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# Optimization of Friction Surfacing parameters On Coating Characteristics Using Aluminium Aa6063 and Low Carbon Medium

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ABSTRACT

**Friction Surfacing has been an interesting issue for researchers to discuss as an attempt in developing the welding field. In the Friction Surfacing process, the coatings produced with aluminium material are relatively low or medium. This is evidenced by the quality level that remains in 80%. The causes of this issue include the parameters such as axial force, rotational speed, and traverse speed which are not optimum in FS process. In this case, this three parameters will be optimized using response surface methodology (RSM) and regression analysis to obtain values from the parameters that result in quality coatings with minimum thickness.**

**Keywords: Response Surface Methodology, Friction Surfacing, optimization,**

## INTRODUCTION

Welding is a technique in connecting metals that has been used widely. The widespread use of welding technology is related to the fact that in the development of a building construction or machine, the weight will become light and simple, making the production cost cheaper and more efficient. The widespread technology development demands human resources. The coverage of welding technique use in construction field is very wide, including naval and others. Many people try to develop the welding technique for a better result. Therefore, there are many researches in this field, intended to find a suitability between welding parameters namely the very good strength of connections.

Friction surfacing has been familiar in welding. Many researches have been done about friction surfacing, but many of them with low quality. One of the causes is the absence of process or method to improve the quality and sensitivity of the existing parameters process (Voutchkov, 2001).The pattern of welding (friction welding) is firstly reported in 1941 (Klopstock &Neelands, 1994), and publish a result that states that friction welding is a development from friction surfacing in 1959 (Tyager, 1959).

SugandhiandRavishankar (2012) have developed an optimization process for friction surfacing parameters, nut the used parameters were not selected. Therefore, the produced confidence (quality level) had not been 99%. Data analysis is one of the solutions to improve the confidence.

According to Lexy J. Moleong, data analysis is a process of ordering the data into patterns, categories, and basic breakdown in order to find and formulate working hypothesis as suggested by the data. Whereas, according to Suporayogo, data analysis is the series of review, classification, systematization, interpretation and verification of data in order that a phenomenon has social, academic and scientific values.

According toVitanovandVoutchkov (2005), data analysis technique has been proved to help in friction surfacing process. Regression analysis and response surface methodology (RSM) are parts of data analysis. Regression analysis s used to see the relationship between one variable and other variable, whereas the RSM can used to optimize the used parameters. Using the regression analysis and response surface technique can assist in optimizing the result. In addition, these two techniques are interrelated and collaborated in finding the good result.

## RESEARCH METHOD

Materials used in this study were Aluminium AA6063 and AISI 1060 as medium. The endpoint of this study was the optimization of used parameters, in order that the coating results have a good quality and minimum thickness in medium. The used variables in this research were response (Y)and independent variable (X). The variable response was the coating thickness and dependent variable (X) was$X_1$ = pressure (axial force), $X_2$ = friction speed (traverse speed), and$X_3$ = rotational speed.

The process performed was by moving the machine according to predetermined values in the studied variables. The process used aluminium (AA6063) that had been designed. The tool design is as follow.

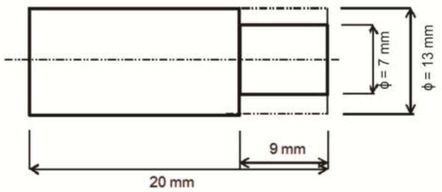


**Figure 1.Tool design to make**

For a more tailored research, there were several steps taken. First, finding and collecting references and theory basics from various sources (articles, journals and manual books) to support the friction surfacing process. This method was intended to obtain a quality by optimizing the parameter. Second, from the available references, problem statement if formulated to optimize the parameters in FS process to obtain good coating quality with aluminum AA6063 as material and steel AISI 1060 as substrate (medium). Third, the tool to be used in this study was designed as to obtain a good quality. Fourth, the tool to be used was pretested to for testing process to see the performance of the tool. This process was performed in the initial stem before the actual process.

**Figure 2.TraverseSpeed measurementFigure 3.Axial Force measurement**

**Figure 4.Rotational Speedmeasurement**

From friction welding process, data were obtained to be processed statistically. The obtained data in 3D graphics were used to observe the extent of coating quality level. The parameters would affect the coating quality, thickness and hardness in working material (AISI 1060). The method used in this study was response surface methodologyand regression analysis.

