Effect of Outside Temperature Change on Energy Consumption in Chiller Machine

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***Abstrak*— Perawatan fasilitas industri manufaktur, terutama pada cleanroom, merupakan hal yang sangat penting untuk menjamin kelancaran operasi dan kualitas produk yang dihasilkan. Salah satu komponen yang memerlukan perhatian khusus adalah sistem pemanas, ventilasi, dan pendingin udara (HVAC). Sistem HVAC digunakan untuk menjaga suhu di dalam ruangan agar tetap sesuai dengan yang diinginkan, dengan mesin chiller sebagai komponen utama yang berfungsi untuk memastikan suhu ruangan tetap memenuhi kebutuhan. Penelitian ini bertujuan untuk melihat pengaruh perubahan suhu luar terhadap konsumsi energi pada mesin chiller dan dampak terhadap kinerja sistem pendinginan tersebut. Pengaruh atau korelasi antara suhu luar terhadap konsumsi daya mesin chiller ditinjau menggunakan pendekatan metode regresi linier untuk mengetahui hubungan antara kedua variabel. pengujian hipotesis juga dilakukan untuk memverifikasi apakah hubungan antara kedua variabel tersebut signifikan secara statistik ataupun tidak. Hasil penelitian menunjukkan bahwa suhu luar memiliki pengaruh signifikat kuat terhadap konsumsi energi dari mesin chiller dengan kenaikan secara proporsional yang direpresentasikan dengan koefisien korelasi sebesar 0,971. Kenaikan suhu luar cenderung meningkatkan beban kerja mesin chiller sehingga konsumsi energi juga meningkat. Hal ini dilakukan untuk mempertahankan suhu di area cleanroom agar tetap stabil.**

***Abstract*— Maintenance of industrial manufacturing facilities, especially cleanrooms, is very important to ensure smooth operations and the quality of the products produced. One component that requires special attention is the heating, ventilation and air conditioning (HVAC) system. The HVAC system is used to maintain the temperature in the room to keep it as desired, with the chiller machine as the main component that functions to ensure the room temperature still meets the needs. This study aims to look at the effect of changes in outside temperature on the energy consumption of the chiller machine and the impact on the performance of the cooling system. The effect or correlation between the outside temperature and the power consumption of the chiller machine is used a linear regression method approach to determine the relationship between the two variables. Hypothesis testing is also carried out to verify whether the relationship between the two variables is statistically significant or only occurs by chance The results showed that the outside temperature has a strong significant effect on the energy consumption of the chiller machine with a proportional increase represented by a correlation coefficient of 0.971. The increase in outside temperature tends to increase the workload of the chiller engine so that energy consumption also increases. This is done to maintain a stable temperature in the cleanroom area.**

Keyword: Chiller Machine, Cleanroom, Heating, Ventilation, and Air-conditioning System (HVAC), Power Consumption, Temperature

I. INTRODUCTION

Semiconductors are components that have conductivity between that of a conductor and an insulator [1]. Semiconductors play an important role in electronic devices. Therefore, semiconductors can be modified according to needs, thus making them a versatile and important component in modern technology. In the manufacturing process, semiconductors have two processes, namely Frontend and Backend [2].

The semiconductor manufacturing process requires a standardized cleanroom. Cleanroom is a room that is designed and made using certain technology to be able to control the concentration of particles in the air and microbial carrier particles [3]. Cleanrooms can regulate temperature, humidity and pressure according to the desired standards [4]. HVAC systems are needed to control the temperature, humidity, airflow and air quality within the cleanroom [5]. A typical system brings in outside air, mixes it with air returning from or exiting the system, filters the air, passes it through heating or cooling coils to the required temperature, and distributes the air to various parts of the building.

HVAC systems consist of several components, one of which is the Chiller Machine. A chiller Machine is a refrigeration system designed to remove heat through a vapor compression, absorption, or adsorption refrigeration cycle. Its main purpose is to cool a fluid or dehumidify air in an industrial or commercial environment. One type of chiller machine is a water-cooled chiller. The basic principle of a water-cooled chiller is the process of heat absorption and release of heat by using media in the form of water cooled in the cooling tube [6-7].

