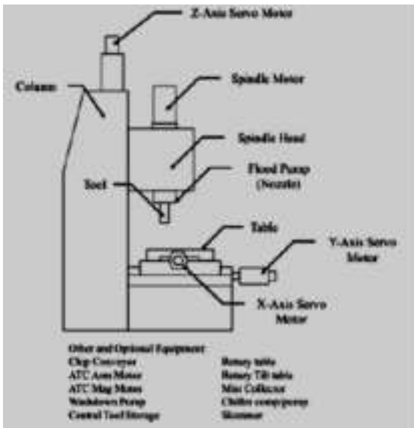

Figure 1. Schematic of CNC vertical machining center (Triebe et al., 2018)

One of the main problems in implementing energy efficiency in manufacturing production systems is the lack of knowledge about energy consumption in production processes and equipment such as machine tools (Wirtz, Biermann, et al 2018).

Energy Consumption

Machining is widely used in most manufacturing industries and therefore represents a major energy demand. A considerable amount of research has been conducted on machining processes, but environmental issues have rarely received much attention, except for the work of Gutowski et al. (2006), who studied the electrical energy requirements of milling processes. Their approach can be used to evaluate energy consumption in machining processes.

Dahmus and Gutowski (2004) presented a material flow diagram for environmental analysis of the machining process as shown in Figure 2. The main contributors to the energy budget and CO2 emissions are the energy used in the machining process and the energy contained in the workpiece material. The energy required for the machining process is drawn from the electricity grid. In generating energy (electricity) from different power generation sources, CO2 is emitted by the process.

Machining is a material removal process in which a hardened cutting tool is used to remove chips from a workpiece. There are various types of machining processes such as turning, milling, drilling, and reaming, but they all undergo the same cutting process that creates chips. Unlike conventional manually controlled machine tools, CNC machine tools are controlled by computers and computer programs so that the operation of CNC machines and their energy consumption are determined for a specific machining process. During the machining process, energy is used to drive components (e.g., CNC control unit, spindle, feed shaft, etc.) of the CNC machine tool to realize a series of operations (e.g., setting, loading, cutting, automatic tool change, etc.). The electrical energy profile during machine tool operation is studied and given for various types of machining processes (Li et al., 2011).

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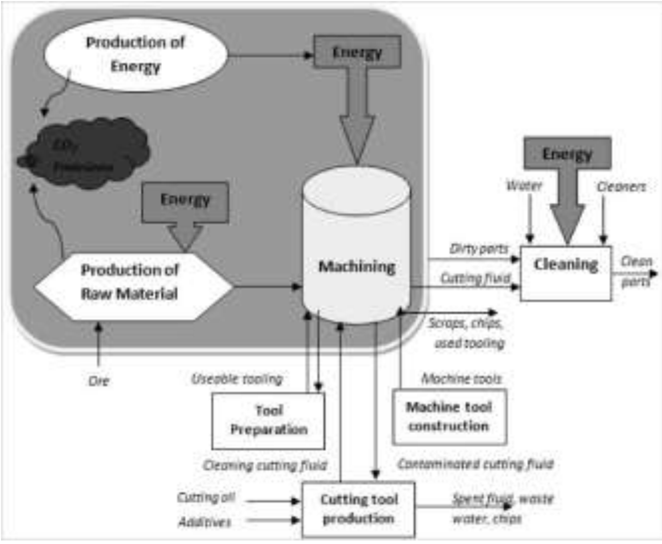

Figure 2. Energy in manufacturing (MH Jamil, et al, 2020)

The power curve can be divided into three parts: constant power, variable power, and peak power. Peak power is usually short and contributes only a small portion of the cumulative energy consumption, so it can be ignored when calculating total energy consumption. Based on this statement, power requirements can generally be divided into variable and constant power (Gutowski et al., 2006). Gutowski et al. reported that the energy required for the material removal process can be very small compared to the total energy for machine tool operation. Based on previous research by Gutowski et al. (2006), the electrical power requirement, P, for a machine can be calculated from the following equation:

$$P = Po + kv \quad (2.7)$$

where, P is the power [W] consumed by the machining process, Po is the power [W] consumed by all machine modules for the machine to operate without load, k is the specific energy requirement [Ws/mm3] in the cutting operation, and v is the amount of material removed (MRR), in [mm3/s].