**Regression Method**

Regression analysis is used when we want to know find out how the dependent variables can be predicted by independent variable or predictor variable, individually. The impact of regression analysis use can be used to decide whether the up and down of dependent variable can be achieved by increasing and decreasing the independent variables aspects, or increased the dependent variable values can be used by increasing the independent variable and vice versa.

Regression model has variable response y and predictor variable x. Response variable is the variable affected by the predictor variable. Response variable is more commonly known as independent variable, because the researcher cannot control it freely. Second, the variable is associated in the form of mathematic equation. Generally, the regression equation can be expressed as follow, 1997:

$$Y = a + bX \qquad (1)$$

where$Y =$subject in predicted dependent variable,

$a =$value of$Y$when$X = 0$ (constant value)

$b =$direction value or coefficient of regression, indicating increased or decreased value of dependent variable based on independent variable. When b is positive increased and vice versa.

$X =$subject in independent variable having certain values.

**Response Surface Methodology**

Response Surface Methodologyisa collection mathematical methods and statistical techniques intended to create a model and analyze the response affected by several variables. RSM is used as an attempt to find appropriate function to predict response.

Response Surface Methodology is useful in analyzing the problems on several independent variable that affect independent variables from response, and intended to optimize the response. Therefore, response surface methodology can be used by researcher to find an appropriate approach function to estimate the upcoming response and determine the values of independent variables that optimize the studied response (Gasperz, 1992).

Response surface methodology is intended to help the researcher in performing improvisation to obtain optimum result appropriately and efficiently. When an experimental area is found, response model with higher accuracy can be used to obtain the actual values of variables that will result in optimum response. This method provide ease in determining the conditions of optimum process either in system or in factor distance required to obtain a very satisfying result (Montgomery, 2001).

Basically, response surface analysis is similar to regression analysis, namely it uses the estimating procedure for response function parameters according to least square (least square method). The difference lies in that linear regression is extended by applying mathematic techniques to determine optimum points in order to determine the optimum response (maximum or minimum) (Montgomery, 2001).

In response surface methodology, independent variables are defined as $X_1, X_2, \ \ldots, X_k$and assumed as continue variable, whereas the response is defined as dependent variable Ywhich is a random variable (Montgomery, 2001). In many cases of this method, the mathematical relationship describes the experimental response and the independent variables are not known, so that the first step to take is determining the appropriate estimation for the mathematical relationship. When the mathematic relationship is known, it can be used to determine the most efficient operating condition (Garsia and Philips, 1995).

$$y_i = \beta_0 + \sum_{i=1}^{k} \beta_i x_i + \sum_{i=1}^{k} \beta_{ii} {x_i}^2 + \sum_{i<j,i\neq j}^{k} \sum \ \beta_{ij} x_i x_j + \varepsilon_i \qquad (2)$$

where, $x_i$is the variable response, it includes axial force, traverse speed, dan rotational speed.And$i = 1 \ldots k, j = 2 \ldots k,$ and $k = 3$.

According to Garsperz (1992), usually the initial step formulate the polynomial regression model with lower order, for example with order one which is linear regression model. Frequently in many cases, it is not known for certain where location of expected maximum values. Therefore, it can happen that the initial estimation on optimum conditions of a system will be different significantly from the actual optimum conditions. To deal with this situation, the steepest incline procedure can help to find the maximum response and the optimum points. Experiment is excited along the steepest incline line until no more response increment observed (Gasperz, 1992).

**Location and Time**

This research was started in December 2016 in mechanical technology laboratory of Hasanuddin University, Makassar.

## RESULTS AND DISCUSSION

**Model Development**

The working material dimension for this test with initial diameter =∅13 mm, length 20 mm. The hardness level can be seen from Table 1. Characteristics of aluminium coating can be described as follow.

$$Y = f(x_1, x_2, x_3)$$

where$x_1$ = axial force, $x_2$ = traverse speed, and$x_3$ = rotational speed.

