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Research paper

Optimization of Micro Resistance Spot Welding Parameters to Maximum Load, Fracture Area, and Nugget Thickness on AA1100 Using Response Surface Method

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Abstract

An improvement of micro welding technology is needed to support assembly of small components. The parameters of the micro resistance spot welding (µRSW) lead to welding quality such as maximum load, fracture area, and nugget thickness, some of welding quality parameters. There are not many researchers studying the welding quality of µRSW. This study aims to optimize welding parameters into maximum load, fracture area, and nugget thickness. The optimization of welding parameters used the response surface method (RSM). The highest value of maximum load 276.8 N could be achieved when welding current and welding time are 2 kA and 1 CT. The welding time on 1CT and welding current on around 1.5 kA can optimize to obtain the maximum load 200 N. 1 CT welding time or more and welding current near 3 kA result more 8 mm2 of fracture area. The thinnest and the thickest of the nugget were 0.553 mm when 1.5 CT of the welding time and 2 kA of welding current, and 0.790 mm when the welding time on 0.5 CT and welding current 1 kA. The value of nugget thickness optimize when the welding current between 1.5 kA and 0.5 kA, the magnitude of welding time less than 1 CT.

Keywords: *Micro Resistance Spot Welding; Optimization; Response Surface Method*

1. Introduction

Welded joint is widely used in automotive industries. Resistance Spot Welding (RSW) is commonly used in automotive industries and is more economist than other welding technology [1, 2]. Welding process for joining thin sheet less than 1mm is called a micro welding [3, 4]. This article studies µRSW on an aluminum AA 1100 [5]. The optimization of the welding parameter is importance to get a best quality of weld joint.

RSM is one of the method that allows engineers to better comprehend the characteristics of a process, which is particularly useful in situations where several process parameters (variables) potentially influence response variables [6]. Wen Wang et.al optimized the laser-assisted glass frit bonding process using RSM [7]. There are limited studies how to optimize the parameters RSW on thin aluminum 1100 using RSM. The µRSW parameters are related to the welding quality.

The parameters of µRSW are similar to RSW parameters. However, a µRSW process is more complex than a RSW. With the materials thickness that less than 1 mm, when the materials are welded, these could be easy to make a hole or a cavity. The change of µRSW process parameters has impact to weldability. This paper presents an optimization of welding parameters of µRSW. Change of the welding current and welding time can determine manufacturing parameters optimization on the morphological feature and mechanical properties [8]. Nugget size is highly dependent on welding current [9]. Optimization of the welding time and welding current to the response of maximum load, fracture size, and nugget thickness, become important to µRSW system development, and there still limited study on this research. The objective of this study is to optimize the welding time and the welding current to maximum load, nugget thickness, and fracture size for improving on µRSW quality.

2. Materials and Method

2.1 Materials

Aluminum AA1100 sheet was cut according to the AWS dimension standard system [10, 11], with the thickness of 0.8 mm according to the AWS standard. The thickness of AA 1100 sheet in this article was 0.4 mm, therefore the total thickness of 2 plates was 0.8 mm. The width of the specimen was 19 mm and the length of specimen was 76 mm. The 5 specimens were welded in each parameter as following: 3 specimens were welded then tensile shear tested and 2 specimens were polished, and etched.

2.2 Machine Setup

RSW machine was commonly used in medium and heavy industries. The water-cooling system was used in the machine that flows in the top and bottom of electrode. The value of maximum load each specimen was shown in the Table 1.

Table 1: Peak load of tensile test results

Welding parameters	Specimen 1 (N)	Specimen 2 (N)	Specimen 3 (N)
HT 10 sec CT 0.5 I 1kA	213.9	201.5	152.5

HT 10 sec CT 1.0 I 1kA	220	205.8	205
HT 10 sec CT 1.5 I 1kA	256	236.8	245.1
HT 10 sec CT 0.5 I 2kA	275.5	265.4	272.1
HT 10 sec CT 1.0 I 2kA	269.4	276.8	270
HT 10 sec CT 1.5 I 2kA	245	270.5	276.8
HT 10 sec CT 0.5 I 3kA	158.6	182	170
HT 10 sec CT 1.0 I 3kA	187.5	227.5	230
HT 10 sec CT 1.5 I 3kA	265	240	245

2.3 Macrostructure Test

In macrostructure test, it is used a digital microscope to measure the fracture size and thickness of nugget. The fracture area was captured by digital microscope and then the fracture area was measured to find the largest fracture area of the welding result.

The value of the fracture area measurement is shown in the Table 2.

Table 2: Fracture area of the welding parameter

Welding Parameters	Specimen 1 (mm^2)	Specimen 2 (mm^2)	Specimen 3 (mm^2)
HT 10 sec CT 0.5 I 1kA	2.703	0.234	0.182
HT 10 sec CT 1.0 I 1kA	2.965	0.077	3.332
HT 10 sec CT 1.5 I 1kA	5.032	3.811	3.918
HT 10 sec CT 0.5 I 2kA	4.296	2.852	5.384
HT 10 sec CT 1.0 I 2kA	6.846	5.765	4.809
HT 10 sec CT 1.5 I 2kA	5.054	5.534	7.111
HT 10 sec CT 0.5 I 3kA	0.183	4.736	4.149
HT 10 sec CT 1.0 I 3kA	3.975	4.607	5.754
HT 10 sec CT 1.5 I 3kA	1.927	8.50	5.045

The nugget thickness affected the weld strength. The nugget thickness of welding parameters is shown in Table 3.

