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AN INVESTIGATON AND OPTIMIZATION OF RESISTANCE WELDING ELECTRODE TO EXTEND LIFE BY TAGUCHI METHOD

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Abstract

Resistance Spot Welding (RSW) is a process that is being used in industry for sheet joining purposes especially in the Automobile and Aerospace industry. The problems associated with RSW are different profile with the electrode resulting in increased tool wear, and subsequent deterioration of weld quality. More current and time lead to expulsion and overheating of the electrode affecting the weld quality and less value result in in sufficient weld strength. The complicated behavior of this process must be analyzed to set the optimum parameters to get good quality weld. This paper presents an experimental investigation for optimization of tool profile and testing by using Taguchi method. The experimental studies were conducted under varying welding current, welding time, electrode diameter and electrode force. Taguchi quality design concepts of L27 orthogonal array has been used to determine Strength to Noise(S/N ratio), Analysis of Variance and F test value for determining most significant parameters affecting the spot weld performance. The experimental results confirmed the validity of used Taguchi method for enhancing welding performance and optimizing the welding parameter in RSW process. The confirmation test indicated that it is possible to increase tensile shear strength significantly.

***Keywords:(** RSW)resistance spot welding, Taguchi, Tool profile*

1. Introduction

Resistance welding is the most commonly used method for joining steel sheets. No filler metal is needed and the heat required for the weld pool is created by means of resistance when a high welding current is directed through the welded work pieces. An electro-conductive contact surface is created between the workpieces by pressing them together. Contact is made using the shape of either the welded surfaces of the workpieces or the shape of the electrodes. Water-cooled electrodes made of alloyed copper are used in resistance welding. Electrodes convey a pressing force to the joint and direct the welding current to the joint in the appropriate manner. After welding, the electrodes rapidly cool down the welded joint. Work stages in resistance welding are very fast. The surfaces to be welded do not usually need to be cleaned before welding, in addition to which the weld does not usually require grinding or post heating. The resistance welding process can be easily automated. Resistance welding is a highly efficient production method that is particularly well-suited for automated production lines and mass production. Resistance welding is also suitable for small batch production, because the method is flexible, equipment simple and the welding process is easy to control.

1.2 Problem Statement:

Resistance spot welding process comprises of electric, thermal and mechanical phenomenon, which makes this process complex and highly non-linear and thus, it becomes difficult to model it. In order to obtain good weld nugget during spot welding, hit and trial welds are usually done which is very costly. Therefore the numerical simulation research has been conducted to understand the whole process. In this paper three different cases were analysed by varying the tip contact area and it was observed that, with the variation of tip contact area the nugget formation at the faying surface is affected. The tip contact area of the welding electrode becomes large with long welding cycles. Therefore in order to maintain consistency of nugget formation during the welding process, the current compensation in control feedback is required. If the contact area of the welding electrode tip is reduced, a large amount of current flows through the faying surface, as a result of which sputtering occurs.

2. Literature Review:

[1] Brožek, Milan & Nováková, Alexandra & Niedermeier, Ota. (2017). Resistance Spot Welding of Steel Sheets of the Same and Different Thickness. Acta Universitatis Agriculturae et Silviculturae Mendelianae Brunensis. 65. 807-814. 10.11118/actaun201765030807. Resistance welding ranks among progressive and in practice often used manufacturing techniques of rigid joints. It is applied in single-part production, short-run production as well as in mass production. The basis of this method is in the utilization of the Joulean heat, which arises at the passage of current through connected sheets at collective influence of compressive force. The aim of the carried out tests was the determination of the dependence between the rupture force of spot welds made using steel sheets of the same and different thickness for different welding conditions. For carrying out of this aim 360 assemblies were prepared. The sheets (a total of 720 pieces) of dimensions 100 × 25 mm and thickness of 0.8 mm, 1.5 mm and 3.0 mm were made from low carbon steel. In the place determined for welding the test specimens were garnet blasted and then degreased with acetone.

