Implementation Of Response Surface Method To Minimize Product Defects On Wax Pattern Injection Process Parameters

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Abstract. Wax injection machining is the only technique to produce many ideal products in large volumes, which is the most common method in the investment casting process. One of the products that has the highest number of orders in metal casting companies that use investment casting techniques is the VS 2/4/6 X pump casing product. The VS 2/4/6 X pump casing product consists of 4 components, each of which is injected into a different mold and eventually assembled into a product. The problem that is often encountered in wax pattern injection results is product defects, where in the wax pattern manufacturing process there are standards for the size and type of product defects, among others, if the size of the sink mark defect is 0.5 mm, for the size of the flow mark with a length of 1 mm and a depth of 0.5 mm and for flash with a wide defect area criterion and a magnitude of 30% of the pattern surface area. The parameters to be analyzed to reduce product defects are injection time, injection pressure, and holding time. This research uses response surface method with 15 run orders with 3 replications and uses Box-Behnken Design for research experiment design and ANOVA to analyze the data. Based on the analysis results. It was found that the optimal parameter combination is the value of injection time 80 seconds, injection pressure 35 bar, and holding time 50 seconds. From this configuration, the minimum product defect is 1.5972 pieces per products.

Keywords: wax pattern; wax injection; dimension accuracy; product defect; response surface; investment casting.

1. Introduction

Modern investment casting technology is often used to produce complex castings, which have complex geometries, tight tolerances and good surface finishes. The investment casting process, also known as "lost-wax", begins with the creation of a pattern with wax material, which will then form a wax pattern (shell ceramic) in the next process. One of the factors that

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affect the precision of investment casting products is the pattern. In this process, wax patterns must be made for each casting part and gating system. The wax pattern and gating system are produced from metal dies by injection [1]. The wax used is a mixture of beeswax, carnauba, ceresin, aerowax, paraffin and other resins that are usually obtained as proprietary blends. The quality of the pattern is highly dependent on the wax's characteristics of shrinkage, strength, and reaction with the slurry. The wax pattern is an important part of the process where the wax is melted by pouring the melt. The wax pattern is made by a wax injection machine [1,2].

The wax injection machine is the only technique to produce many ideal products in large volumes which is the most common method in manufacturing. The wax injection process begins with mold filling, the wax material that has been in the cavity will be held in the mold to maintain no shrinkage during product cooling. Holding pressure will be applied until the wax material in the gate freezes, After the injection is complete the diverter valve shifts. The final step is part ejection where the mold will open and the frozen product will be pushed out of the cavity by the ejector [3] .

One of the products that has the highest number of orders in a metal casting company with investment casting technique is the pump casing VS 2/4/6 X product. This product is one of the products made for the pipe and valve industry. This pump casing VS 2/4/6 X product is required to have the right dimensional accuracy so that each constituent component can be fused to each other during connection or assembly. In addition, another factor that must be considered is the visual of the injection product. If the visual of the injection product has many failures when it will be sent to the fixing and assembly area and other areas, this can result in obstruction of the production process, the occurrence of porosity and high shrinkage rates in the manufacture of ceramic shells.

These problems occur because the process parameter settings on the wax injection machine are not appropriate. So that the parameters on the wax injection machine play an important role in determining the quality and quantity of injection product results. Therefore, an appropriate experimental design is needed to identify process parameters in wax injection to produce optimum product defect. The experimental design method is the main basis in engineering activities. In this case, the optimization parameters to be researched are injection time, injection time and holding time to product defect response in pump casing products VS 2/4/6 X.

Optimization is done to get the right combination of process variables in wax injection, so that it can produce an optimum response. Some methods that can be used for optimization in the injection process are Response Surface Methodology (RSM), Taguchi Method and Genetic Algorithm (GA), Artificial Neural Networks (ANN), Finite Element Method (FEM), Grey Rational Analysis and Principle Component Analysis (PCA) [4]. Many experiments are required for conventional techniques, such as the methods do not represent the combined effect. They also require more data to determine the optimal level and take a long time, which is unreliable [5]. The primary purpose of experimental design techniques is to understand the interactions among parameters, which can help in the optimization of experimental parameters and provide statistical models [6].

The method often used for parameter optimization is response surfaces. The methodology based on RSM was found to be convenient because a model can be generated with minimum process knowledge which leads to save time and cost of experimental work. Model developed using RSM are accurate only for a narrow range of input process parameters. Alternatively, the development of higher order RSM models requires a larger number of experiments to be performed. This is the limitation on the use of RSM models for highly non-linear processes, such as burnishing. These constraints have led to the model development based on artificial neural networks. [7].

