

# Analysis of the Influence of Room Temperature and Humidity on the Printing Results of Inkjet Printing Machines at PT. Philips Industries Batam

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The implementation of the Industry 4.0 system has become a major focus for companies in Indonesian, including *PT. Philips Industries Batam*, which uses Inkjet Printing machines. This machine, although it has great potential in cell biology applications and biomedical research, still faces high reject problems, especially related to missing prints. This study aims to reduce the reject missing print on the Inkjet Printing machine by analyzing the effect of room temperature and humidity on printing quality. The research method involves collecting data from running production results to analyze reject patterns, as well as experiments to test the effect of temperature and humidity on printing quality. The results, temperature and humidity 22 and 23 which have a low reject percentage, namely the combination of temperature 22C and humidity 40% obtained a percentage of 0.39%, the combination of temperature 22C and humidity 50% obtained a percentage of 0.43%, the combination of temperature 23C and humidity 40% obtained a percentage of 0.49% and the combination of temperature 23C and humidity 50% obtained a percentage of 0.30%. After it is found that the combination of temperatures 22C and 23C has a low percentage of reject, then the next combination will be done with *Tavg* 40,41,42

and 43, *Tavg* 40 = Average reject result: Around 0.51%, Interpretation: At *Tavg* 40, the reject rate is relatively low, even the lowest is 0.25%. Temperatures of 22–23°C and humidity of 40–50% have not significantly affected the reject rate.

**Keyword:** Industry 4.0, Inkjet Printing machines, room temperature and humidity.

## I. INTRODUCTION

The Indonesian government is currently implementing strategic steps set out in the Making Indonesian 4.0 roadmap. One of the visions of the Making Indonesian 4.0 plan is to make Indonesian one of the 10 countries with the strongest economies in the world by 2030 [1]. Many companies are now implementing the industry 4.0 system.

One of them is *PT. Philips Industries Batam*, which operates in the manufacturing and electronics sector. The machine at *PT. Philips* that implements the industry 4.0 system is the Inkjet Printing machine. Inkjet Printing is a new and versatile technology whose applications are new in cell biology and related biomedical research [2]. Inkjet Printing is also known as droplet-based Printing because the ink is sprayed through

the nozzle of the flow device in the form of droplets with a volume range of nano to pico-liters [3].

Temperature measurement is essential for thermal control, which is necessary for the advancement of mechanical and electronic devices. However, current temperature sensors are limited by their inability to measure curved surfaces [4].

Relative humidity (or *RH*) is the ratio between the actual water vapor pressure at a given temperature to the saturated water vapor pressure at that temperature. Another definition of humidity is the ratio between the amount of water vapor contained in the air at a given time to the maximum amount of water vapor that the air can hold at the same pressure and temperature. [5].

The more output that can be produced by the Inkjet Printing machine, the more rejects will be produced. According to data obtained during running production on June 26, 2024, from 24 hours of running production, the output was 184,125 *pcs*, and the rejects were 2491 *pcs*. This means that rejects have a percentage of 1.3%. And the target reject from production is <1%.

There are various types of rejects on Inkjet Printing machines such as missing print, miss alignment, hairy, missing white, missing yellow, missing cyan, missing yellow and cyan, scratch, dented, blurry and incorret loaded parts. Based on data from running production results for a year. From the rejects mentioned, there is 1 type of reject that has the largest percentage of rejects. Therefore, this study will focus on the missing print reject.

## II. METHOD

This method employs a systematic analysis approach, using techniques to examine inkjet printing machines. By leveraging articles related to the analysis of the influence of room temperature and humidity on inkjet printing results, research is conducted. Article searches are carried out using databases such as Google Scholar or Google Cendikia with keywords like "Analysis of the influence of room temperature and humidity

+ Inkjet Printing." Articles selected are from the past five years.

