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Optimization of Friction Welding Using Response Surface Method and Taguchi

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Abstract. Welding process affect to the reducing tensile strength value in the weld joint. Improvement to weld joint performance is still studied such as friction welding. This study discussed optimization from welding parameters with Response Surface Method and Taguchi. Based on ANOVA results, that RSM and Taguchi method could be used to optimize the welding parameter. Welding parameter of friction welding could join SS304 with the highest tensile strength 766 pascal. Weld join optimize was 766.5 Pascal when welded with 920 rpm of rotation speed, 9 mm for diameter, and joining time was 2 sec. RSM recommended optimize could be achieved when tensile strength was 624 pascal, rotation speed was 556 rpm, joining time was 0.45 sec, and diameter of specimen 9 mm. Taguchi method could optimize when rotation speed 1466 rpm, diameter specimen 9 mm, and joining time 0.32 sec.

INTRODUCTION

Welding technology is a joining process which is importance in assembly or manufacturing process. However the welding process affect to the reducing performance of joining. Studies to improve the performance of weld joint are still working by researcher and scientists such as friction welding.

Friction welding was used by S.R. Sundara Bharathi et al to join aluminum alloy difference type. An Aluminum alloy 2024 and Aluminum alloy 6061 joint when welded with friction change the microstructure of the join zone, the tensile strength of this dissimilar joint decrease around 20 % from based metals[1]. Effect of variation stir zone and thermo mechanically on AA 5083 with AA 6082 was studied by U. Donatus et al. They stated that at least 60% of both based metals in stir zone retread to weld join[2]. Zhibo Dong studied the effect of welding joining time to intermetallic developed by Aluminum and Magnesium as based metal welded by friction stir spot welding [3]. Some researchers also studied the optimization of welding parameters to get good weld joint performance.

Optimization of process parameters from friction stir welding to join AA 2014-T6 used Response Surface Method (RSM) studied by Ramanjaneyulu KADAGANCHI et al[4]. R. Adalarasan et al optimized parameter of laser cutting used to cut composite[5]. RSM also used to optimize hybrid welding laser-TIG to joint 316LN had been studied by M. Ragavendran[5]. RSM and artificial neural network used to optimize bioethanol production were studied by Eriola Betiku and Abiola Ezekiel Taiwo[6].

Taguchi and RSM used to optimize friction welding parameters were studied in this study. Welding parameters to get a good weld joint, tensile performance from weld joint were also discussed in this work.

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MATERIALS AND METHOD

Stainless steel 304 cylinders was used in this, SS304 joining was represented by Fig. 1. A Lathe machine used practicum in a system manufacturing laboratory of Engineering Faculty of Universitas Trunojoyo was used in this study. The machine which was used was presented in Fig. 2.

FIGURE 1. Specimen

FIGURE 2. Lathe Machine

The welding parameters in this study such as diameter of materials with the values 6 mm, 9 mm and 12 mm, Rotation of machine was used as welding parameters, the values of rotation speed is 850, 950, and 1500 rpm. Joining time is surface of both based metal in melting plastic temperature the machine turn off some time. The values of joining time are 1s, 2s, and 3s.

Tensile test was used to know performance of weld joint. some researchers used this test to know of mechanical properties of weld joint such as Hakam [7]. Specification and picture of a universal test machine was presented in Fig. 3.

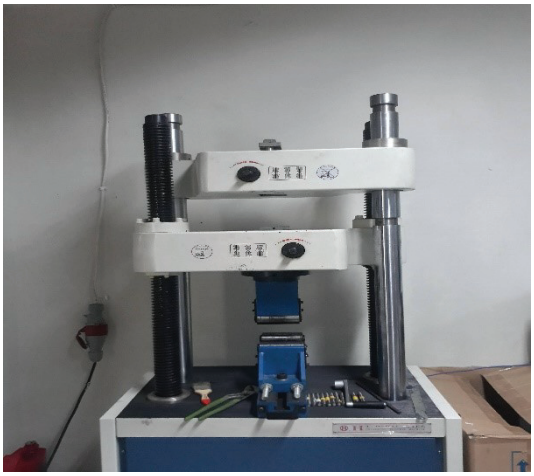

FIGURE 3. Universal tensile test machine

In tensile test setting machine affect the testing result [Baskoro, 2017 #9]. Before testing, the machine was set according condition and tensile test standard.

RESULT AND DISCUSSION

Welding parameter combination each values, design of experimental code, and tensile test results were represented in table 1.

