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THE EFFECT OF CHILLER AND HOT RUNNER TEMPERATURE ON APPEARANCE OF 100 mL PET BOTTLE PRODUCTS THROUGH THE STRETCH BLOW MOLDING PROCESS

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Abstract. The using of plastic in human life is increasing over time. This increase occurs because plastic is not easily broken, flexible, practical, economical, and can replace the function of other items. One of the plastic molding processes is Injection Stretch Blow Molding, a plastic molding machine method that combines two processes, namely injection molding and stretch blow molding. The injection stretch blow molding process is a plastic molding machine that is melted and then injected into the mold to form a preform that is stretched and blown to form the product. This machine has a high level of precision so that the aspects of strength and appearance quality on the packaging bottle are the main assessment. The aim of this research is to determine the effect of temperature parameters on black spots, stripes and stripes on 100 mL PET bottle products. It is necessary to handle chiller temperature, hot runner temperature as independent variables in printing preforms. The control variables are material composition, cycle time, holding time, and component gap position. This type of research is experimental research and the processing method used in this research uses the design of experiments using statistical software. The level of variation in hot runner temperature parameter settings is 265°C, 270°C, and 275°C and chiller temperature is 17°C, 18°C, and 19°C. From the results of this research, it can be concluded that the significant parameters used for the chiller are 18°C, the appearance defect is 0.2% and for the hot runner it is 270°C, the appearance defect is 0.4%. This number is a significant parameter that produces fewer appearance defects for 100 mL PET bottle products in order to reduce the number of rejects.

Keywords :Injection Stretch Blow Molding, chiller, hot runner, preform, appearance.

1. INTRODUCTION

The use of plastics in human life is increasing from time to time. This increase occurs because plastic is lightweight, unbreakable, flexible, practical, economical which can replace the function of other goods. Currently, the production capacity of the national plastic products industry reaches 7.679 million tons, and the total consumption of plastic finished products reaches 8.227 million tons. Of the total consumption of plastic finished products, 7.12 million tons are met domestically. The large amount of imported products to meet the needs of plastic finished products and raw materials for the plastic industry shows that there is still a need to increase production capacity and new investment in this sector to replace imported products [1].

The plastic molding process has various types of processes in processing raw ore into the final product. The types of plastic molding processes are injection stretch blow molding, blow molding, extrusion molding, and vacuum molding, rotation molding. All of these types of processes are applied according to the material used and the shape of the product volume produced. For cosmetic and food packaging products tend to use injection stretch blow molding machines, one of the products produced is 100 mL PET bottles, it is necessary to conduct research on the treatment of temperature parameter settings because it has an influence on product results, besides that the composition of material ore, type of mold material, and volume of product molds also have an influence on product results.

Injection stretch blow molding is machine that focuses on cosmetic packaging products. Unique and elegant shapes are often judged in the stretch blow molding process. The molding process has a high level of precision so that aspects of strength and quality of appearance on the packaging bottle become the main assessment. So as to get results close to perfect value according to the production standards set by the company's Quality Assurance. It is necessary to handle the chiller temperature, hot runner temperature in printing the preform until it becomes a product, as well as adjusting the cycle time, holding time, and the position of the component gap. The purpose of the handling carried out is to reduce defects in products such as stripes, black spots, hair on the bottom of packaging bottles, and uneven dimensions. These defects can be seen visually and sampling of each production for organoleptic testing by Quality Assurance in the laboratory.

Organoleptic or sensory assessment is the most primitive way of assessment. Sensory assessment became a field of science after the assessment procedure was standardized, rationalized, linked to objective assessment, data analysis became more systematic, as well as statistical methods used in analysis and decision making. Organoleptic assessment is widely used to assess quality in the food industry and other agricultural products industry. Sometimes this assessment can give very precise assessment results. In some cases the assessment with the senses even exceeds the accuracy of the most sensitive tools [2]. Plastic molding molding companies have targets according to the vision and mission. Experimental treatment in the production process will have an impact on the production target timeline and the impression of consumers who work with the company. Based on the description of all aspects of plastic molding. In line with the vision of the plastic molding industry that wants the production process to be a professional company that excels.

2. METHODS

2.1 Types of Research

The data collection method in this study uses quantitative experimental methods. Furthermore, data analysis processing was carried out to determine the effect of the independent variable on the dependent variable using statistical software and DOE factorial experimental design.