A flowchart can be seen in Figure 1.1

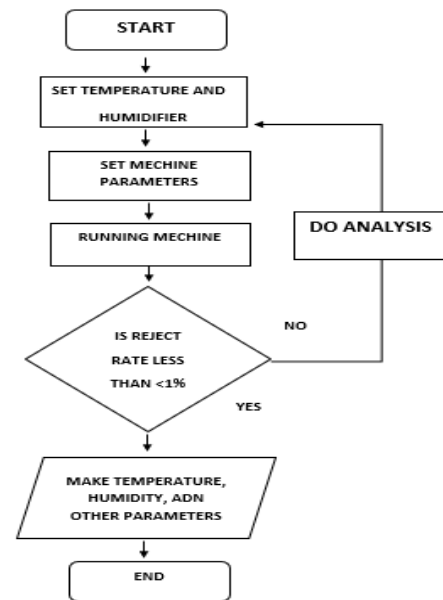


Figure 1. 1 Flowchart

which is used starts with setting the air conditioner temperature and room humidity, then setting the parameters in the flow module, after that the machine runs for 1 shift, the results are recorded in Excel, then the data is processed with Minitab19 software, when the reject results do not show below 1% then repeat the initial stage, setting the temperature and humidity, and if the reject shows a percentage below 1% then the temperature and humidity and module parameters will be created which will be used for future running.

### Design of Subsystem 1

This research is a descriptive-analytical study conducted using multiple linear regression. In the multiple linear regression method, one dependent variable and two independent variables are required. In this research, the independent variables are temperature and humidity, while the dependent variable is the number of reject missing prints. To perform multiple linear regression, Minitab 19 software is used. There are several steps involved in performing the multiple linear regression method :

- I. Performing a residue analysis

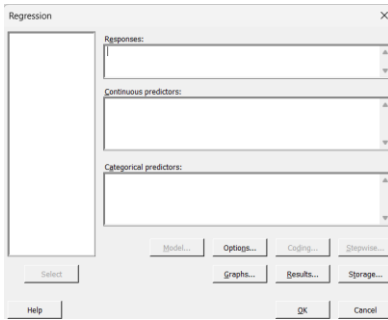


Figure 1. 2 Residu Test

In the responses section (Figure 1.2 ), the dependent variable, reject missing print, will be entered. In the continuous predictors, the independent variables, temperature and humidity, will be entered.

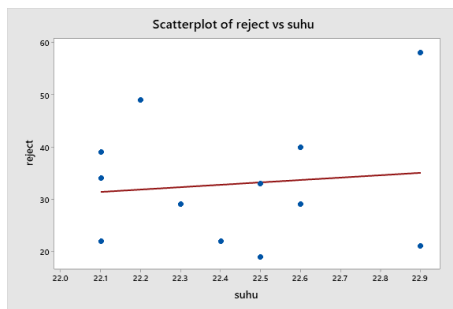


Figure 1. 3 Scatterplot

In the responses section (Figure 1.3 ), the dependent variable, which is the number of reject missing prints, will be entered. The independent variables, temperature and humidity, will be entered into the continuous predictors section.

## II. Next, a normality test is performed

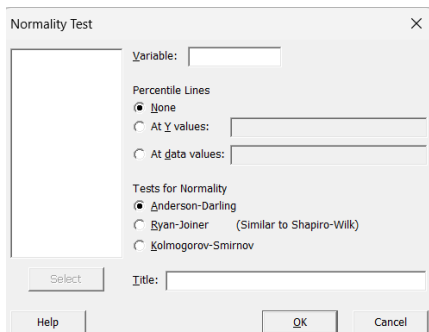


Figure 1. 4 Normality Test

In the variable column (Figure 1.4 ), the residual values will be entered. The Kolmogorov-Smirnov test will be used to assess normality.

## III. Linearity

Linearity (Figure 1.5 ) is used to determine whether there is a linear relationship between temperature and reject missing print, and between humidity and reject missing print.

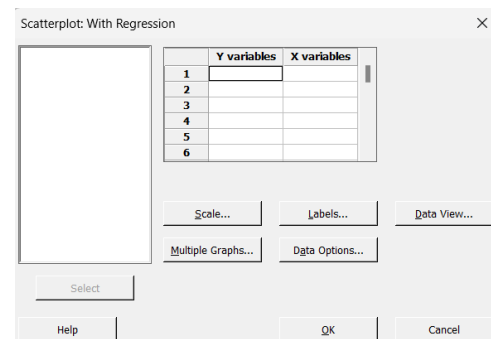


Figure 1. 5 Linearity

## IV. Homoscedasticity

Homoscedasticity is assessed by examining the scatterplot of residuals versus fitted values. The absence of any discernible pattern, with data points evenly scattered above and below the zero line, suggests homoscedasticity.

## V. Non-multicollinearity

Non-multicollinearity is assessed by examining the Variance Inflation Factor (VIF) values in the coefficients table. To ensure the absence of multicollinearity, all VIF values should be less than 5.

## VI. Regression Equation

After completing these steps, the Regression Equation will be obtained.