TABLE 1. tensile test values and level combination code for ANOVA

No	Kode Level			v (rpm/min)	m (mm)	t (s)	Pascal(Pa)
1	-1	-1	-1	850	6	1	447,52
2	1	-1	-1	1500	6	1	502,85
3	-1	1	-1	850	12	1	375,43
4	1	1	-1	1500	12	1	282,23
5	-1	-1	1	850	6	3	168,57
6	1	-1	1	1500	6	3	414,41
7	-1	1	1	850	12	3	389,93
8	1	1	1	1500	12	3	388,31
9	-1,682	0	0	374	9	2	493,44
10	1,682	0	0	1466	9	2	624,77
11	0	-1,682	0	920	3,96	2	134,5
12	0	1,682	0	920	14,04	2	353,09
13	0	0	-1,682	920	9	0,32	671,77
14	0	0	1,682	920	9	3,68	345,72
15	0	0	0	920	9	2	766,42
16	0	0	0	920	9	2	552,6
17	0	0	0	920	9	2	450,34
18	0	0	0	920	9	2	568,47
19	0	0	0	920	9	2	766,5
20	0	0	0	920	9	2	403,58

Table 1. used as a based analysis of Varian (ANOVA) to analyze that level of weld parameters combination have effect signivican, each welding parameter has similar effect to tensile value, and that tensile test has normal distribution. The ANOVA result of tensile test values was shown in Table 2.

TABLE 2. ANOVA results

Analysis of Variance							
Source	**DF**	**Adj SS**	**Adj MS**	**F-Hitung**	**F-tabel**	**sig**	**α**
Model	9	404448	44939	3.04	2.42	0.049	0.05
Lack-of-Fit	5	29644	5929	0.25	2.74	0.922	
Pure Error	5	118224	23645				
Total	19	552316					

Table 2. shown that F count was 3.04 and F table value is 2.42 with degree of freedom model 9 and confidence (α) 0.05 so F count > F table (3.04>2.42) and also Sig > α (0.922 > 0.05). It could conclude that model has effect significant to respon surface model. To analyze that regression model is according to used table 2 also represent that sig value from lack of fit > α (0.922 > 0.05).

Based on ANOVA result the regression model which cloud be used in this study represented by Equation 1.

$$\text{Tensile strengh} = -912 + 0{,}068X1 + 302{,}8X2 - 226X3 - 0{,}00016X_1^2 - 15{,}03X_2^2 - 41{,}4X_3^2 - 0{,}0613X1X2 + 0{,}139X1X3 + 20X2X3$$

From ANOVA represented that this data can gate the optimization with RSM and Taguchi Method. Optimization weld parameters of friction welding to tensile strength used RSM was presented Fig. 4 and Fig. 5

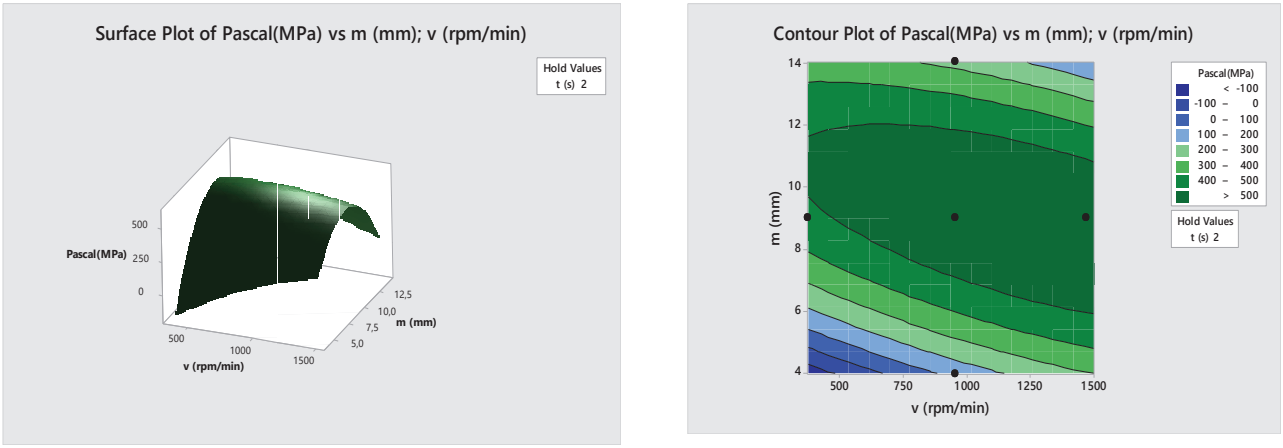

FIGURE 4 Surface plot for rotation speed – diameter and the counter plot

Fig 4 shown that the surface plot tensile strength at highest value at around 7.5 up to 10 mm when rpm or rotation speed around 1000 rpm up to 1200 rpm, tensile strength value optimize at 500 Pascal.