Therefore, this research seeks an equation that connects the wax injection process parameters and the response under study. The equation that connects parameters and responses is determined by the response surface method using input experimental data results with various parameter variations. The response studied is the result of the visual quality of the wax pattern with the minimum value of the resulting product defect.

2. Literature Review

2.1. Pump Casing VS 2/4/6 X

Casing pump is one of the products produced in metal casting companies with investment casting techniques for industries engaged in the pipe or valve sector, this product has a function as a protective element inside and as a flow channel from the impeller which will convert speed energy into pressure energy. The pump casing component vs 2/4/6 X uses a material that is parrafin wax type wax material, the reason this material is used is low cost, easy availability, has high lubricity and low liquid viscosity.

2.2. Wax Injection

Wax injection is the process of inserting wax into a mold that has silicone coated inside. This process requires air pressure to help the wax enter the mold [8].

Pressure greatly affects the volume of the wax pattern size if the pressure used is too large, there will be an increase in volume, and if the pressure used is too large it can cause the volume to decrease or can cause the wax not to enter the mold cavity completely. To prevent this from happening, it is necessary to apply the appropriate pressure at the right time to produce perfect wax pattern results.

2.3. Wax Injection Machine

The wax injection machine is a machine used to process wax material, where the melted wax material that has gone through the recycle wax process for ± 8 hours is transferred to the wax injection machine then through the nozzle the melted wax is injected into the mold which is cooled by the sealer where the material will cool and harden so that it can be removed from the mold.

2.4. Type of Product Defects

- Flash
  Flash is a type of minor defect in the material, which occurs when some molten wax comes out of the mold cavity. This means that the material can still be said to be ok but cleaning must be done on the product.

Fig. 1. Flash defect in wax

- Sink Mark
  Sink marks are hollows or curves that occur on the outer surface of the molded component. The occurrence of thickness differences on the surface of the object can also be referred to as sink marks. The causes of sink marks in wax patterns are due to differences in product thickness but not from the product design, temperature differences between the core and cavity, die temperature, too high or low injection speed, and lack of cooling ability of the die itself.

For the calculation of the number of each type of defect based on the standards contained in the company. Where the type of sink mark, this type is counted as a defect if the size of the sink mark defect is 0.5 mm, for the size of the flow mark with a length of 1 mm and a depth of 0.5 mm and for flash with the criteria for defect area width and magnitude of 30% of the surface area of the pattern.

2.5. Design of Experiment

Design of experiments is a statistical technique used in the study of experiments in order to improve quality and processes. Classic experimental designs such as Completely Randomized Design, Randomized Block Design to Factorial Design are widely applied to help researchers investigate the effect of single or multi-factors [6]. Design of Experiment is an experiment conducted in an experiment to discover or study an existing process or compare the effects of several conditions in the most efficient way. In conducting DoE, it is necessary to define the problem and variables or so-called parameter factors. The number of variables assumed in DoE is limited or assumed to be small. The DoE technique and the number of levels should be chosen according to the number of trials that can be given. The number of levels is usually the same for all variables, but some DoE techniques allow differentiation of the number of levels for each variable [7,9]. The instructions for conducting an experimental design are as follows:

1. Identify the problem.
2. Selecting the response variable.
3. Selecting process and level variables.
4. Selecting the experimental design.
5. Conducting the experiment.
6. Statistical analysis on the data.
7. Making and deciding decisions.

2.6. Respon Surface Method (RSM)

Response surface methodology or RSM is a set of methods of mathematical techniques and statistical techniques used in modeling and analyzing problems where the response is influenced by variables, which aims to see the effect of several quantitative variables on a response variable and to optimize the response variable. For example, we will find the levels of temperature ($x1$) and pressure ($x2$) that can optimize a production yield (y). The relationship between these variables can be written in an equation as follows:

$$y = f\,(x_{1,} x_2, \dots\, x_i) + \in \quad (1)$$

Where:

y = response variable

x_i = independent variable/factor (i = 1,2,3,…,k)

ε = error

f (0,1,2,3,....k) = variable model

Where ε_i is the observation error on response y. If the expected value of the response is written $E(y) = f(x1 + x2) = \eta$, the response surface is presented.