[2] Abd al al, Sahm Alden & Ákos, Meilinger & Gáspár, Marcell. (2024). Physical Heat Cycle Measurement of Resistance Spot Welding. Key Engineering Materials. 989. 65-75. 10.4028/p-Tb0OWj. Resistance spot welding (RSW) is still the ideal joining method in the automotive industry. Mostly steel sheets are used in the car body, so overlap and layering are required for welding or riveting, as spot welding provides simultaneous clamping force with interfacial welding to ensure the required strength and quality. A fundamental understanding of heating and cooling rates in thermal distributions is essential for predicting microstructure formation in the weld and the heat-affected zones (HAZ) of RSW joints. The ability to measure the heat cycle in the RSW process can be valuable in weld control and welding parameter optimization. RSW parameters can be optimized through tensile shear tests and microscopic investigations. Heat cycle measurement (HCM) demonstrates the welding consequences in terms of the change in mechanical properties and microstructural formations. The accuracy of cooling rate measurements including t8/5 cooling time is very important to predict the microstructural evolution in the HAZ, however, the thermocouple measurement raises numerous challenges due to the high temperature gradient and small weld and HAZ size measurement and appears as a noisy curve that is filtered out and smoothed.

[3] Qin, Yahang & Xiao, Shou & Lu, Liantao & Yang, Bing & Li, Xiangjie & Guangwu, Yang. (2020). Structural Stress–Fatigue Life Curve Improvement of Spot Welding Based on Quasi-Newton Method. Chinese Journal of Mechanical Engineering. 33. 10.1186/s10033-020-00453-3. F-N curves are usually used to predict the fatigue life of spot welding in engineering, but they are time-consuming and laborious and not universal. For the purpose of predicting the fatigue life of spot welding accurately and efficiently, tensile–shear fatigue tests were conducted to obtain the fatigue life of spot-welded specimens with different sheet thicknesses combinations. These specimens were simulated by using the finite element method, and the structural stress was theoretically calculated. In the double logarithmic coordinate system, the structural stress–fatigue life (S–N) curve of spot welding was fitted by the least-squares method, based on the quasi-Newton method. The square of the correlation coefficient of the S-N curve was taken as the optimization objective, with the correction coefficients of force, bending moment, spot welding diameter, and sheet thickness as the variables.

[4] Kishore, Kaushal & Kumar, Pankaj & Mukhopadhyay, Goutam. (2019). Resistance spot weldability of galvannealed and bare DP600 steel. Journal of Materials Processing Technology. 271. 10.1016/j.jmatprotec.2019.04.005. Resistance spot welding (RSW) of galvannealed and bare dual phase (DP600) steel is a challenging task as it involves the additional complexity of zinc coating layer. This study is focused on optimization of spot welding parameters, viz., welding current and time to achieve maximum load bearing capacity in tensile-shear and coach-peel configurations. Study revealed a minimum critical nugget diameter is needed above which favorable pull-out failure is observed. Critical nugget diameter for pull-out failure is determined to be 4.4 mm. Applicability of different empirical and metallurgical models for determination of critical nugget diameter were assessed. Transition from partial interfacial to pullout failure mode has been explained on the basis of combined effect of increased nugget diameter and micro-mechanism of fracture. It was observed that the there was an increase in nugget diameter and load bearing capacity of the spot welds with an increase in welding current as well as welding time.

[5] Jalal, Nawzad & Hasan, Aysha & A. Hussein, Ahmed & Ali, Obed. (2018). Effect of Spot-Welding Current-Cycle for Medium Carbon Steel And Stainless Steel on Mechanical Properties. Spot welding involves the joining of two or more plate metals in localized areas where melting and jointure of a little volume of fabric happens from heating caused by resistance to the passage of an electrical current. This process is typically used for obtaining a lap joint of plate metal parts. In this work, stainless steels and medium carbon steel were used. Three rules for welding setup , lowest tap on the fastening electrical device, highest % current setting on the weld management and shortest weld time setting on the weld management were adopted. Experiments conducted to show the effect of these variables on the welding diameter and tensile strength for each sample for medium carbon steel and stainless steel separately and joining both metals together by spot welding. The results show that the utmost durability was at stainless steel specimens and minimum tensile strength was at medium carbon steel specimens. Furthermore, the obtained results showed that the maximum heat generated was at stainless steel specimens and minimum heat generated values was at medium carbon steel specimens for all current dependent in this work. Meanwhile, slight effect of heat generated on the spot diameter for the current of 10.6 & 5.3 kA, and so significant effect on the spot diameter for the last current (2.3kA).