2.2 Time of Research

This research was conducted from February to April 2024

2.3 Research Tool and Material

The tools and material used in this research include

1. Injection Stretch Blow Molding Machine [3].

Spesification Machine

- Standard Screw Diameter (φ) : 54 mm
- Theoretical Injection Capacity : 366*3 cm^3
- Injection Clamping Force : 687 kN
- Blow Clamping Force : 242 kN
- Driving Power (Rated) : 33 kW
- Heater Capacity (Rated) : 25.8*4 kW
- Oil Reservoir Capacity : 600 L
- Machine Size (L×W×H) : 5,643 ×1,896 ×3,208 mm
- Machine Weight (Approx.) : 9.0 Ton
- Numbers of cavity : 6

2. Plastic Material

The material used in making polyethylene terephthalate [4] (PET) 100%.

Figure 1. Polyethylene Terephthalate

3. Camera

Macro photography is a technique that can capture small objects, looks more interesting because the resulting perspective observed can be experimental data as well as documentation to show reality during research.

2.4 Research Variables

In the research, there are variables that play an important role in taking data during research, as in Table 1. Next:

Table 1. Research variables.

Independent variable		
1	Temperatur chiller (°C)	: 17°C, 18°C, and 19°C
2.	Temperatur hot runner (°C)	: 265°C, 270°C, and 275°C
Dependent variables		
1.	Quality Appearance Product (%)	
Controlled Variables		
1	Materials	: PET (polyethylene terephthalate)
2	Composition material	: 100 % original
3	Cycle time (t)	: 1.48 s
4	Pressure Inject (bar)	: 4.48
5	Holding time (t)	: 1.31 s

2.5 Research Hypothesis

The hypothesis in this research are:

Hypothesis Zero (H_0) : There is no effect of chiller temperature and hot runner on the appearance quality of 100 mL PET bottle products in the stretch blow molding process.

Hypothesis Alternative (H_1): There is an effect of chiller temperature and hot runner on the appearance quality of 100 mL PET bottles in the stretch blow molding process.

3. RESULTS AND DISCUSSION

3.1 Result

10 replications were carried out, the results of product identification and attribute data from the data collection process were 90 pieces of 100 mL PET bottle products for the normal standard of defects in 100 mL PET bottle products as a benchmark is no. 2 with a chiller temperature of 18°C and a hot runner temperature of 270°C which produces minimal defects shown in Table 2:

Table 2. Research results and observations

No	Temperature *Chiller* (°C)	Temperature Hot Runner (°C)	Product Result Appearance										Chance of Failure
			1	2	3	4	5	6	7	8	9	10	
1	17	265	1	1	1	1	1	1	1	1	1	1	1
		270	1	1	1	1	1	1	1	1	1	0	0,9
		275	0	0	0	0	0	0	0	1	1	1	0,3
2	18	265	1	1	1	1	0	0	0	0	0	0	0,4
		270	0	0	0	0	0	0	0	0	0	0	0
		275	0	0	0	0	0	0	0	0	1	1	0,2
3	19	265	1	1	1	1	1	1	1	1	1	1	1
		270	1	1	1	0	0	0	0	0	0	0	0,3
		275	1	1	1	0	0	0	0	0	0	0	0,3

From the data collection of 90 products, the product documentation data value 1 indicates the defective effect while 0 indicates no defect. The following figure 2 is a normal sample of 100 mL PET bottle without defects:

Figure 2. Good product

Figure 2 above is an example of a good product without defects in a 100 mL PET bottle as a reference, with optimal temperature settings and no problems in the production process machine. Data colection that has been carried out, then the data processing is continued using statistical software. The following are the result of the analysis that has been carried out:

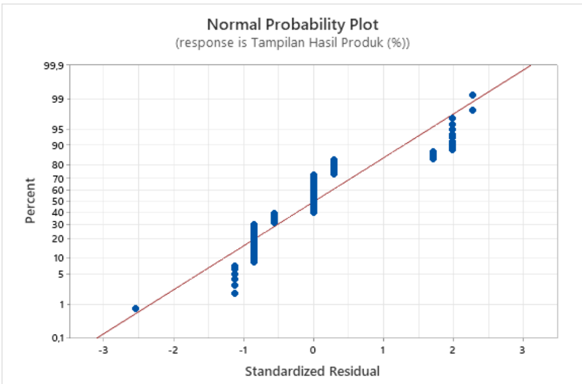

Figure 3. Grapich normal probability plot

The normal probability plot graph shows that the residual points formed are close to the red line. The significant value shown (P-Value> 0.05). If the significant value> 0.05 then the data is normally distributed. The results of the residual normality test can be said that the data follows a distribution that is close to normal. It is assumed that the regression model that has been made can be used.