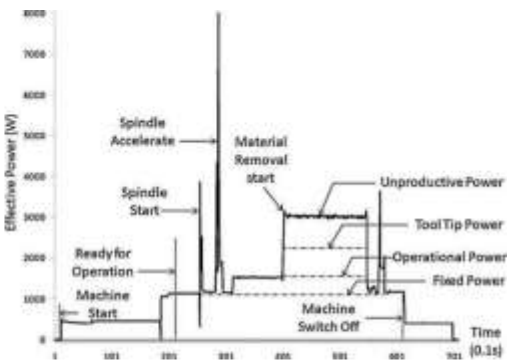

Figure 3. Power profile of turning process (Li et al., 2011)

As shown in equation (1), the energy requirement for a machining process depends on the power consumed and the specific energy in the cutting operation. Representative specific energy for different machined materials is published by Kalpakjian and Schmid (2006). The value to adapt depends on the combination of the tool and the workpiece material/grade used. Thus, from equation (2.7) the total power for the machine can be divided into two, namely no-load power (P) and machining power (kv). Idle power is the power required or needed for equipment features that support the machine. For example, the power

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to start computers and fans, motors, cooling pumps and others. The power drawn on machine tools using three-phase motors, P, is calculated using the following equation:

$$P = V \cdot I \cdot \sqrt{3} \quad Cos \qquad (2.6)$$

where V is voltage, I is current [A] and Cosis the power factor. The electrical energy required for the turning process,*E*, can be obtained by substituting the previous equation

$$E = (P + kv)\,t \qquad (2.7)$$

where t is the time required for machining in seconds.

3. Research Methods

This study uses a quantitative descriptive-comparative approach that aims to analyze and compare the electrical energy consumption and power efficiency levels of conventional lathes and CNC lathes used at CV Wakinara Teknik. The quantitative approach was chosen because the data analyzed are in the form of electrical quantities that can be measured numerically, while the descriptive-comparative method is used to describe the characteristics of the energy use of each machine and identify differences in power efficiency between the two types of lathes. This study was conducted directly in the field so that the results obtained represent actual operational conditions in small and medium industrial environments. The type of research used is a field experimental study, where measurements are made directly on the lathe while operating in the normal production process. This study does not provide special treatment or modifications to the machine, but rather observes the performance of electrical energy consumption based on common operating conditions in the company. Thus, the data obtained is expected to reflect the actual pattern of electrical energy use on conventional lathes and CNC lathes at CV Wakinara Teknik.

The research location is in the production area of CV Wakinara Teknik, a manufacturing company that uses both types of lathes in its production activities. This location was selected based on the availability of research objects that are in accordance with the study objectives and their relevance to energy efficiency issues in the manufacturing industry. The research time includes the stages of measuring instrument preparation, initial observation, energy consumption data collection, data processing, analysis of results, and preparation of the research report. The research objects consist of two lathe units, namely a conventional lathe and a CNC lathe that are actively used in the process of turning metal components. Both machines were chosen because they have the same work function, but use different drive and control systems. To maintain the objectivity of the comparison, the turning process carried out on both machines was adjusted to have relatively comparable workload characteristics. The research variables in this study are divided into three groups, namely independent variables, dependent variables, and controlled variables. The independent variable is the type of lathe used, namely a conventional lathe and a CNC lathe. The dependent variables include electrical energy consumption and machine power efficiency. Meanwhile, the controlled variables include the type of turning process, machine operating time, and workload conditions which are made comparable on both machines to minimize the influence of external factors on the measurement results.

The electrical parameters analyzed in this study include active electrical power (Watts or kW), electrical energy consumption (kWh), power factor, and power efficiency. Electrical power is used to determine the amount of power absorbed by the machine during the turning process, electrical energy consumption indicates the total energy used during a certain operating time, power factor describes the quality of electrical power utilization, while power efficiency is used as an indicator of the level of effectiveness of electrical energy use by each machine. The tools used in this study include a power meter or energy analyzer that functions to measure voltage, current, electrical power, power factor, and electrical energy consumption directly. In addition, a stopwatch is used to measure the duration of machine operation time, as well as supporting measurement installation devices that are adjusted to the conditions of the electrical panel at CV Wakinara Teknik. All measurements are carried out with attention to occupational safety aspects according to procedures applicable in the industrial environment. The data collection procedure is carried out through several stages. The first stage is initial observation to determine the condition of the machine, electrical system, and the type of turning work commonly performed. The second stage is determining the test scenario by selecting the same or comparable turning process on both machines. The third stage involves installing measuring instruments on the lathe's power supply line in accordance with electrical measurement standards. The machine is then run under normal operating conditions, and the turning process is carried out according to company procedures. During machine operation, voltage, current, power, power factor, and electrical energy consumption are recorded periodically until the turning process is complete. To obtain more accurate and representative data, measurements are taken more than once and the results are averaged.