3. Profile Analysis & Selection:

The size of the weld will not be larger than the electrode face. Therefore, it is important to utilize electrodes of the same tip diameter as the desired weld nugget. The current density at the workpiece interfaces varies as the square of the diameter of the electrode face. Electrode positioning is critical: electrodes should be positioned where the weld is desired, should generally not overhang the edges of the part (except in wire and small terminal welding), should not bend, should be perpendicular to the plane of the workpieces, should maintain constant diameter (constant area) as they wear, and should be cleaned and dressed regularly. Electrodes should be dressed with 600 grit silicon carbide paper or polishing disk pulled with light force in one direction only. Electrodes should be replaced when the tip is damaged or blows out. It is best to have all electrode tips reground regularly by a qualified machine shop

.3.1 Electrode Model:

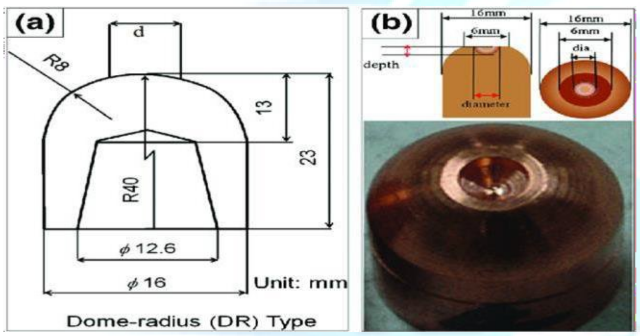

Figure1: Electrode profile model

The electrodes used in this study have been designed by us. And are shown in Figure 1. These electrodes are very similar to a tapered and domed with a slightly curved weld face with a set diameter. Both profile variations of this electrode were used in this study. The coating employed is not the same as the employed for resistance welding of steel alloys.

4. Materials and methods:

4.1 Materials:

Galvanized steel sheet having chemical composition of (w_t%) 0.065C, 0.095Si, 0.017Cr 0.032 ,Ni, 0.053Cu, 0.404M_n, 0.34S_i, 0.017S, 0.018P, (balance)Few as used. A batch of sheet samples in dimensions of 100mm × 30mm × 1mm were used for spot welding in order to determine weld quality. Electrode used was Cu Cr alloy having varying diameters.

4.2 Methods:

Following input and output parameters are considered:

- Input parameters selected are welding current,
- weld time,
- electrode diameter and L welding force.
- Output parameter predicting strength of weld joint is Tensile shear strength.TheinputparametersareshowninTable-1.

Table 1: Process parameters with their values at three levels.

Level	Welding current (amph) (A)	Weldtime (Cycle) (B)	Electrode diameter (mm) (C)	Welding force (kN) (D)
1	20	8	4	5
2	40	8	4	5
3	60	8	4	5
4	80	8	4	5
5	100	8	4	5
6	120	8	4	5
7	140	8	4	5
8	160	8	4	5
9	180	8	4	5
10	200	8	4	5

5. Experimentation:

Experimentation is the important step in the total analysis. Total 20 runs of experiments based on randomized OA were done. Current, weld time, electrode diameter and force are varied as per values for each level mentioned in Table-1. Three responses are taken for each setting.

Figure 2: Material welding

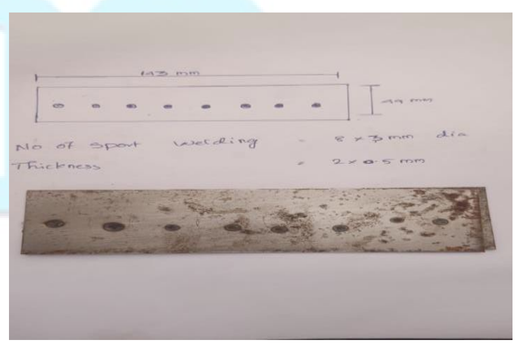

Figure 3: Welded material

Conclusion:

This paper has presented an investigation on the optimization and the effect of welding parameters on the profile changed spot welding electrodes. The level of importance of the welding parameters on the tensile shear strength is determined by using TAGUCHI. Based on the TAGUCHI method, the highly effective parameters on tensile shear strength were found as welding current and welding time, whereas electrode force and electrode diameter were less effective factors. The results showed that welding current was about two times more important than the second factor weld time for controlling the tensile shear strength. An optimum parameter combination for the maximum tensile shear strength was obtained by using the analysis of S/N ratio. The confirmation test syndicated that it is possible to increase tensile shear strength significantly (14 %) by using the proposed statistical technique. The experimental results confirmed the validity of Taguchi method for enhancing the welding performance and optimizing the welding parameters in resistance spot welding operations.

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[6] G. Mukhopadhyaya, S. Bhattacharya, K.K. Ray. 2009.Strengthassessmentofspotweldedsheetsofinterstitialfreesteels. 209:1995-2007.

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