By using function (2) with$i = 1 \dots k, j = 2 \dots k$, and$= 3$ , the following model can be presented.

$$Y = \beta_0 + \sum_{i=1}^{k} \beta_i x_i + \sum_{i=1}^{k} \beta_{ii} {x_i}^2 + \sum_{i<j,i\neq j}^{k} \sum \beta_{ij} x_i x_j + \varepsilon_i \quad (3)$$

$$Y = \beta_0 + \sum_{i=1}^{3} \beta_i x_i + \sum_{i=1}^{3} \beta_{ii} {x_i}^2 + \sum_{i<j,i\neq j}^{3} \sum \beta_{ij} x_i x_j + \varepsilon_i \quad (4)$$

$$Y = \beta_0 + [\beta_1 x_1 + \beta_2 x_2 + \beta_3 x_3] + [\beta_{11} {x_1}^2 + \beta_{22} {x_2}^2 + \beta_{33} {x_3}^2] + [\beta_{12} x_1 x_2 + \beta_{13} x_1 x_3 + \beta_{23} x_2 x_3] + \varepsilon \quad (5)$$

The value of the coefficient can be found with the help of the function. The final model will be obtained after the coefficient lies in significant level. The obtained model with yas coating thickness.

$$y = \beta_0 + \beta_1 x_1 + \beta_2 x_2 + \beta_3 x_3 + \beta_{22} {x_2}^2 + \beta_{33} {x_3}^2 + \beta_{12} x_1 x_2 + \beta_{13} x_1 x_3 + \beta_{23} x_2 x_3 \quad (6)$$

$$y = -0.069 + 0.0393x_1 - 0.01132x_2 + 0.000552x_3 + 0.000052{x_2}^2 - 0.000000{x_3}^2 + 0.000021x_1 x_2 - 0.000020x_1 x_3 + 0.000002x_2 x_3 \quad (7)$$

Variable$x_1^2$cannot be omitted because it cannot be estimated. Because it cannot be estimated, the $\beta_{11}$ was turned into 0.

The given model will be used to compensate the limitations, that the above model can be resulted. The result of prediction of the above model will be presented in Table 1 together with inter-variable coefficient.

In the table we can see that the qualified SE coefficient was only in axial force and rotational speed variables, meaning that these two variables can be considered significant or had higher appropriateness compared to other variables.

**Model Testing**

The drawback of a model can be fund by testing it using varian analysis technique (ANOVA). The higher the confidence level, the more robust the model. For example, when the confidence level to be used is 95%, with $\propto = 0.05$.Axial force and rotational speed were the two variables that have significant influence on coating, as can be seen in graphic and p value with confidence level above 95%.

**Table 1.Variance analysis**

| Term | Coef | SE Coef | T-Value | P-Value |
|---|---|---|---|---|
| Constant | 0.1195 | 0.023 | 5.19 | 0.001 |
| Axial Force (k N) | 0.0351 | 0.0101 | 3.46 | 0.007 |
| Traverse Speed (mm/min) | -0.018 | 0.0124 | -1.45 | 0.181 |
| Rotational Speed (rpm) | 0.0375 | 0.0124 | 3.02 | 0.014 |
| Traverse Speed (mm/min)*Traverse Speed (mm/min) | 0.0208 | 0.0215 | 0.97 | 0.358 |
| Rotational Speed (rpm)*Rotational Speed (rpm) | -0.0192 | 0.022 | -0.87 | 0.406 |
| Axial Force (k N)*Traverse Speed (mm/min) | 0.0008 | 0.0124 | 0.07 | 0.948 |

| | | | | |
|---|---|---|---|---|
| Axial Force (k N)*Rotational Speed (rpm) | -0.0143 | 0.0124 | -1.15 | 0.278 |
| Traverse Speed (mm/min)*Rotational Speed (rpm) | 0.0114 | 0.0151 | 0.75 | 0.473 |

**The Effect of Rotation Speed on Coating**

The predetermined values for this variable (rotation speed) had met some of the standards in model development, so that the coating level, either the thickness or quality were better independent of other variables such as traverse speed and axial force. Other variables will be equal when the speed level of the mechtrode is reduced.