Value optimize could be achieved between rotation speed with diameter of specimen, value optimize could be achieved between rotation speed with joining time represented at Fig. 5.

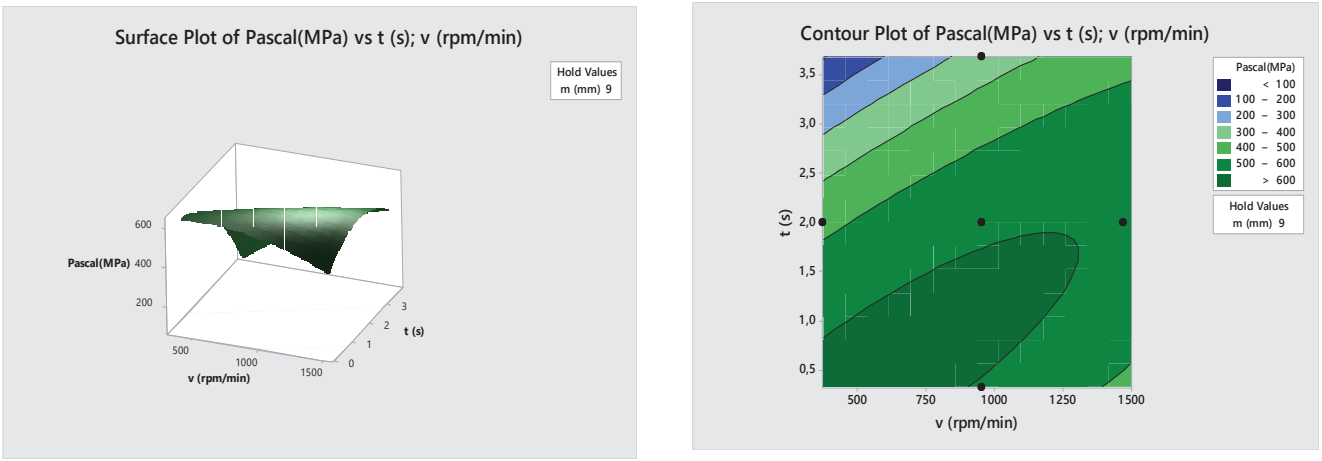

FIGURE 5 surface and contour plot developed between the Rotation speed and joining time

Fig. 5. Surface plot shown that when rotation speed tend to decrees, the tensile strength tend to increase however joining time increase the tensile strength tend to increase. Contour plot represented that joining time rise the tensile strength increase but not maximize. Tensile strength optimize when tensile strength 600 Pascal, 500 to 1500 rpm, and joining time 0 up to 1.5. Optimization tensile strength which developed between joining time to diameter of based metal was shown by Fig 6.

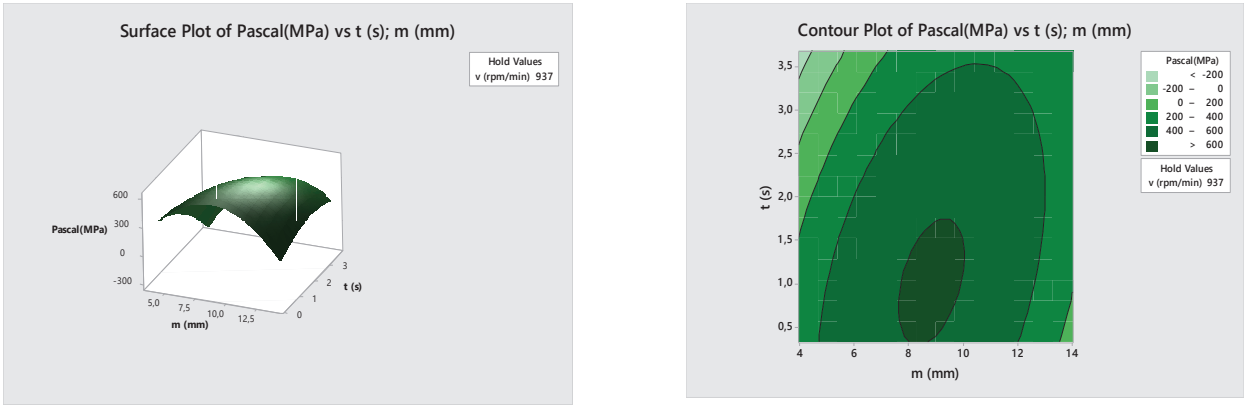

FIGURE 6. Surface and contour plot from optimization from joining time and diameters

The tensile strength optimize at 600 MPa when diameter around 8 to 10 mm and joining time at 0 to 1.5 s. Combination each welding parameters which get an optimize from tensile strength values was presented in Fig. 7.