## Design of Subsystem 2

Before starting production, the AC temperature and humidifier humidity must be set. After adjusting the AC temperature and humidifier settings, the next step is to configure the parameters of the flow module. These parameters include:

1. Temperature average (*Tavg*): This is the average operating temperature of the flow module.
2. Pressure different (*Pdiff*): This is the pressure within the ink tank of the flow module.
3. Pressure meniscus (*Pmen*): This is the pressure used to pump ink to the printhead.

After configuring all the settings, the researcher will monitor the circulation pump within the flow module. After setting the temperature, humidity, and parameters, the researcher will create a document outlining the temperature, humidity, and parameter settings required for production.

### Testing

To conduct the testing, we will utilize Minitab software and employ a trial-and-error method. A comparison will be made using the initial data from the production run on June 26, 2024, and the data collected after the research. The dependent variable is "Reject missing print", while the independent variables are temperature, humidity, and machine parameters: *Tavg* (average temperature), *Pdiff* (pressure difference), and *Pmen* (meniscus pressure). In the testing, a table as shown below (Table 1) will be used.

### III. RESULT

In this study, the data processing process used Minitab 19 software with two independent variables and one dependent variable. Where the independent variables were room temperature and room humidity, and one dependent variable was reject missing print. The data collection process was carried out simultaneously with running production on the inkjet printing line. With a room temperature range of 18-24°C and a room humidity range of 40-50%. The following data processing results were obtained:

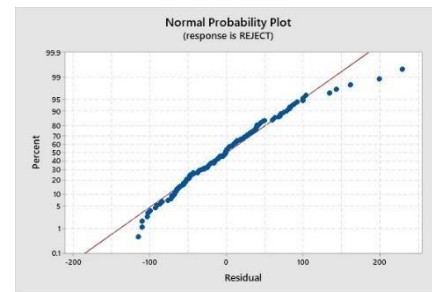


Figure 3. 1 Accumulated residual value graph from temperature 18-24 c and humidity 40-50%

From Figure 3.1, the accumulated residual value graph from a temperature of 18-24°C and humidity of 40-50%, the residual distribution is generally normal, as the majority of points follow the line. Slight deviations in the tails can be tolerated depending on the context and the model's sensitivity to normality.

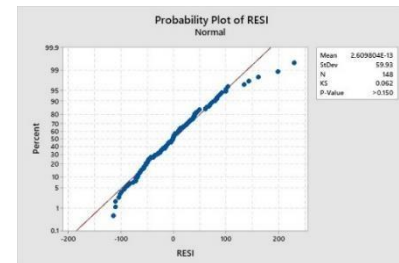


Figure 3. 2 Accumulation of normality test graphs for a combination of humidity levels of 18-24°C and 40-50% humidity.

From Figure 3.2, the accumulated normality test graph for temperatures of 18-24°C and humidity of 40-50% shows that, since the P-Value is > 0.05, there is insufficient evidence to reject the null hypothesis that the residuals are normally distributed. This means that the residuals are statistically normally distributed.

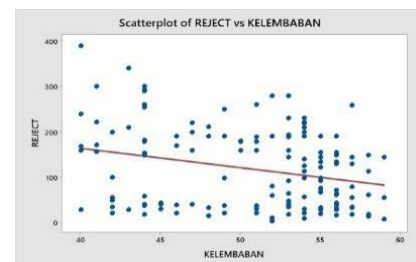


Figure 3. 3 Scatterplot accumulation of humidity combinations of 18-24°C temperature and 40-50% humidity

From Figure 3.3, the accumulated scatterplot of temperature 18-24°C and humidity 40-50%, there is a tendency that increasing humidity slightly reduces the number of rejects. Because the distribution of points is very spread out, this relationship is most likely statistically weak.

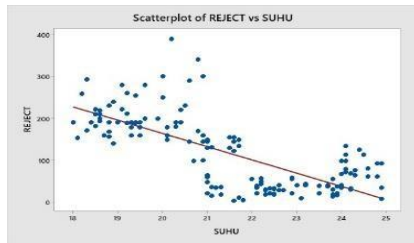


Figure 3. 4 Scatterplot accumulation against humidity combination of temperature 18-24c and humidity 40-50%

From Figure 3.4 , the accumulated scatterplot of temperatures of 18-24°C and humidity of 40-50% shows that the higher the temperature, the lower the number of rejected products. This relationship appears quite strong visually, so temperature may be an important variable affecting the number of rejects.