$$\eta = f(x_1 + x_2) \tag{2}$$

A common problem in the response surface method is that the shape of the relationship between the response variable and the independent variables is unknown. Therefore, the first step in the response surface method is to find the form of the relationship between the response and several independent variables through an appropriate approach. The linear relationship form is the first tried relationship form because it is the simplest relationship form (low-orderpolynomial). If it turns out that the form of the relationship between the response and the independent variables is a linear function, the function approach is called the first-order model, as shown in the following equation:

$$Y = \beta_0 + \sum_{i=1}^{k} \beta_i x_i \tag{3}$$

With:
Y = Response variable
β_0 = Interception
β_i = Model parameter coefficients
x_i = Free variable

If the form of the relationship is quadratic, then a higher degree of polynomial is used to approximate the function, namely the second-order model.

$$Y = \beta_0 + \sum_{i=1}^{k} \beta_i x_i + \sum_{i=1}^{k} \beta_{ii} x_i^2 + \sum\sum_{i<j} \beta_{ij} x_i x_j \tag{4}$$

With:
Y = Response variable
β_i = Regression coefficient (i = 0,1,2,3 ..)
x_i = Variable Independent (i = 1,2,3 ..)

Almost all problems in the response surface method use one or both of the above models. Once the most suitable form of relationship is obtained, the next step is to optimize the relationship. If the best-fit surface is sought through sufficient approximation, the results of this analysis will be close to the actual function [10]. Myers states that the response surface method is useful as a solution to statistical or engineering problems. In general, problems are divided into three categories, namely.

1. Mapping the response surface over an area.
2. Optimization of the response.
3. Selection of operating conditions to achieve specifications.

3. Methodology and Implementation

The product that is the object of research are pump casing VS 2/4/6 X in a metal casting company with investment casting technique. Two variables are used, namely independent variables or predictor variables and response variables. Independent variables or predictor variables are variables whose values can be controlled and determined based on the objectives and object of research under study. Determination of the value of this variable is based on operator experience in the field and product quality plan data.

While the response variable is the variable observed in the research and its quantity cannot be determined, and its value is influenced by the independent variable that has been determined, and the results are known after carrying out the experiment.

Tabel I. Independent Variables And Control Levels

Independent Variables	**Level**		
	-1	**0**	**1**
Injection Time (second)	40	60	80
Injection Pressure (bar)	25	30	35
Holding Time (second)	30	40	50

In this experimental design, research will be carried out by combining the levels of the parameters used, then the design is used as a reference. The experimental process is carried out using Minitab software using the Box Behnken method. Data Retrieval

Data was collected by injecting the wax pattern with different pressures of 25 bar, 30 bar and 35 bar. With different injection times of 40 seconds, 60 seconds and 80 seconds. In addition to differences in pressure and injection time, variations will also be made in holding time during the injection process, namely 30 seconds, 40 seconds and 50 seconds. After performing the injection process with three different parameters and levels, the next process is to measure the length and depth of product defects.

Hypothesis Testing

- Influence of injection time on product defects

  H0 = that there is no effect of injection time parameters on product defects.

  H1 = that there is an effect of injection time parameters on product defects.

- Influence of injection pressure on product defects

  H0 = that there is no effect of injection pressure parameters on product defects.

  H1 = that there is an effect of injection pressure parameters on product defects.

- Influence of holding time on product defects

  H0 = that there is no effect of holding time parameters on product defects.

  H1 = that there is an effect of holding time parameters on product defects.

4. Result and Discussion

All experiments were conducted sequentially with three replications to obtain diverse results. Then proceed to calculate the average of the three replications to get the actual response value. .The results of this experiment are as shown in table 2.

Tabel II. Experiment Result Data

Injection Time (second)	Injection Pressure (bar)	Holding Time (second)	R1	R2	R3	Average
40	25	40	3	3	3	3.000
80	25	40	3	3	3	3.000
40	35	40	1	1	2	1.333
80	35	40	1	2	2	1.667
40	30	30	2	2	2	2.000
80	30	30	2	2	2	2.000
40	30	50	2	2	2	2.000
80	30	50	2	2	2	2.000
60	25	30	3	3	3	3.000
60	35	30	1	2	2	1.667
60	25	50	3	3	3	3.000
60	35	50	2	1	2	1.667
60	30	40	2	3	2	2.333
60	30	40	2	3	2	2.333
60	30	40	2	2	2	2.000

These results are based on measurements that have been carried out previously, where for the calculation of the number of each type of defect based on the standards contained in the company. For the type of sink mark, this type is counted as a defect if the size of the sink mark defect is 0.5 mm, for the size of the flow mark with a length of 1 mm and a depth of 0.5 mm and for flash with wide and large defect area criteria, for this standard each type of defect if it fits this size or more than this size the number of defects is counted as one.