Table 3. Analysis of variance

Source	DF	Adj SS	Adj MS	F-Value	P-Value
Model	8	11,289	1,4111	10,21	0,000
Linear	4	8,978	2,2444	16,23	0,000
Temperatur Chiller (°C)	2	4,356	2,1778	15,75	0,000
Temperatur Hot Runner (°C)	2	4,622	2,3111	16,71	0,000
2-Way Interactions	4	2,311	0,5778	4,18	0,004
Temperatur Chiller (°C)*Temperatur Hot Runner (°C)	4	2,311	0,5778	4,18	0,004
Error	81	11,200	0,1383		
Total	89	22,489			

The ANOVA table shows that the chiller temperature and hot runner temperature have an interaction value of P-value of 0.004 so that based on the hypothesis in this study the decision taken is to reject the initial hypothesis because the P-value is smaller than the alpha (α) tolerance level of 5% or 0.05 that has been set (p-value < alpha (α)). So that the null hypothesis (H0) is rejected and the alternative hypothesis (H1) is accepted, then the appearance defects on 100 mL PET bottles are also influenced by the hot runner temperature and chiller temperature significantly.

Table 4. Model summary

S	R-sq	R-sq(adj)	R-sq(pred)
0,371849	50,20%	45,28%	38,52%

The coefficient of determination (R-square) value aims to predict or see how much influence the independent variable contributes to the dependent variable. Based on the model summary above, it shows the coefficient of determination of 50.20%, the percentage value of the coefficient of determination is closer to 100%, it can be concluded that it has a significant influence. Approaching perfectly the total of the two independent variables used on the dependent variable, the R-sq number above means that the chiller temperature and hot runner temperature have an influence on appearance defects in 100 mL PET bottles of 50.20%, and the remaining half of 40.80% is caused by other variables not examined outside the regression. Then the variable that is not used in this study is known as error symbolized by (e).

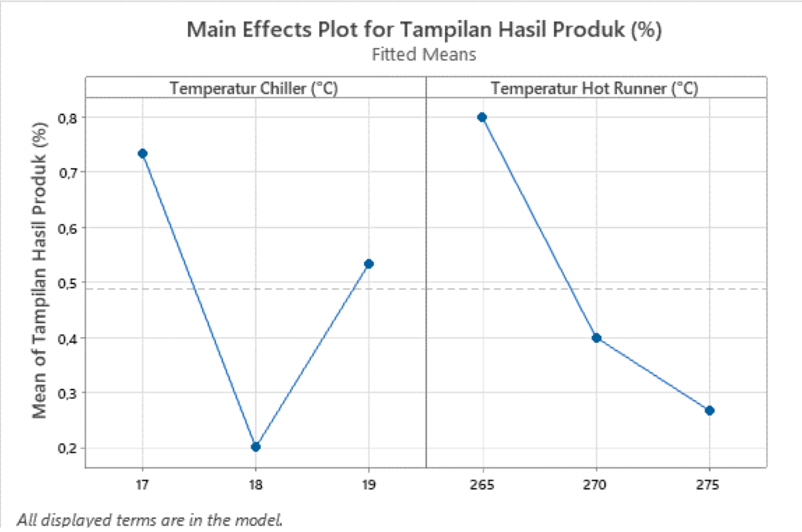

Figure 4. Main effect plot

Based on the results of this study, figure 4 factorial plot can be seen that the chiller temperature level of 17 °C has the most percentage defect opportunities with values between 0.7% to 0.8% the lower the chiller temperature level causes the product appearance defects to be large, at the chiller temperature there are striped defects, this is because at that temperature the preform has problems during the blow process, Likewise, the value of many defects is at a chiller temperature of 19 °C. The higher the chiller temperature level causes product appearance defects not to be safe because the character of each mold is not the same which can occur spotted and haired defects, while the smallest chance of appearance defects worth 0.2% is in the temperature range between the two chiller temperatures, namely 18 °C.

