Experimental Investigation of Resistance Spot Welding: A Literature Review

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***Abstract*--Welding input parameters play a very significant role in determining the quality of a weld joint. The joint quality can be defined in terms of properties such as weld-bead geometry, mechanical properties, and distortion. The main emphasis of this review is to study the effect of different input parameter of resistance spot welding on the weld quality. Nowadays, application of design of experiment (DoE), evolutionary algorithms and computational network are widely used to develop a mathematical relationship between the welding process input parameters and the output variables of the weld joint in order to determine the welding input parameters that lead to the desired weld quality.**

The experimental studies have been conducted under varying welding current and welding time, squeeze and hold time. In this investigation the quality characteristic (tensile strength) has been considered using Grey Relational Analysis Method. Optimal parameters collection of the RSW operation was obtained via grey relational analysis.

Keywords: Resistance spot welding, Optimization bibliography, Welding bibliography

I. INTRODUCTION

Resistance spot welding (RSW) is a major sheet metal joining process in many industries, such as the automobile, domestic appliances, air craft and space craft fabrications. It is an efficient joining process widely used for the fabrication of sheet metal assemblies. There are 3000-6000 spot welds in any car, which shows the level importance of the resistance spot welding. RSW has excellent techno-economic benefits such as low cost, high production rate and adaptability for automation which make it an attractive choice for auto-body assemblies, truck cabins, rail vehicles and home appliances. It is one of the oldest of the electric welding processes in use by industry today[1]. Furthermore, other metal-to-metal connections, such as wire-to-wire joints in the electronics industry, are accomplished by resistance spot welding. Application-specific measures, such as the diameter of the welding spot, determine the quality of the joint. The weld is made by a combination of heat, pressure, and time. As the name implies, it uses the resistance of the materials to the flow of current that causes localized heating between the parts to be joined. Understanding of physical mechanisms for easily manipulating and controlling weld qualities in advance is important. Resistance spot welding is the most widely used form of the electric resistance welding process in which faying surfaces are joined in one or more spots. The RSW process fundamentally consists of four stages which are squeeze cycle, weld cycle, hold cycle and off cycle.

Resistance Welding Parameters

There are three main parameters which control the quality of resistance spot welding. Diagrammatically shown in figure:

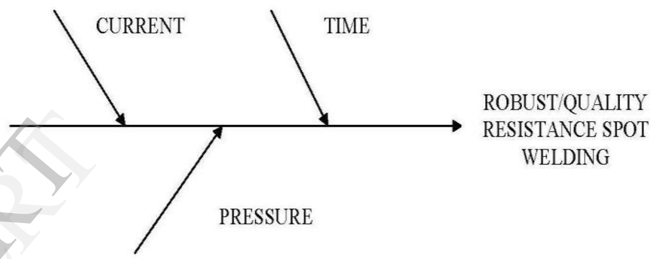

Figure.1 Cause and effect diagram of main welding parameters[1]

A. *Effect of Welding Current*

Current controls the heat which generated according to the equation $Q = I^2Rt$.this shows that the current has more influence on the amount of heat generated.

Tensile shear strength increases rapidly with increasing current density. Excessive current density will cause molten metal expulsion (resulting in internal voids), weld cracking, and lower mechanical strength properties. Typical variations in shear strength of spot welds as a function of current magnitude are shown in Figure 2. In the case of spot welding excessive current will overheat the base metal and result in deep indentations in the parts and, it will cause overheating and rapid deterioration of the electrodes.

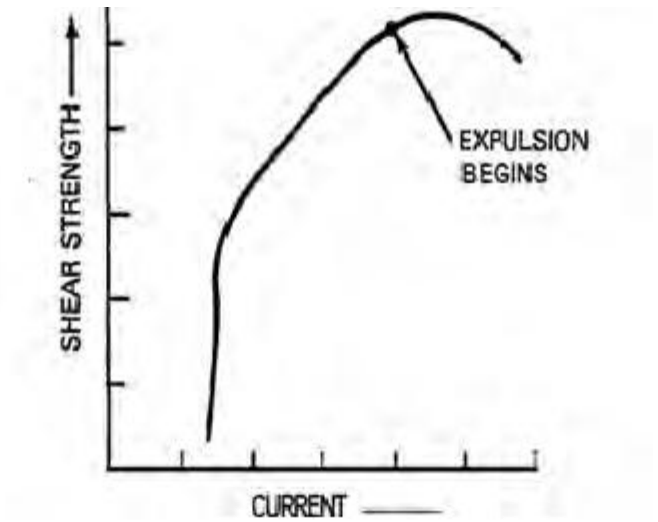

Figure.2 Effect of welding current on spot weld shear strength[1]

B. *Effect of Weld Time*

The rate of heat generation must be such that welds with adequate strength will be produced without excessiveelectrode heating and rapid deterioration. The total heat developed is proportional to weld time. During a spot welding operation, some minimum time is required to reach melting temperature at some suitable current density. Excessively long weld time will have the same effect as excessive amperage on the base metal and electrodes. Furthermore, the weld heat-affected zone will extend farther into the base metal.