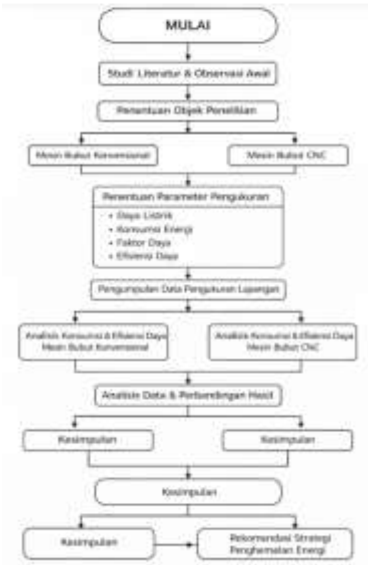

Figure 4. Research Flowchart

The data obtained from the measurement results were then analyzed using quantitative analysis methods. Electrical energy consumption was calculated based on the energy values measured during the machine's operating time. Power factor analysis was conducted to assess the quality of electrical power usage on each machine, while power efficiency was analyzed by comparing electrical energy consumption with the resulting turning process performance. The results of the analysis of energy consumption and power efficiency on conventional lathes and CNC lathes were then compared descriptively to determine the differences in electrical energy usage characteristics between the two machines. The presentation of research data was carried out in the form of tables and graphs to facilitate data interpretation and comparison. Tables were used to display the results of power, energy, and power factor measurements in detail, while graphs were used to show the comparison of energy consumption and power efficiency between conventional lathes and CNC lathes. Descriptive analysis was used to explain data trends and their implications for energy efficiency in industrial environments. The general research stages included a literature study related to energy consumption and power efficiency in industrial machines, field observations, data collection of electrical energy consumption, data processing and analysis, as well as drawing conclusions and compiling recommendations. The resulting recommendations are focused on electrical energy saving strategies that can be implemented by CV

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Wakinara Teknik, either through optimizing machine operation, improving energy management, or selecting more efficient machines. The output of this study is a comparative analysis of energy consumption and electrical power efficiency on conventional lathes and CNC lathes, which is expected to be a basis for consideration for companies in efforts to save energy and increase operational efficiency, as well as being a reference for similar research in the field of industrial electricity and energy efficiency.

4. Analysis and Results

Analysis of Electrical Energy Consumption

The analysis of electrical energy consumption was conducted based on direct measurement data on conventional lathes and CNC lathes operating at CV Wakinara Teknik. The measurements focused on machine conditions during normal turning processes with comparable types of work, so that the results obtained reflect actual electrical energy use during production activities. The main parameters analyzed included active electrical power, electrical energy consumption, power factor, and power efficiency on each machine.

Based on the measurement results, conventional lathes exhibit electrical power values that tend to fluctuate during the turning process. This fluctuation occurs due to manual speed and load settings, so that changes in cutting load directly affect the current and power consumed by the machine. This condition causes the electrical energy consumption of conventional lathes to be relatively unstable, especially when there are changes in cutting depth or spindle rotation speed. In addition, the power factor on conventional lathes tends to be lower, indicating that electrical power utilization is not optimal and there is still a significant reactive power component.

Table 1. Comparison of Electrical Energy Consumption

Day	Machine Type	Average Power (kW)	Operating Hours (hours)	Energy Consumption (kWh)	SEnergy difference
1	Conventional Lathe	4.10	3	12.30	2.55
	CNC lathe	3.25	3	9.75	
2	Conventional Lathe	3.95	3	9.88	1.63
	CNC lathe	3.30	3	8.25	
3	Conventional Lathe	4.20	3	14.70	2.80
	CNC lathe	3.40	3	11.90	
4	Conventional Lathe	4.00	3	8.00	1.70
	CNC lathe	3.15	3	6.30	
5	Conventional Lathe	4.15	3	12.45	2.40
	CNC lathe	3.35	3	10.05	

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Figure 5. Lathe machine testing Conventional

Figure 6. Machine testing CNC Lathe

Difference in energy consumption The average energy difference is ≈ 2.22 kWh per day, where the conventional lathe is always more energy-intensive and the largest difference occurs on Day 3 (2.80 kWh) The use of CNC machines can save energy of around 1.6 – 2.8 kWh per day, making it more efficient for long-term operations. Because the power factor of CNC lathes also tends to be higher than conventional lathes, which indicates a better and more efficient quality of electrical energy utilization.