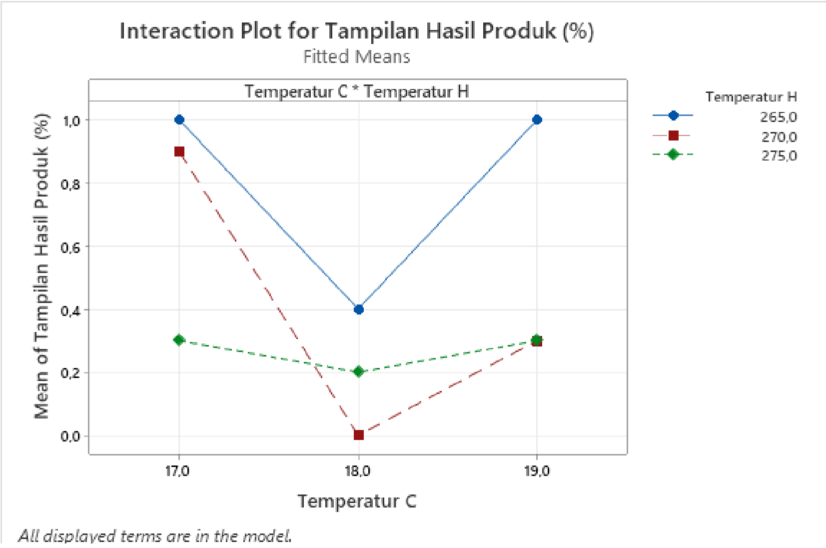

Figure 5. Graphic interaction plot

In figure 5 there are 3 kinds of colors and types of lines that indicate the hot runner temperature used. The first blue line is shaped like the letter V which indicates the level of use of the hot runner temperature of 265 °C, the second line is red dotted indicating the level of use of the hot runner temperature of 270 °C, then the last is a green short dotted line indicating the use of the hot runner temperature of 275 °C. Then the horizontal line across the graph shows the chiller temperature used with levels of 17 °C, 18 °C, and 19 °C. The vertical line shows the dependent variable that occurs or appearance defects in 100 mL PET products. Based on the figure 5 graph, it explains that the chances of defects in the appearance that occur are on the blue line, the lower the chiller temperature is set and the hot runner temperature of 265 °C the product will experience appearance defects, but if the chiller temperature is increased by 1 level to 18 °C, the defect decreases slightly to around 0.4%. However, when the chiller temperature is increased further, the defects increase significantly. The position of the right parameter setting is minimal or even 0 chance of defects shown on the dashed red line with a large value of 18 °C chiller temperature, but when the chiller temperature is lowered it experiences a steep graph approaching the blue line point defect of about 0.9%, the difference is that when the chiller temperature is increased to 19 °C the defect is not too high around 0.3% this figure is one point with a dashed red line. Then the short dotted green graph line shows a gentle slope, the low value of defective appearance on the product at 18 °C chiller temperature setting of 0.2%, when raised and lowered experiencing the same defect ratio. This means that of the three interactions of hot runner temperature levels, there is a low product display defect at the 18 °C chiller temperature level. Chiller temperatures at 17 °C and 19 °C show the same graph point results that occur on the blue line 1.0% and green 0.3%.