Previous research on the effect of ambient temperature on power consumption in cooling containers was conducted for 7 days with a setpoint temperature of -20°C, proving that higher ambient temperatures correlate with increased power consumption in cooling containers. The highest power consumption was recorded at 35.9°C, reaching 12 kW at 12:00 pm, while the lowest power consumption occurred at 30.2°C, which was 10 kW at 04:00 am [8]. Maintenance of manufacturing facilities is carried out to support productivity in the manufacturing industry in a sustainable manner. maintenance of manufacturing facilities is needed because the company's profits depend on the good working condition of assets [9]. To find out if there is an effect of temperature changes on energy consumption. In this research, the authors investigated the effect of temperature changes on the power used in the chiller engine. By taking outside temperature data and the power used by the chiller machine at that time.

II. METHOD

This research uses quantitative descriptive statistical techniques. Data on external temperature and power consumption were collected during observation to determine the relationship between the two data variables. Furthermore, to see the significant impact of power consumption, a linear regression approach was used. The linear regression equation is as follows [10-12]:

$$Y = a + bX \quad \ldots.(1)$$

Description:

Y is the response variable, X is the predictor variable, a is a constant; b is the regression coefficient (slope) of the response amount caused by the Predictor. From equation one, y is defined as the power machine variable and x as the outside temperature parameter.

Furthermore, Relative error is used to measure the level of inaccuracy of a measurement compared to the true or reference value. With the following formula[13]:

$$KR = \frac{Measured\ Value - Reference\ Value}{Reference\ Value} \text{ x } 100\% \quad \ldots.(2)$$

Description:

KR is relative error, reference value is the value measured using a clamp meter, and measured value is the value on the chiller machine screen display.

Furthermore, the interpretation of the correlation relationship between outside temperature parameters and chiller engine power is expressed by the correlation coefficient (r) value which refers to the provisions of table 1.

TABLE I
INTERPRETATION OF CORRELATION COEFFICIENT

Correlation Coeficient Interval	Degree of Association
0,00- 0,199	Very low
0,020 – 0,399	Low
0,40 – 0,599	Moderate
0,60 – 0, 799	Strong
0,70 – 1,000	Very strong

In addition, hypothesis testing was also conducted to verify whether the relationship between the two variables is statistically significant or merely coincidental. With the formulation that the Null Hypothesis (H0) there is no significant change in power consumption if the outside temperature changes. While the Alternative Hypothesis (H1) there is a significant change in power consumption if the outside temperature changes [14-15].

Furthermore, to prove whether H1 or H0 is accepted, the p-value is used as a reference. If the p-value obtained is smaller than the specified significance level (0.05), then H0 is rejected [16], meaning that there is enough evidence to conclude that the outside temperature affects power consumption. Conversely, if the p-value is greater than the significance level, then H0 is accepted, meaning that the relationship between outside temperature and power consumption is considered statistically insignificant.

In this research, both variable parameters x and y are practically or technically measured power measurements taken using a clamp meter and monitoring on the chiller machine screen. Handheld temperature humidity is used to measure the temperature around the chiller machine.

Clamp meters are used to measure the electric current flowing into the chiller machine during its operational process [17], thus allowing direct monitoring of the machine's power consumption. To measure the temperature around the chiller machine area using handheld temperature humidity.

III. RESULT AND DISCUSSION

Observations of energy consumption on the chiller engine have been carried out during the research. The results of monitoring the energy consumption output are displayed on the screen display of the chiller machine as shown in Figure 1. Furthermore, data collection of outside temperature parameters was carried out to observe changes in the power consumption generated in the chiller machine. Measurements on the chiller machine are obtained from the clamp meter readings and screen monitoring on the chiller machine, the use of a clamp meter to ensure that the readings displayed on the chiller machine screen match the actual electric current flowing in the chiller machine. The partial measurement data of power consumption during temperature change is shown in Table 2.. Figure 2 shows the trend graph of changes in outside temperature against energy consumption on the chiller engine. There appears to be a consistent pattern between changes in ambient temperature and the level of energy consumption in the cooling system. The highest temperature measured during the observation reached 32°C, with an observed power of 280 kW/Ton.R. and then based on the total measurements, the average value of the relative error percentage is 2.1%. In addition, the graph shows an R-sq value of 94.4%, indicating that there is a significant linear correlation between outside temperature and power consumption. As the ambient temperature increases, there is a proportional increase in the energy consumption required by the cooling system to maintain the room temperature in accordance with the standards set for cleanrooms at 22° Celcius.