Electrical Power Efficiency Analysis

Electrical power efficiency is analyzed by comparing electrical energy consumption to the resulting turning process performance over a specified operating time. Conventional lathes exhibit lower efficiency levels due to the relatively higher energy consumption required to produce the same output. This is influenced by the still-dominant mechanical system, power transmission losses, and imprecise operating settings.

Table 2. Conventional Lathe Measurement Result Data

No	Voltage (V)	Current (A)	Active Power (kW)	Power Factor	Operating Hours (hours)	Energy Consumption (kWh)
1	380	7.2	3.80	0.78	1.0	3.80
2	380	7.5	4.05	0.77	1.0	4.05
3	380	7.3	3.90	0.79	1.0	3.90
Average	—	—	**3.92**	**0.78**	—	**3.92**

Based on the measurement results, electrical parameter data were obtained, including voltage, current, active power, power factor, and energy consumption on the machine during three tests. The measured voltage showed a constant value of 380 V at each data collection, which indicates that the system uses a three-phase power supply with relatively stable voltage conditions. The measured current value is in the range of 7.2 A to 7.5 A. This current variation is influenced by changes in the machine's workload during the operating process. When the load increases, the flowing current also increases, thus impacting the increase in power used.

The active power generated ranged from 3.80 kW to 4.05 kW, with an average value of 3.92 kW. This active power is the real power used by the machine to perform mechanical work. The difference in power values in each test indicates fluctuations in operational loads, which is a common condition in industrial equipment. The power factor obtained ranged from 0.77 to 0.79 with an average of 0.78. This value indicates that the system is not working optimally, because the ideal power factor is close to 1. A low power factor indicates the presence of a reactive power component in the system, which can cause increased energy losses and reduce the efficiency of electrical power use. With an operating time of 1 hour in each test, the energy consumption generated ranged from 3.80 kWh to 4.05 kWh, with an average value of 3.92 kWh. This indicates that energy consumption is proportional to the active power used, considering the constant operating duration. Overall, the electrical system in the machine shows relatively stable performance, but there is still opportunity to improve energy efficiency, especially through improving the power factor. Measures such as installing capacitor banks can be considered to reduce reactive power, thereby increasing system efficiency and lowering overall energy consumption.

Table 3.CNC Lathe Machine Measurement Result Data

No	Voltage (V)	Current (A)	Active Power (kW)	Power Factor	Operating Hours (hours)	Energy Consumption (kWh)
1	380	6.5	3.20	0.90	1.0	3.20
2	380	6.6	3.25	0.91	1.0	3.25
3	380	6.4	3.15	0.92	1.0	3.15
Average	—	—	**3.20**	**0.91**	—	**3.20**

Based on three measurements, electrical parameters were obtained, including voltage, current, active power, power factor, and energy consumption. The measured voltage showed a constant value of 380 V in each test, indicating that the system uses a three-phase power supply with stable voltage conditions.
The current values obtained ranged from 6.4 A to 6.6 A. This relatively small current variation indicates that the machine's workload tends to be stable throughout the operation process. This reflects the characteristics of a more controlled system, especially in machines with automated systems.

The measured active power ranged from 3.15 kW to 3.25 kW, with an average value of 3.20 kW. This value indicates the actual power used by the machine to perform its work processes. Low power fluctuations indicate that the machine's performance was fairly consistent throughout the test.
The power factor obtained ranges from 0.90 to 0.92, with an average of 0.91. This value is considered good and close to ideal conditions, indicating that the system's electrical power utilization is efficient. A high power factor indicates that the reactive power in the system is relatively low, thus minimizing energy losses.

With a 1-hour operating time for each test, the resulting energy consumption ranged from 3.15 kWh to 3.25 kWh, with an average of 3.20 kWh. This value is comparable to the active power used, considering the constant operating duration.