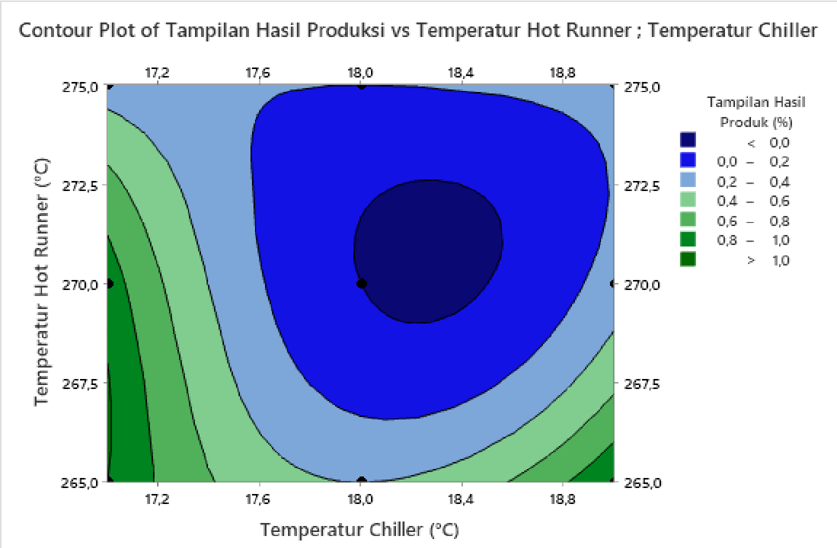

Figure 6. Graph contour plot

Based on figure 6, there are 7 different scale colors, but in the graph above that only 6 colors come out to find out the boundary area that occurs appearance defects in the product, there are 3 blue color degradation which indicates if the blue color is getting older then the chance of defects that occur will be even lower at 0 - 0.2%, it can also be seen with a black dot in the dark blue boundary line area showing minimal defective production, and there are also 3 green color degradation which states that the older the green color displays the starting level of appearance defects that occur will be higher. The contour plot graph above for the appearance defect of 100 mL PET bottle products is the lowest at 0 which is found in the darkest blue area, namely in the combination of chiller temperature of 18°C - 18.4°C and hot runner temperature of 269°C - 272.2°C. Meanwhile, the highest defect occurs in the area where the chiller temperature is 18 °C - 18.4 °C and the hot runner temperature is 269°C - 272.2°C. The highest defect occurs in the area where the chiller temperature is 18°C - 272.2°C. Meanwhile, the highest defect occurs in the darkest green area with a value of 1 which occurs in the combination of hot runner temperature of 265°C – 270°C and chiller temperature of 17°C - 17.2°C.

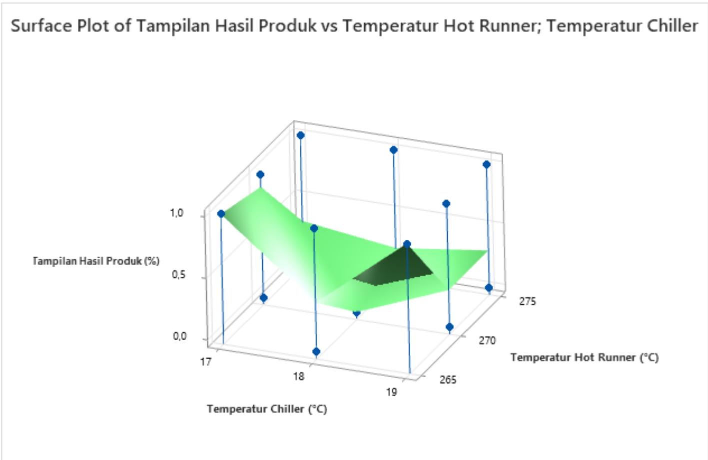

Figure 7. Graph surface plot

Figure 7 above displays a shape resembling a concave crater in the middle, meaning that at low chiller temperatures with low hot runner temperatures the chances of appearance defects in 100 mL PET bottles that occur will be higher located at temperatures of 19 °C and 265 °C depicted on a very high surface touching the number 1 on the chances of appearance defects results. Then the higher the temperature of the hot runner and chiller does not show a high steep surface like the effect at low temperatures, defects occur but are not too severe. Then the low concave shape in the middle of the graph that the stable level of temperature used between the two temperatures that can produce a minimum defect value scale even 0 product appearance on 100 mL PET bottles. so that the normal level of stable temperature temperature parameters has a significant sensitive interaction.

3.2 Discussion

Defects that Occur

Three types of appearance defects in accordance with the literature review which are influenced by the temperature of the hot runner and chiller are black spot, defect line, stripes. In this research, it is also in line with research conducted [5] entitled "Causes of Wavy Preforms and Their Effect on Bottle Products at PT Jayatama, Selaras, Bogor, West Java" the cause of wavy preforms, one of which can be influenced by machine factors, such as mold temperatures that are too high, chillers that are obstructed, and unstable heating systems. Various defects in products that occur in addition to the three types of appearance defects mentioned in the literature review in the form of black spots, hairly or defect lines, and stripes. There are also short shot, bubble or void, shrinkage, off center base, failed blowing, embossed bracelet, rough parting line.

1) Black spot

Black spots on the surface area of the bottle give rise to a dull, spotty appearance which is caused by one of the hot runner and barrel temperatures being too high, overheating, the material becomes burnt, and the material becomes contaminated with scale or small particles of dirt.

Figure 8. Black Spot Defect

2) Hairline defect

Hairline defect or defects on the bottom and neck of the bottle look like hair scratches, this is rare but occurs usually because the nozzle is dirty and the metal oring on the runner needs to be replaced combined with an incorrect cycle time.

Figure 9. Hairline defect.

3) Stripes

Stripes or opaque spots on the body of the bottle are cases that occur during production so that the color display is uneven, due to the interaction of temperature in the unstable material, making the color look uneven and streaky.

Figure 10. Stripes defect

4) Shrinkage

Shrinkage in thermoplastic undergoes a cooling process combined with changes in dimensions (shrinking) after the product is ejected out of the lip cavity in the injection stretch blow molding process. Shrinkage that occurs in thermoplastic materials is caused by compressibility and thermal expansion which usually occurs at the neck of the bottle, shrinkage defects also exist in the ISBM process but this rarely happens.