Figure. 1. Chiller Machine Screen Display

TABLE II
MEASUREMENT DATA

Temp (°C)	Power Clamp Meter (KW/TON.R)	Power Screen Machine (kW/Ton.R)	Error Relative (%)
30,3	260	265	1,9
30,3	260	265	1,9
31,0	266	270	1,5
31,0	266	270	1,5
31,0	266	270	1,5
31,0	266	270	1,5
31,0	266	270	1,5
30,0	260	265	1,9
30,0	260	265	1,9
29,8	255	263	3,1
30,0	260	265	1,9
30,0	260	265	1,9
31,0	266	270	1,5
31,0	266	270	1,5
32,0	292	280	4,1
31,5	268	275	2,6
31,0	266	270	1,5
30,8	260	268	3,1
30,0	260	265	1,9
30,0	260	265	1,9

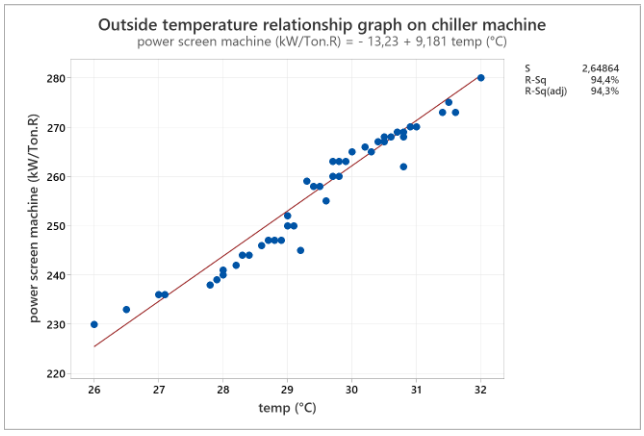

Figure. 2. Relationship graph between outside temperature and chiller engine power consumption

Based on the results of the fitted line using the regression method, a linear regression equation is obtained, namely power screen machine (kW / ton.R) = -13.23 + 9.181 temp (°C). This equation can then be used to estimate the power consumption of the chiller engine, specifically for the temperature parameter values that have not been recorded. The following is presented some data on Power estimation values using the Fitted line plot equation (Table 3).

TABLE III
POWER MACHINE ESTIMATION USING THE FITTED LINE PLOT EQUATION

No	Temperature (°C)	Power (kW/Ton.R)
1	26,9	234
2	27,5	239
3	29,7	259
4	30,4	266
5	31,3	273

Based on the distribution of outside temperature data (x) and chiller engine power (y), the Pearson correlation coefficient value r = 0.971 was obtained. This coefficient value interprets the two variables as strong correlation data (table 1). While proving the Ho and H1 hypotheses is determined based on the P-value. The P-value is obtained from the fitted line data plot. The p-value of 0.000 is smaller than the set significance level of 0.05. This indicates that there is a significant relationship between the outside temperature variable (X) and energy consumption (Y) in the Chiller machine. In other words, changes in outside temperature have a real influence on the level of energy consumption of the machine. This result also indicates that the null hypothesis (H0) is rejected, so the alternative hypothesis (H1) which states that there is a significant influence between the two variables is accepted.

Based on data distribution observations, the minimum power consumption value was recorded at 230 kW/Ton.R at an ambient temperature of 26°C, while the maximum power consumption reached 280 kW/Ton.R at an outside temperature of 32°C. The average power consumption during the measurement period was 260 kW/Ton.R. with an average ambient temperature of 29.7°C.

The increase in outside temperature has a significant impact on the performance and energy consumption of the chiller engine. Periodic maintenance on the chiller machine needs to be done to keep the machine in good condition and damage before it becomes a more serious problem. Dirt, scale, or leaks on chiller components can hinder the performance of the chiller engine. As a result, the chiller machine must work harder to maintain the temperature in the cleanroom as desired which automatically makes the power consumption increase [18].

IV. CONCLUSION

Based on the observation show that the outside temperature has an influence on the energy consumption of the chiller engine which is very strong with a Pearson correlation coefficient value of 0.971. The change in outside temperature increase is positively linearly proportional to the increase in chiller engine power. This tendency to increase the outside temperature increases the workload of the chiller engine, which results in an increase in energy consumption. When the outside

temperature increases, the chiller engine needs to work harder to maintain a stable temperature in the cleanroom area at 22° Celcius. Knowing the effect of outside temperature changes on energy consumption makes it possible to design a better chiller system by considering the specific environmental conditions in which the components will operate and routine maintenance should be carried out to keep the chiller machine in proper working condition..

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