Overall, the system demonstrated stable performance with good efficiency. A high power factor and low power fluctuations indicate that the electrical system is operating optimally. This indicates that the machine has a better level of energy efficiency and lower potential power losses compared to systems with a low power factor.

Comparison of Energy Consumption and Efficiency

The comparison results show that CNC lathes have more efficient electrical energy consumption than conventional lathes for comparable types of turning jobs. Although the installed power of CNC machines is relatively higher, precise and stable operating settings optimize total energy consumption. In contrast, conventional lathes tend to use more electrical energy due to load fluctuations and low power factors.

These differences indicate that the use of CNC lathes offers advantages in terms of energy efficiency, especially in the long term. However, conventional lathes still play an important role in certain production activities, especially for simple and flexible work, although efforts to optimize electrical energy use are necessary. The results of this study indicate that conventional lathes have more fluctuating electrical energy consumption and lower power efficiency levels compared to CNC lathes. The power factor of conventional lathes is also relatively lower, indicating that electrical power utilization is not optimal. In contrast, CNC lathes show more stable energy consumption, better power factor, and higher electrical energy efficiency during the turning process.

Table 4. Recapitulation of Research Data Results

Parameter	Conventional Lathe	CNC lathe
Average power (kW)	3.92	3.20
Power factor	0.78	0.91
Energy consumption (kWh/hour)	3.92	3.20
Power efficiency (%)	72%	86%
Power stability	Low	Tall

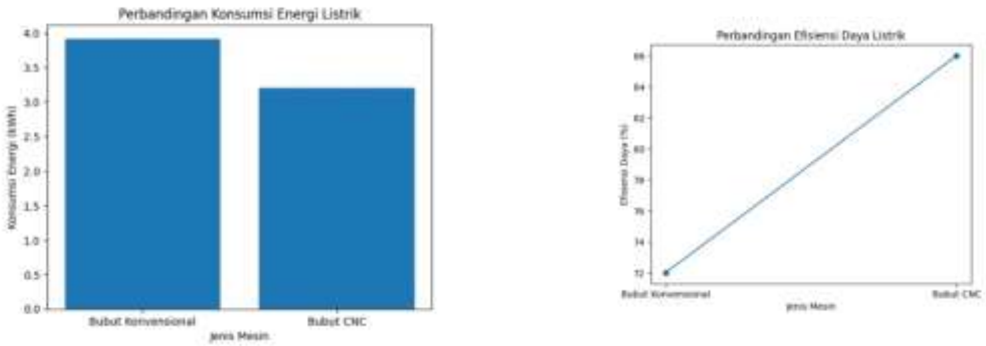

Figure 5. Comparison of Consumption and Efficiency

Based on the results of the analysis, it can be concluded that CNC lathes are superior in terms of electrical energy efficiency compared to conventional lathes. However, the potential for energy savings in conventional lathes can still be increased through more precise operational settings, electrical system maintenance, and the implementation of better energy management. Based on the research results, several recommendations for electrical energy saving strategies that can be implemented at CV Wakinara Teknik include optimizing conventional lathe operating parameters, increasing the power factor through electrical system improvements, and utilizing CNC lathes for jobs that require high precision and long operating durations. In addition, the company is advised to monitor energy consumption regularly as part of the implementation of energy management to reduce electricity costs and improve operational efficiency.

5. Conclusion

Based on the results of research and analysis that have been conducted regarding energy consumption and electrical power efficiency on conventional lathes and CNC lathes at CV Wakinara Teknik, it can be concluded that CNC lathes have better energy performance than conventional lathes. For the same time and operating conditions, CNC lathes consume 3.20 kWh of electrical energy, lower than conventional lathes which reach 3.92 kWh, which shows that the automatic control system on CNC machines is able to

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reduce energy waste during the turning process. In addition, the level of electrical power efficiency of CNC lathes is also higher, namely 86%, compared to conventional lathes which only reach 72%, which is caused by a more stable power factor and more precise load settings. In contrast, conventional lathes tend to experience fluctuations in power consumption due to manual operation and load variations during the work process, thereby increasing wasted electrical energy and reducing overall system efficiency. Therefore, the use of CNC lathes is more recommended to increase energy efficiency and reduce electricity operational costs, especially in continuous and high-intensity production activities, and can be a basis for consideration for industry in choosing production machines that are more energy efficient and environmentally friendly.

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