**The Effect of Axial Force on Coating**

The effect of axial force on coating was the most significant toward thickness or quality. This will favor more when the rotational seed variable id equalized.

**The Effect of Traverse Speedon Coating**

Width and thickness of coating will be better when this variable is significant. This variable will be significant when the axial force and rotation speed are more balanced, as stated above. The other factor that cause insignificance is the relatively lower value of the parameter variables.

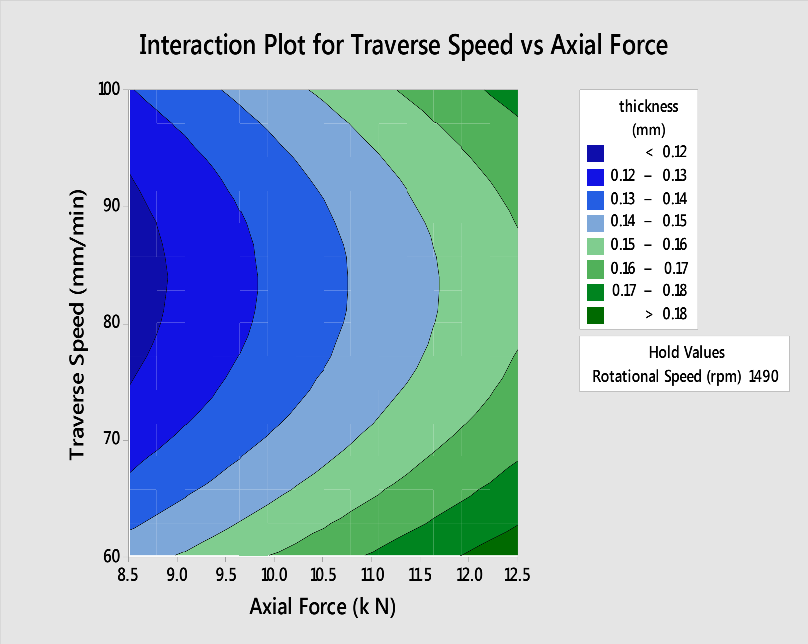


Figure 5.Coating thickness, traverse speedvsaxial force

**Optimization of Parameters**

Incontour plot, there are two variables presented as x and y, whereas the third variable is presented with regions or parts (can be seen from color intensity). Contour plot with value adjustment in order to be optimum. Contour plot is very important for learning response surface. The optimum value will result in good accuracy in surface characteristic.

Figure 5 indicates contour plot of thickness on traverse speed and axial force. From the figure it can be seen that minimum thickness can be obtained from high traverse speed value and low axial force value.

Figure 6 indicates the contour plot of thickness against rotational speed and axial force. From the figure it can be seen that minimum thickness can be obtained from low rotational speed and axial force values.

Figure 7 indicates the contour plot of thickness on rotational and traverse peed. It can be seen form the figure that minimum thickness can be obtained from low rotational speed and high traverse speed values.