Figure 11. Shrinkage

5) Short shot

Short shot is a product defect caused by incomplete filling in the mold cavity. This is due to insufficient material being injected into the molding, insufficient injection pressure, lack of ventilation so that air is trapped in the cavity. This defect rarely occurs on ISBM machines because the preform used in the initial injection process does not immediately form a product on the machine.

Figure 12. Shrinkage

(Norman, 2021)[6]

6) Bubble

Bubbles are pockets of air bubbles that are trapped on the surface of the product. This defect occurs due to air humidity and the temperature of the material injected into the cavity mold when the clambing is being blown. Air does not have time to escape through the vents in the mold.

Figure 13. Bubble defect

(Diego, 2018)[7]

7) Bracelet defect

This defect in the bottle body ring on the inside occurs due to a lack of pressure from the air nozzle. There is a problem when the preform is blown into the mold cavity.

Figure 14. Bracelet defect

8) Slanted navel point (Off center base)

Slanted navel point (Off center base) This defect is because the initial shape is not yet standard. This occurs at an early stage during the stretching process of the preform before it is blown, causing the bottom of the bottle, the navel point or injection channel of the preform material to deviate from the middle. This defect also occurs because the wind pressure on the blow nozzle and the pen rod hits the bottom cavity. Meanwhile, the flexibility of the preform is not yet stable, so this defect is not caused by the influence of the temperature of the chiller, hot runner and preform heater.

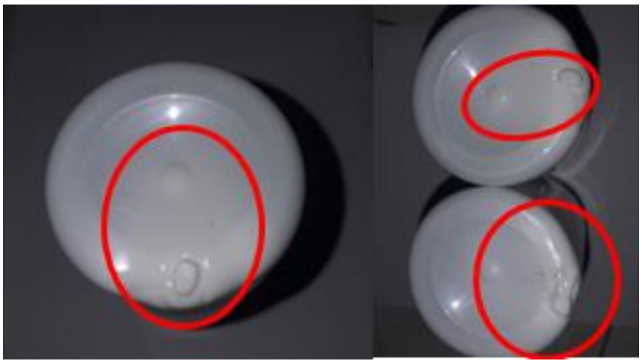

Figure 15. Slanted navel point (Off center base)

9) Failed blowing

Failure to blow is a defect because the initial shape cannot form a perfect bottle. This is influenced by the function of the preform pen rod whose position in the blowing cavity hits the preform until it penetrates [8], and the heating temperature or heating core does not reach the optimal temperature. These defects can be in the form of creased bottles, dents, stunted bottles, torn or leaking bottles.

Figure 16. Failure to blow

10) Rough joint line defect

Rough Parting Line is a defect that appears in the connecting line that occurs on the bottle body, this is because there is a problem with the cavity mold or the installation is not suitable. Dimensional defects are caused by component mechanisms and temperature parameter settings.

Figure 17. Rough joint line defect

The events in the research carried out produced an R-Squere figure of 50.20% and a p-value of 0.004. This figure shows that it is not synchronous, this is because the research data taken is attribute or defect data which in the data is in the form of visual defects. There is no measurement level for defects.

4. CONCLUSION

In researching the effect of chiller temperature and hot runner temperature in the plastic molding process on the appearance quality of 100 mL PET bottles, the conclusions obtained are:

1. The effect of the chiller temperature for the plastic molding process on the appearance quality is that the lower it is, the smaller it will cause defects in the form of lines or blurring due to poor preform formation making it difficult to blow. a chiller temperature of 17 °C produces a high level of product defects of 0.74%, and at a temperature of 19 °C product defects show a scale of 0.54%, this figure is in accordance with the mean factorial plot graph.
2. The effect of the hot runner temperature of the plastic molding process on the appearance quality is that the lower it is, the smaller it will cause defects in the form of black spots because the melted material is not stable evenly, and does not follow the heat from the screw barrel. The hot runner temperature at the level of 265 °C produces high product defects, namely 0.80 and the higher it will cause hairline defects on the bottle body because the material exceeds the melting limit in the 100 mL PET bottle preform. at 275 °C, product defects show a scale of 0.28%, this figure comes from the average factorial plot graph.
3. Research analysis of the interaction of the two independent variables, namely chiller temperature and hot runner temperature on the appearance quality of 100 mL PET bottles, shows that the actual optimal temperature rarely causes defects at the chiller setting of 18 °C and the hot runner setting of 270 °C in order to get the value results significant actual.

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