4.1. Lack of Fits Test

The average data results from experiments on product defects are then analyzed using Minitab software. The lack of fit test is used to determine the discrepancy between the predicted model and the actual model [4]. The confidence interval value used in this study is 0.1, with the following hypotheses: H0: P value < α, means there is no lack of fit in the model and H1: P value ≥ α, means there is a lack of fit in the model. The output from minitab can be seen that there is a Pvalue that is smaller than α, as shown in table 3.

Tabel III. ANOVA Calculation Of Product Defects

Source	DF	Adj SS	Adj MS	F - Value	P - Value
Regression	3	4.03	1.34	39.66	0.000
Injection Time (detik)	1	0.01	0.01	0.41	0.535
Injection Pressure	1	4.01	4.01	118.62	0.000

(bar)					
Holding Time (detik)	1	0.00	0.00	0.00	1.000
Error	11	0.37	0.03		

4.2. Surface Regression

Surface regression analysis testing was conducted in this study to determine the effect of parameters on the response. The confidence interval value used in this study is 0.1. Pvalue must be less than α. The output of minitab can be seen that the P-value of the injection pressure parameter is 0.000, which means that the parameter has an influence on the response as shown in table 4.

. **Tabel IV.** Surface Regression

Source	DF	Adj SS	Adj MS	F - Value	P - Value
Regression	3	4.03	1.34	39.66	0.000
Injection Time (detik)	1	0.01	0.01	0.41	0.535
Injection Pressure (bar)	1	4.01	4.01	118.62	0.000
Holding Time (detik)	1	0.00	0.00	0.00	1.000
Error	11	0.37	0.03		
Lack of-Fit	9	0.30	0.03	0.89	0.632
Pure Error	2	0.07	0.04		
Total	14	4.40			

The next test is the Multiple Determination Coefficient (R2) test, where the multiple coefficient of determination (R2) is used to determine the suitability of the regression model. The coefficient of multiple determination (R2) is in the range of values 0 - 100%. If the coefficient of multiple determination approaches a value of 100%, so that it can be concluded that the model is of good quality. The results of model analysis on minitab software are shown in table 5.

Tabel V. Model Summary

S	R-sq	R-sq (adj)	R-sq (pred)
0.142725	97.69%	93.52%	86.11%

4.3. Contour and Surface Plot

The response can be displayed with a graph or in 3-dimensional form which has the aim of providing visualization results of the shape of the response. Each contour plot has a different color and size according to the parameters being compared. Meanwhile, the surface plot is a projection of the contour plot which is converted into a 3-dimensional form. As shown in Figures 4 and 5 regarding the results of the contour plot output of the response variable to product defects as follows.

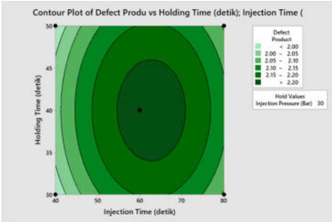

Fig. 2. Contour Plot.

The contour plot shows curved contours because the model contains a statistically significant quadratic term. Figure 2 shows that minimizing the number of product defects will be achieved if the holding time is between 30 seconds to 50 seconds and the injection time is between 40 seconds to 42 seconds, while the injection bar is at 30 bars. By setting the parameters at these levels, we will obtain a value of the number of product defects of less than 2 pieces to 2 pieces.

Meanwhile, Figure 3 is a surface plot showing that the greater the parameter settings made, the greater the value of the number of defective products produced. Then it will gradually decrease after reaching the highest response. Where the figure shows the parameter configuration that produces the highest response is in the injection time setting of 78 seconds, holding time 48 seconds and injection pressure 30 bar. With these settings can produce the number of defective products as much as 2.2 pieces.

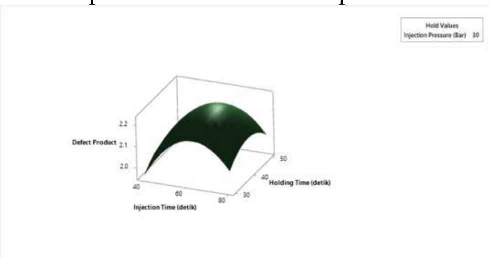

Fig. 3. Surface Plot.