The relationship between weld time and spot weld shear strength is shown in Figure.3 assuming all other conditions remain constant. To a certain extent, weld time and amperage may be complementary. The total heat may be changed by adjusting either the amperage or the weld time. Heat transfer is a function of time and the development of the proper nugget size requires a minimum length of time, regardless of amperage.

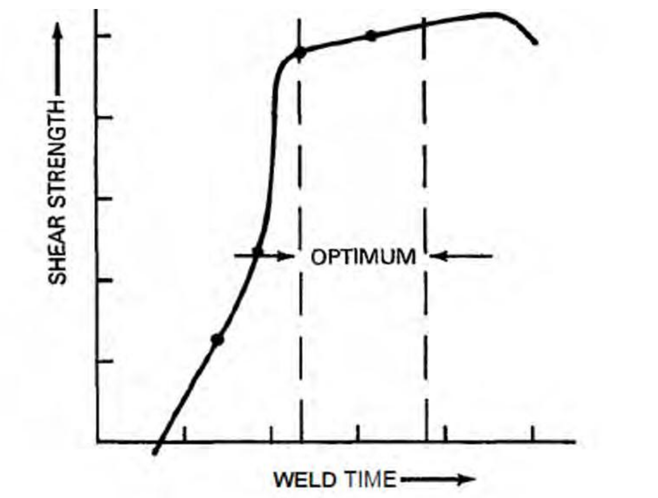

Figure.3 Tensile-shear strength as a function of weld time[1]

C. *Effect of Welding Pressure*

Welding pressure is produced by the force exerted on the joint by the electrodes. Electrode force is considered to be the net dynamic force of the electrodes upon the work, and it is the resultant pressure produced by this force that affects the contact resistance. As the pressure is increased, the contact resistance and the heat generated at the interface will decrease. To increase the heat to the previous level, amperage or weld time must be increased to compensate for the reduced resistance. The surfaces of metal components, on a microscopic scale, are a series of peaks and valleys. When they are subjected to light pressure, the actual metal-to-metal contact will be only at the contacting peaks, a small percentage of the area. Contact resistance will be high. As the pressure is increased, the high spots are depressed and the actual metal-to-metal contact area is increased, thus decreasing the contact resistance.

II. LITERATURE SURVEY

Optimization method used for the austenitic stainless steel AISI 301L in RSW (Mr. Niranjan Kumar Singh et al, 2012) [1]. A two-dimensional model is utilized to predict temperature and stress fields during and after resistance spot welding process, Increasing the applied welding voltage leads to an increase in the weld nugget size. Welding time has the same role, however, increasing the welding time causes to enhance heat transfer to surroundings and therefore less heat is consumed in formation of weld nugget (I. Ranjbar Nodeh et al, 2008) [2]. To study of mechanical strength for three test geometry lap-shear, cross-tension and coach-peel, For lap-shear strength, a strong relationship with weld nugget diameter was observed; whilst discrete strength levels were found for coach-peel test geometry. For cross-tension strength; there is a relationship with nugget diameter; but data are sensitive to nugget periphery defects (L. Han, M. Thornton, D. Boomer, M. Shergold, 2011) [3]. Tests of thin-walled beams joined by spot welding (Rusi´nski et al, 2004) [4].

(Yanjun Xiao et al, 2011) [5] To establish thermoelectric coupling finite element model, this model can predict the temperature distribution and spot welding joints melt nuclear forming process. By providing the necessary conditions to conclude that: The workpiece and the contact position of workpiece formed melted, first, with initial molten nuclear heating process, melting with nuclear size increases; Along with the increase of contact resistance welding are also on the increase nuclear size; The decrease of the electrode pressure can reduce molten nuclear size, which because of increased contact surface area, smaller contact resistance, heat generation also subsequently reduced; If the increase of the diameter workpiece, form qualified nuclear needed current fusion and electrode pressure should also increase.

Optimum algorithm used for the find out the maximum fatigue life of the resistance spot welding and compared to the FEA ANSYS software and increase the fatigue life of the joint in the resistance spot welding (Ahmet H. Erta and FazılO.Sonmez, 2011) [6]. Experimental and modeling investigation of the failure resistance of Advanced

High Strength Steels spot welds (S. Dancette et al, 2011) [7]. Contact conditions on nugget development during resistance spot welding of Zn coated steel sheets using rounded tip electrodes and compared to the flatted tip electrode, analysis has to be carryout (R. Raoelison, A. Fuentes, 2012) [8].