The measurement results of data with a combination of temperature 18-24 C and humidity 40-50% are shown in the following table 3.1

Table 3. 1 data with a combination of temperature 18-24 C and humidity 40 and 50%

No	Suhu (°C)	Kelembaban (%)	Reject	Output	Hasil (%)
1	18	40	2311	100541	2.30
2	18	50	1663	65868	2.52
3	19	40	1706	63214	2.70
4	19	50	2464	100639	2.45
5	20	40	2768	102733	2.69
6	20	50	1419	60931	2.33
7	21	40	1432	102986	1.39
8	21	50	1689	100770	1.68
9	22	40	395	102173	0.39
10	22	50	433	99984	0.43
11	23	40	307	62185	0.49
12	23	50	199	65388	0.30
13	24	40	1650	101717	1.62
14	24	50	1585	101095	1.57

Based on the data above, it can be seen that the temperature and humidity of 22 and 23 have the lowest rejection percentages. The combination of 22°C and 40% humidity yields a percentage of 0.39%, the combination of 22°C and 50% humidity yields a percentage of 0.43%, the combination of 23°C and 40% humidity yields a percentage of 0.49%, and the combination of 23°C and 50% humidity yields a percentage of 0.30%. After determining that the combination of 22°C and 23°C has a low rejection percentage, the next step is to combine it with *Tavg* values of 40, 41, 42, and 43, yielding the following results. the number of rejected products and total output, and the percentage of rejected results (results %) is calculated. The measurement results of the combined data with *Tavg* 40, 41, 42 and 43 are shown in the following table 3.2

Table 3. 2 combination with *Tavg* 40,41,42 and 43, and the following results are obtained.

No	Suhu (°C)	Kelembaban (%)	Tavg	Reject	Output	Hasil (%)
1	22	40	40	259	102173	0.25
2	22	50	40	820	99984	0.82
3	23	40	40	399	62185	0.64
4	23	50	40	220	65388	0.33
5	22	40	41	1445	97532	1.48
6	22	50	41	1634	101022	1.61
7	23	40	41	1620	91850	1.76
8	23	50	41	1637	97636	1.67
9	22	40	43	1499	98350	1.52
10	22	50	43	1927	95561	2.01
11	23	40	43	1487	88129	1.68
12	23	50	43	963	37927	2.53

- *Tavg* 40 = Average reject rate: Approximately 0.51%. Interpretation: At *Tavg* 40, the reject rate is relatively low, with the lowest being 0.25%. Temperatures of 22–23°C and humidity of 40–50% do not significantly affect the reject rate.
- *Tavg* 41 = Average reject rate: Approximately 1.63%. Interpretation: Increasing *Tavg* from 40 to 41 causes a significant increase in the reject rate (almost threefold). The combination of temperature 23°C and high humidity (50%) results in the highest reject rate at this *Tavg*.
- *Tavg* 43 = Average reject rate: Approximately 1.93%.

Interpretation: Although  $T_{avg}$  increases to 43, the reject rate does not increase uniformly. In fact, the last row (23°C, 50% RH)

yields the highest reject rate (2.53%), even though the number of rejects isn't the highest — this is because its output is the lowest. This means that productivity is low but rejects remain high, resulting in a high failure rate.

- Conclusion: The higher the  $T_{avg}$ , the higher the reject rate, indicating that the process may be less stable/efficient at a given temperature. Humidity also plays a role, especially when  $T_{avg}$  is high. 50% humidity tends to produce a higher yield (%) than 40%. 23°C is slightly worse than 22°C in terms of rejects, but not too extreme.

- $T_{avg} = 40$  with a temperature of 22°C and 40% humidity is the most optimal condition (lowest reject rate: 0.25%). Avoid high  $T_{avg}$  ( $\geq 41$ ), especially if humidity and temperature are also high  $\rightarrow$  resulting in a reject rate of  $>2\%$ . It is recommended to maintain stable and low temperature and humidity.

#### IV. COCLUSION

From this research, it can be concluded that room temperature and humidity significantly influence inkjet printing results at PT. Philips Industries *Batam*. The analysis found that:

1. Optimal Temperature: Higher temperatures tend to reduce the number of rejects, as ink can flow and mix better at ideal temperatures.
2. Controlled Humidity: Humidity in the range of 40%-60% is the most ideal condition for maintaining print quality. Humidity that is too low or too high can lead to an increase in the number of rejects. Production Quality: Proper temperature and humidity control are crucial for increasing production efficiency and reducing product rejection rates, which in turn positively impacts output and product quality.

#### V. REFERENCES

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