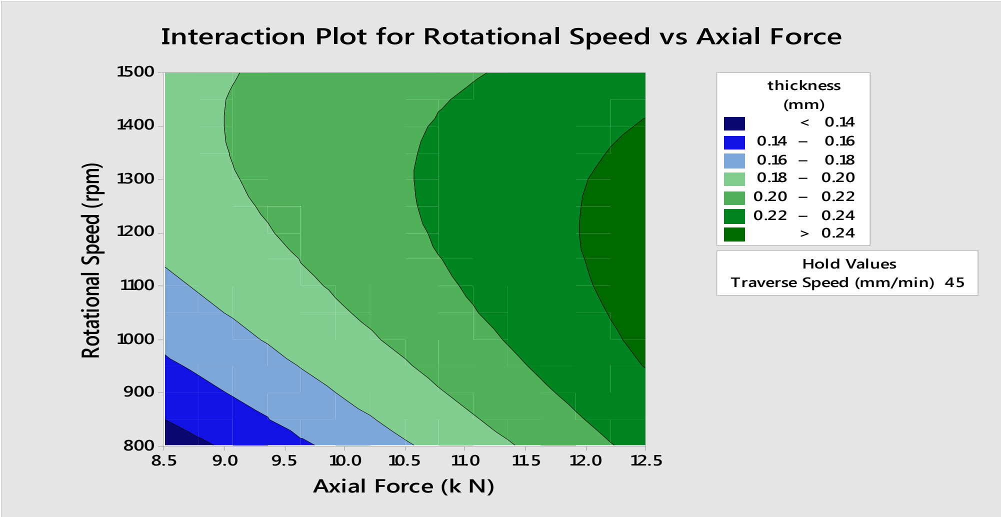


**Figure 6.coating thickness, rotational speedvsaxial force**

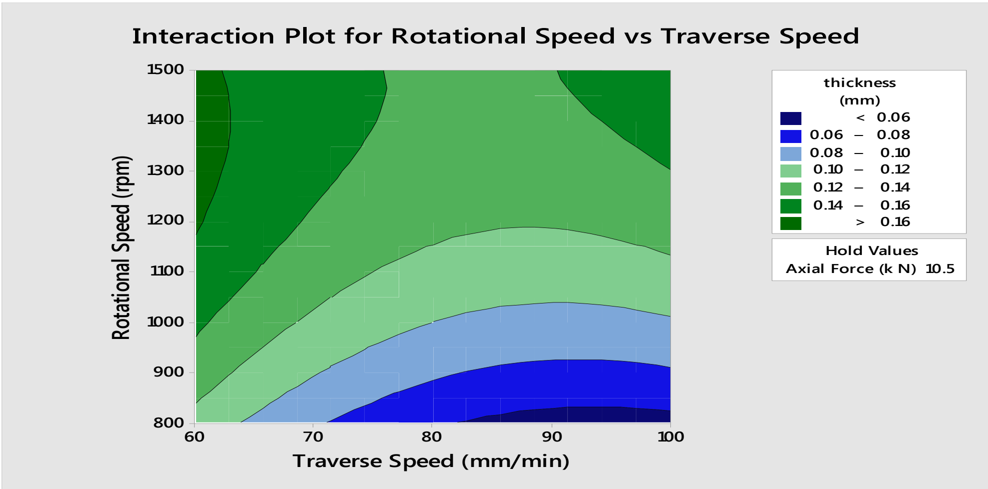


Figure 7.coating thickness, rotational speedvstraverse speed

Response surface methodology is used to optimize the parameters so that resulted in values from surface that were maximum or minimum. In this study, parameters will be processed as such that result in minimum coating thickness by using formula (7). Therefore, when the parameters are processed, it will enable to achieve minimum coating thickness. The values of the three used parameters in the plot had significant effect in determining the optimization of a surface coating. The optimization of a surface coating thickness level can be seen from the contour that tends to shape round. The adjustment of values for balancing will affect the formation. The balanced contour plot can be assisted with the presence of surface plot.

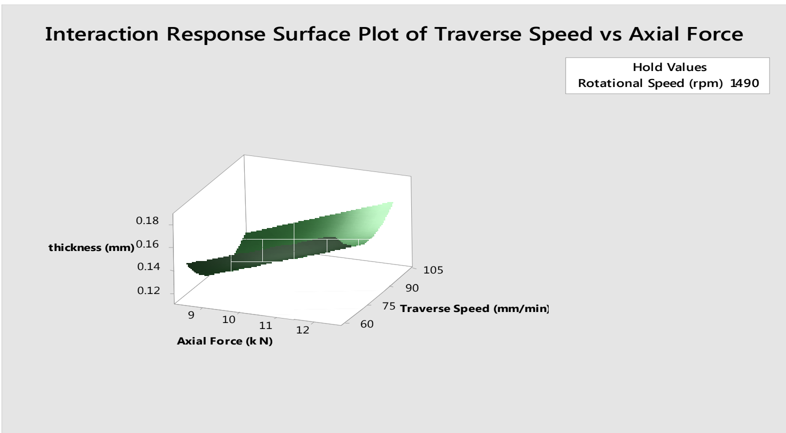


**Figure 8.Coating thickness, traverse speed vs axial force**

In surface plot, there 3 variables presented as x, y, andz. With the optimum stabilization value presented in the upper part of the plot.

Figure 8 indicates that surface plot of thickness against traverse speed and axial force. It can be seen from the figure that optimum result is obtained when the rotation speed is 1490 rpm.