Table 3: Nugget thickness of the welding parameter

Welding Parameter	Nugget Thickness (mm)
CT 0.5 I 1kA	0.790
CT 1 I 1kA	0.658
CT 1.5 I 1kA	0.737
CT 0.5 I 2kA	0.605
CT 1 I 2kA	0.632
CT 1.5 I 2kA	0.553
CT 0.5 I 3kA	0.736
CT 1 I 3kA	0.611
CT 1.5 I 3kA	0.580

2.4 Response Surface Method (RSM)

RSM was used to find those settings of process parameters that give an optimum value of the response [12]. This research uses RSM to optimize three purposes as follows: 1) to optimize load maximum, 2) to optimize fracture area, and 3) to optimize nugget thickness. It continues process of linear regression. Contour plots were used to determine the process parameter values that give optimum response. These were plotted for each response and any of the two influential process parameters, while other parameters are kept constant [12].

3. Results and Discussions

One independent variable used two dependent variables. Each response constant has three levels. The level of the dependent variable of welding time of 0.5, 1, 1.5CT, and the three level of welding current of 1, 2, and 3kA. The value of independent was affected by each combination of dependent variable. It is used to develop response surface model, where the values were presented in the Table 2, 3, and 4. The response surface model was shown in the equation 1. Matlab® software used to process the data. The optimization of the maximum load explained by a graphic was presented in Figure 1.

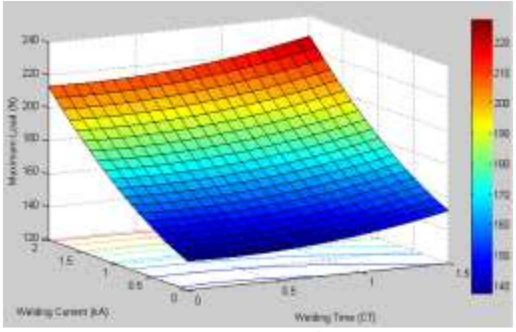

Figure 1: The optimization of maximum load

Figure 1 represents the optimization of welding time and welding current to maximum load. The maximum load is more than 220 N when the welding time and welding current are more than 2 kA. 200 N of maximum load can be achieved by the welding current of around 1.5 kA. The optimization value of the maximum load is 220 N when 1.5 kA of welding current and 1.5 CT of welding time.

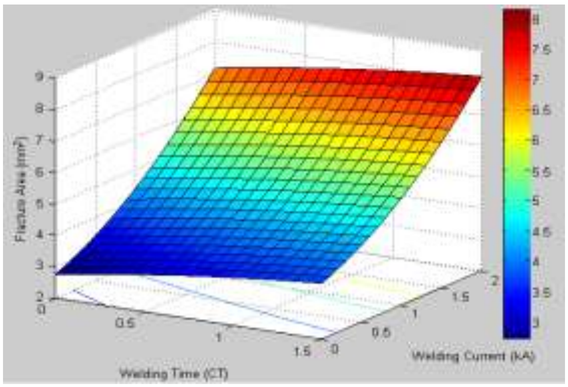

Figure 2: The optimization of fracture area

The optimization fracture area was developed and it is shown in the Figure 2. Figure 2 explains that the fracture area tends to increase when the welding time and the welding current were increased. The fracture area reached more 6 mm2 when welding time is more than 0.5 CT and welding current is at less on 2 kA. Welding time 1 CT and welding current near 3 kA achieve more than 8 mm2 of area.

Experimental design of response surface model in this paper uses three factorials. The graph of optimization nugget thickness presents in the Figure 3.

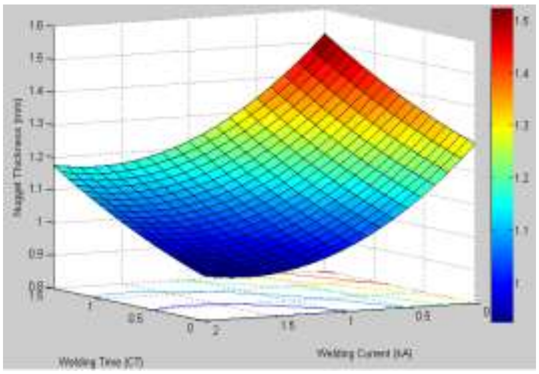

Figure 3: The optimization of nugget thickness

Figure 3 shows an optimization that the nugget thickness will be decrease when the welding time and welding current increase. Nugget thickness is less than 1mm when welding current between 1 kA and 2 kA, and 0.5 CT of welding time. The nugget thickness will be optimized when the welding current between 1.5 kA and 0.5 kA, and the welding time less than 1 CT.

4. Conclusions

This research concludes that 2 kA the welding current and welding time of 1.0 CT and 1.5 yield to 276.8 N of maximum load. The thinnest of the nugget was 0.553 mm when 1.5 of the welding time and 2 kA of welding current. The thickness nugget is 0.79 mm when the welding time on 0.5 CT and welding current of 1kA. The nugget thickness is 0.737 mm when welding time 1.5 CT and welding current 1 kA.

The optimization value of the maximum load is 220 N on 1.5 kA welding current and 1.5 CT welding time. The fracture area is 6 mm2 when welding time is more than 0.5 CT and welding current is at less on 2 kA. Welding time 1 CT and welding current near 3 kA achieved more than 8 mm2 of area. The value of nugget thickness will be optimized when the welding current between 0.5 kA and 1.5 kA, and the magnitude of welding time less than 1 CT.

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