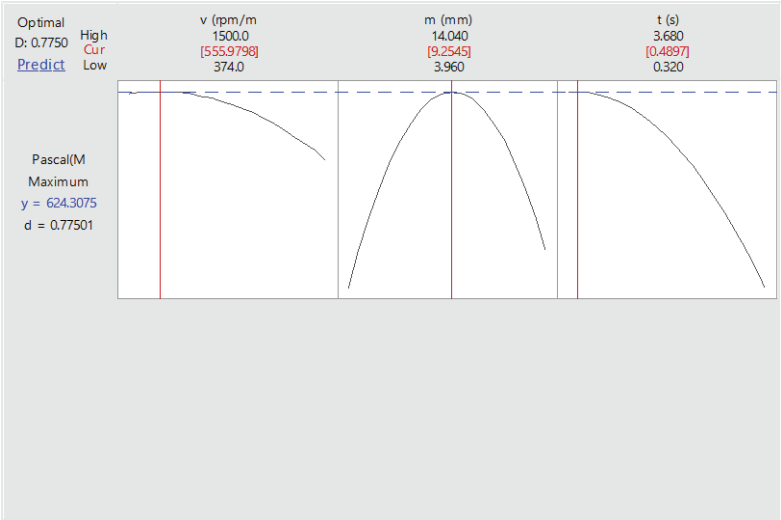

FIGURE 7. combination from optimize each weld parameter

D-optimality Respon shown that rotation speed optimize at 556 rpm, joining time at 0.45 s and diameter of steel at 9.25 so tensile strength optimize at 624 Pascal.

Taguchi Method is a optimization method used when the data has normal distribution, identic, and independent. ANOVA results shown that this data could optimize with Taguchi Method. Effect of welding parameter levels to tensile strength was presented by Table 3.

TABLE 3. value tensile tested each combination of welding parameter level

Level	v (rpm/min)	m (mm)	t (s)
1	493,4	134,5	671,8
2	345,4	383,3	402
3	417,9	544,1	438,1
4	624,8	359	340,3
5	396,9	353,1	345,7
Delta	279,4	409,6	331,5
Rank	3	1	2

Table 3. shown the highest value of delta from level was 409.6 Pascal, it was diameter, the second was 331.5 Pascal as the joining time, and the threat 279.4 Pascal as a rotation speed. The graphic of main effects plot to S/N ratio of tensile test, the graphic presented with Fiq 8.

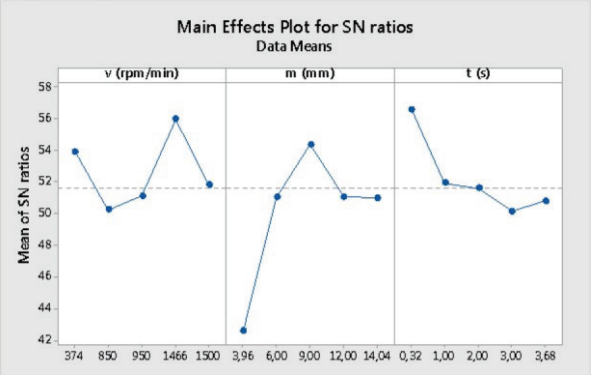

Figure 8. plotting of S/N value

Fig. 8 shown the ploting of each parameter effect based on S/N that value of this rotasion speed was 1466 rpm, the specimen diameter 9 mm, and joining time 0.32 s.

CONCLUSION

1. Stainless steel could join with the rotation speed was 920 rpm, diameter 9 mm, and joining time was 2 Sec. this welding parameters combination effected tensile strength up to 766.5 Pascal.
2. RSM recommended that rotation speed optimal when 624 Pascal, 556 rpm, joining time optimize 0.45 sec, and the diameter 9.25 mm
3. Taguchi Method conclude that hight rotation speed 1466 rpm, diameter 9 mm, and the joining time was 0.32

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