Figure 9 indicates the surface plot of thickness against rotational speed and axial force. It can be seen that the result is optimum when the traverse speed is 45 mm/min.

Figure 10 indicates that the surface plot of thickness on rotational and traverse speed. It can be seen that the result is optimum when the axial force is 10.5 kN.

By observing the developed model above, the optimization of parameter for the coating thickness to achieve minimum lies in 1490 rom for rotational speed variable, 10.5 mm/min for traverse speed variable, and 4.5 kg for axial force variable.

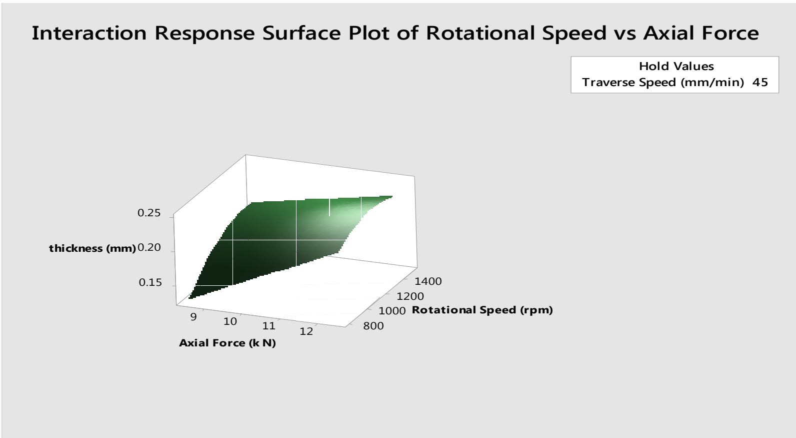


**Figure 9: Coating thickness, rotational speed vs axial force**

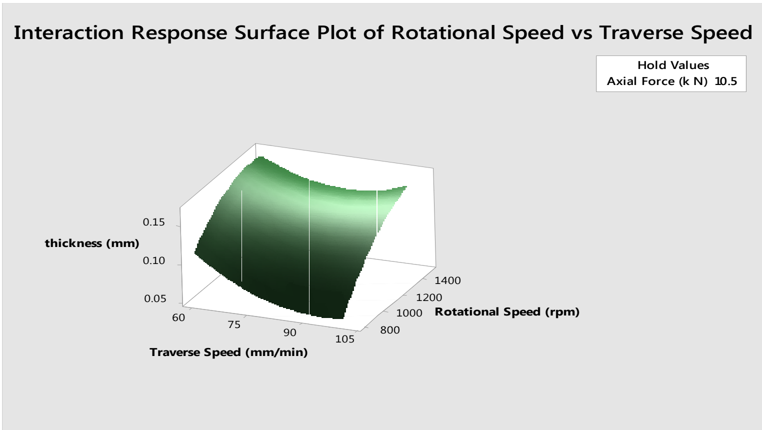


**Figure 10: Coating thickness, rotational speed vs traverse speed.**

## CONCLUSION

The model used to achieve minimum optimum level of the coating thickness is:

$$y = -0.069 + 0.0393x_1 - 0.01132x_2 + 0.000552x_3 + 0.000052{x_2}^2 - 0.000000{x_3}^2 + 0.000021x_1x_2 - 0.000020x_1x_3 + 0.000002x_2x_3$$

wherey =coating thickness, $x_1$= axial force, $x_2$= traverse speed, dan $x_3$ = rotational speed. Therefore, the effect of rotation speed on coating or the values predetermined in this variable (rotation speed) has been adequate as a standard in model development, so that the coating level either the thickness or quality is better. The effect of axial force on coating is the most significant toward thickness or quality. And traverse speed without effect on coating was due to imbalance between the two variables. The optimization of parameters for the coating thickness to reach minimum lied in 1490 rpm for rotation speed, 10.5 for mm/min for traverse speed, and 4.5 kg for axial force.

Good results have been developed to see the coating thickness by combining the variables in friction surfacing and the derivation of a model of a function. This result will be more optimum when the higher confidence level was used (probably 96% or 97%) and will result in better value balance between the parameters.

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