4.4. Identical Assumption Test

The identical test is a plot between the residual values of the three variables and the ŷ value of the product defect estimate. If in the plot the residual values of the three variables with the estimated ŷ value spread out (the residual value does not tend to increase or decrease), it can be interpreted that the residual values are identical. The results of identical analysis on product defects are shown in Figure 6.

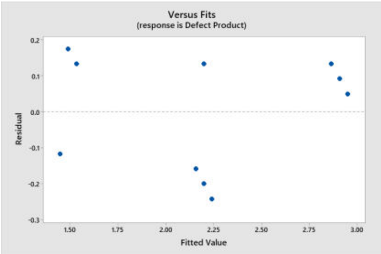

Fig. 4. Identical Assumption Test.

In Figure 4, it can be seen that the residual value tends to increase or decrease and does not spread randomly so that the residuals do not fulfill the assumption of being identical.

4.5. Independent Assumption Test

The independent assumption test is a test conducted to determine the dependence between the residual values of the three variables under study. The test results can be said to be independent if there is no lag out of the significant limit, this indicates that the independent assumption has been fulfilled. As shown in Figure 5.

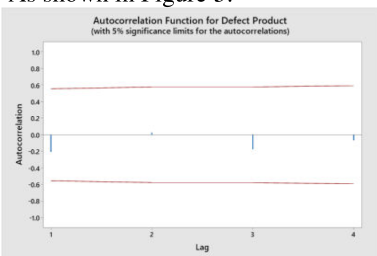

Fig. 5. Independent Assumption Test

Figure 5 shows that there are no lags that cross the significant limit. Where the blue line is the lag and the red line is the significant limit. So it can be concluded that the independent assumption on product defects is fulfilled.

4.6. Normal Distribution Test

In this research, the normal distribution residual test used is the Kolmorogov - Smirnov test. If the value (p-value) is greater than α then the data is declared normally distributed, if the value (p-value) is α then the data is declared abnormally distributed. In this study using the value of α (significance level) is 0.1. The results of the distribution test are shown in Figure 6 as follows.

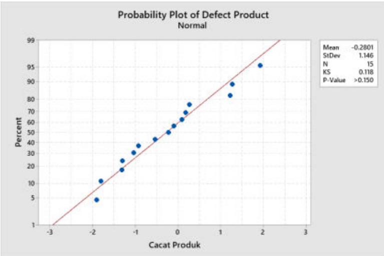

Fig. 6. Normal Distribution Test

Based on Figure 6, it can be seen that the Kolmogorov-smirnov test results in a Pvalue of> 150. It shows that the Pvalue is more than α, so the decision that can be taken is H0 accepted, it means that the residuals on product defects are normally distributed.

4.7. Multicollinearity Test

Detection of the presence or absence of multicollinearity is done by looking at the VIF value. If the VIF value is <10, then the model is free from multicollinearity. multicollinearity test results, VIF values are shown in table 6 as follows.. Based on Table 6, the analysis results show that the VIF value for the injection time, injection pressure, and holding time variables is 1 where the VIF value is less than 10. So it can be concluded that the data does not contain multicollinearity.

Tabel VI. Multicollinearity Test

Predictor	Coef	SE Coef	T-Value	P-Value	VIF
Constant	6.325	0.510	12.40	0.000	
Injection Time (detik)	0.00208	0.00325	0.64	0.535	1.00
Injection Pressure (Bar)	-0.1417	0.0130	-10.89	0.000	1.00
Holding Time (detik)	0.00000	0.00650	0.00	1.000	1.00

4.8. Response Optimization

To obtain the parameter values (independent variable values) studied, namely: injection time, injection pressure and holding time that produce optimal product defects, the desirability approach is used. The function of the desirability approach is to determine the value of the combination between the response variable and the independent variable so that it can be in accordance with the size specification.

Based on the results of the minitab software data input, the optimal parameter combination is obtained in Figure 9 with a combination of injection time of 40 seconds, injection pressure of 35 bar and holding time of 50 seconds. From the combination of these parameters, it can produce an optimal response, namely a minimum product defect of 1.3472 pieces with composite desirability 0.991666.