Weld growth mechanism of resistance spot welds in zinc coated steel and compared to the uncoated steel and micrographs showing the location of initial heat development in both steel palte (N. Harlin, T.B. Jones , J.D. Parker, 2003) [9]. NDT test has been carryout through C-scan in resistance spot welding (M. Thornton et al, 2012) [10]. In small-scale resistance welding to analyze the effect of electrode force and compared to the large scale resistance welding (B.H. Chang, Y. Zhou, 2003) [11] and also to monitoring the weld quality of small-scale resistance welding for titanium alloy (Dawei Zhao and Yuanxun Wang, 2013) [12]. To discuss the dynamic joint strength evaluation procedures and the measured dynamic strength data for 13 joint populations of self-piercing rivets (SPR) and resistance spot welds (RSWs) joining similar and dissimilar metals(Xin Sun, Mohammad A. Khaleel, 2007) [13]. A study investigating the effect of sheet surface condition on resistance spot welding (RSW) of aluminium has been carried out (L. Han et al, 2010) [14].

(A. K. PANDEY et al, 2013) using the Taguchi method to optimize the resistance spot welding [15] and The concentration of current density at the edge of contact area which forms sharp corners was reproduced by the proposed FEM simulation method (Ninshu Ma and Hidekazu Murakawa, 2010) [16]. (Heli Koskim¨aki et al) use of the k-nearest neighbours (knn) method to identify similar welding processes with the similarity measure, it could be decided whether a similar enough process is already stored in the database or whether a more extensive data set is needed in RSW application[17]. (S.R. Lee and Y.J. Choo, 2001) studied the quality assurance technique using a Neuro-Fuzzy Algorithm for RSW [18]. (A. AMBROZIAK et al, 2010) use the spot welding for joining aluminium elements in automotive industry[19]. (Zhenzhen Lei et al, 2011) use the Three Sheets assemblies for Transient Thermal Characteristics through FEA in resistance spot welding[20]. (J.H. Song and H.Huh, 2011) proposes an accurate failure criterion to investigate of spot welds under combined axial and shear loading condition[21]. (V.-X. Tran and J. Pan, 2009) investigated Fatigue behavior of dissimilar friction stir spot welds or spot friction welds in lap-shear and cross-tension specimens[22]. (P.-C. Lin and D.-A. Wang, 2010) investigated stress intensity factor by the finite element analysis for U shape element [23]. (Ding Min et al, 2013) researched on the effects of parameters on microstructures and mechanical properties of spot welding ferrite steel [24]. (J. Pan et al, 2003) investigated the circumferential failure mode of spot welds under combined loading conditions [25]. (G.R. Payen et al, 2012) developed a novel test for the in situ failure analysis of spot-welded joints , Facing the need of a better understanding of spot-weld strength and failure mechanisms of advanced high strength steels[26]. (Francesco Vivio and Pierluigi Fanelli, 2008) using original analytical method to create a centre nugget in spot welding fir variable thickness over a circular plate [27].

III. Gap Identification

RSW process experimental work has been carried out by researchers for process parameters like welding current, welding time and squeeze time and hold time, Electrode pressing force, electrode geometry, the choice of electrode material. Also research has been done for product parameters like penetration, heat affected zone, sheet thickness, overlapping length, strength of weld and distortion stresses.

There are very researching carryout by the researchers based on FEA and Optimization techniques for various material like low alloy & steel and stainless steel, Aluminium & Light alloy, Nickel & its alloy, Galvanized sheets, Brass & copper. The tensile strength of spot weld depends on the nugget diameter, nugget penetration, thickness & strength of w/p, electrode indentation & possible defects & benefits of welds. Following points were also not covered by reference researchers.

In resistance spot welding, there are many research gap found .

- To required for the ring identification both upper and lower side electrode by using desirable apparatus.
- To require RSW analysis, mostly on constant force sometimes limited forces.
- To investigate the three sheets welding analysis for the three method : 1) coach peel,2) cross tension, 3) lap shear
- Comparison between the traditional A scan and C scan system for the various sheet thickness and different material of sheet.
- Influence of various process parameters for different thickness of sheet.
- Comparison of experimental result with FEA results from this to optimize the process parameter in spot welding.
- Guidelines for achieving good strength of sheets weld joints.
- Use of different FEA analysis software for different thickness of sheet of different material.
- To require various design of experimental method for the optimization of process parameter and its effect on output.
- To required the two different material used for the experiment and compared both material based on nugget strength.

IV. Conclusion

From the literature it is found there are remarkable works carried out in the field of process parameter optimization for the material like mild steel, stainless steel and aluminium. But that work carryout only for limited materials not for other material. The researcher used different Design of experimental method for resistance spot welding like Taguchi method etc but not more used grey relational method for the optimization purposed in RSW by researcher. By the used of the grey relational analysis method for the optimization of process parameter in resistance spot welding very accurate result came out includes but this result getting only for when both used in combine purpose only. To analysis of this process parameter after the experiment by using the this DOE method.

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