The next step after getting the optimum point is to perform calculations to obtain the optimum for maximum value equation using the following equation:

$$Y = b_0 + b_1X_1 + b_2X_2 + b_3X_3 + b_{11}X_1{}^2 + b_{22}X_2{}^2 + b_{33}X_3{}^2 + b_{12}X_1X_2 + b_{13}X_1X_3 + b_{23}X_2X_3$$

$$Y = 6{,}325 + (0{,}002083)(80) + (-0{,}14167)(35) + (0{,}0100)(50) + (0{,}00030)(80)(35) + (0{,}00002083)(80)(50) + (-0{,}000235)(35)(50)$$

$$= 2{,}54502 \text{ pieces}$$

5. Conclusion

This research uses the response surface method for data collection and in the analysis process using the response surface and Minitab 19 software. Response surface can be used in parameter design applications to optimize parameter settings in the machining process, the purpose of this optimization is to improve machine performance in order to produce good quality products. The results of the analysis and discussion in this study are on the parameters of injection time, injection pressure, and holding time on the production of VS 246 X casing pump using the Response Surface method it can be concluded that:

1. The regression analysis results show that in the Wax Pattern Injection Molding process there are several parameters that affect the response. This study uses a confidence interval (α) of 10% or 0.1. With this α value on the product defect response, there is one parameter that has an influence on the response, namely the injection pressure parameter with a Pvalue of 0.000. The injection time and holding time parameters have a Pvalue of 0.535 and 1.000, so it is stated that these two parameters have no influence on the product defect response.
2. The optimum parameter configuration in the wax pattern injection process on the VS 246 X pump casing product is injection time of 40 seconds, injection pressure of 35 bar and injection time of 50 seconds which results in a minimum product defect of 1.3472 pieces and maximum product defect is 2,54502 pieces. These results are in accordance with the target of the company for the type of product defect in 1 product there are only a maximum of 2 types of product defects.

References

1. Heine, R. W., Loper, C.: R., & Rosenthal, P. C.. Principles of metal casting (Eight edition), (2014).
2. Sahoo, M., & Sahu, S.: Principles of metal casting (3rd ed.). McGraw-Hill Education, (2014).
3. Bansode, S. N., Phalle, V. M., & Mantha, S. S.: Optimization of process parameters to improve dimensional accuracy of investment casting using Taguchi approach. Advances in Mechanical Engineering, 11(4), (2019).
4. Harshit P. bhavsar, Ajay kumar kaviti.: Optimization of Wax Tank Parameter to Improve the Quality of Wax Pattern in Investment Casting. International Journal of Engineering Research and Development. 8(12), pp. 49 - 54. Bhopal, (2013).
5. Farizi Rachman, Bayu Wiro Kurniawan, Oktaviana Vara IP.: Implementation of Response Surface Methods For Process Parameters Optimization In Laminated Wood Manufacturing. Proceedings of the International Conference on Innovation in Science and Technology (ICIST 2020). https://doi.org/10.2991/aer.k.211129.077, (2021).
6. Montgomery DC. Design and analysis of experiments. 8th ed. New York: John Wiley and Sons; 2014.
7. Dharu Fadillansyah Putra.: Optimasi Parameter Proses Injection Molding Terhadap Produk Pot Cream 10 Gram Menggunakan Metode Respon Surface. Tugas Akhir, Politeknik Perkapalan Negeri Surabaya, (2018).
8. R. Singh, Sunpreet S., M. s. J. Hashmi, "Investment Casting", Materials Science and Materials Engineering, Elsevier, pp. 1- 18,: DOI: 10.1016/B978-0-12-803581-8.04163-1, (2016).
9. Isanda Ika Damayanti, Bayu Wiro Karuniawan, Farizi Rachman.: Optimasi Parameter Edm Sinking Pada Material Baja Sks3 Menggunakan Metode Response Surface. Proceeding 6th Conference on Design and Manufacture Engineering and its Application, (2022).
10. Jones, B., & Montgomery, D. C.: *Design of experiments: A modern approach*. Wiley, (2020).
11. Ridhani Anita Fajardini, Dhika Aditya Purnomo, Farizi Rachman.: Optimasi Multirespon Proses Permesinan EDM Sinking pada Material AISI P20 Menggunakan Metode Taguchi-Grey Relational Analysis. Proceeding 4th Conference on Design and Manufacture Engineering and its Application, (2020).
12. Er. Keshav Kamboj.: Optimization of process parameters of wax pattern in the investment casting process by using different form of waxes. International Journal for Innovative Research in Science & Technolog, .3(08). India, (2017).
13. Callister.: *Materials science and engineering: An introduction* (10th ed.), (2017).
14. Yanto, H., Saputra, I., & Satoto, S. W.: Analisa Pengaruh Temperatur Dan Tekanan Injeksi moulding terhadap Cacat Produk. JURNAL INTEGRASI, 10(1), 1-6, (2018).