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A REVIEW ON OPTIMIZATION OF RESISTANCE SPOT WELDING OF ALUMINUM COMPONENTS USED IN AUTOMOTIVE INDUSTRY

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Abstract* -- Resistance Spot welding (RSW) is one of the common welding processes used for sheet joining especially in the automobile and aerospace industry. It is used in a wide range of industries but notably for the assembly of sheet steel vehicle bodies. This is a type of resistance welding where the spot welds are made at regular intervals on overlapping sheets of metal. Spot welding is primarily used for joining parts that are normally up to 3 mm in thickness. The joint quality can be defined in terms of properties such as weld-bead geometry, mechanical properties and distortion.The objective of the research is to determine the optimum combination of parameters responsible for better quality of joints. The complicated behavior of the process must be analyzed to set the optimum parameters to get the optimum weld quality. The paper also presents the FEA simulation of the RSW process.

Keywords: ***Resistance spot welding, Optimization, Non-destructive testing.***

1. INTRODUCTION

In the automotive industry in particular, resistance spot welding (RSW) has for recent decades been the main joining technology. The method's low cost, high reliability, high time efficiency, high accessibility and high ability for robot atomization, compared to other joining methods, make it ideal for automotive production. A typical modern automobile contains around 3000 – 5000 resistance spot welds, while other joining methods, such as laser welding, arc welding or mechanical fastenings is used in a much more limited scale. Today, the automotive industry struggles with weight problem, which should be taken into account by the engineers. The demands of customers regarding safety and luxury cause the thicker sheets and components for more responsible parts of body like frame, chairs, reinforcement must be applied. This is the reason some parts of body are replaced by light materials (like aluminum and magnesium alloys, which mechanical properties are similar or even better than steel. Resistance welding is a fusion welding process that requires the application of both heat and pressure to achieve a sound joint. The simplest form of the process is spot welding where the pressure is provided by clamping two or more overlapping sheets between two electrodes. Resistance spot welding is a complex process in which coupled interactions exist between electrical, thermal, mechanical, metallurgical phenomena and even surface behaviors. In the recent years, finite element method has provided a powerful tool in studying these interactions and many related works have been carried out on the FEM modeling of RSW. Welding input parameters play a very significant role in determining the quality of a weld joint.Understanding of physical mechanisms for easily manipulating and controlling weld qualities in advance is important. Finite Element Model has been developed for the analysis of transient thermal behavior of process using ANSYS software to simulate the thermal characteristics of RSW process. Numerical simulation of welding process by ANSYS software for gaining the temperature field of workpiece, the effect of parameter variation on temperature field and process optimization for different cases are done.. The influence of the welding parameter for each mode on the dimensions and shape of the welds and on their ferrite contents is investigated.

II. LITERATURE SURVEY

A.Ambroziaket. al. [1], proposed work on, "Using resistance spot welding for joining aluminum elements in automotive industry" in 2010. In this article the comprehensive summary concerning technology of resistance spot welding of aluminums alloys was presented. The welding schedules, electric parameters of welding, electrodes materials and electrodes life time by resistance spot welding aluminum were described. Few examples directly from automotive industry were presented and advantages of aluminum as a material for some vehicle parts were also discussed.

Thakur.A.Get.al.,[2]carriedouttheFinite Element Analysis of resistance spot welding to study nugget formationin2010. This Paper presents the FEA simulation of the RSW process. It requires modeling of complex interactions between electrical, thermal, metallurgical and mechanical phenomena. A 2D axsymmetric FEM model has been developed to analyze the transie nt thermal behaviors of process using ANSYS software to simulate the thermal characteristics of RSW process.

The objectives of this analysis is to understand physics of the process and to develop a predictive tool reducing the number of experiments for the optimization of welding parameters. Through the thermal histories and temperature distributions obtained from this analysis, the geometry and dimensions of the nugget can be calculated. A. V. Dennison et. al.,[3] worked on Control and process based optimization of Spot Welding in Manufacturing systems in 1997. The objective of the research was to examine potential mechanisms for improvement of the spot welding process, which is a major component of automotive industry. The paper documents the outcomes of the two techniques and we demonstrate how the significant improvements can be made to the overall spot welding process through the adaptation of such technologies. In particular, both traditional techniques for improving suboptimal parameters in the process and advanced techniques, based upon digital signal processing control of the process were applied to the industrial spot welding test case. Ali. Moarrefzadehet. al.,[4] proposed the "Finite-Element Simulation of Resistance Welding Process" in 2011. In this paper, the Resistance Welding is studied and Steel temperature field is gained in this process. The thermal effect of Resistance Welding that specially depends on the electrical and temperature field of it in workpiece, is the main key of analysis and optimization of this process, from which the main goal of this paper has been defined. The paper reports the determination of optimum welding conditions (welding intensity and travel speed) for butt joints of Steel Alloys sheets using Resistance Welding. The influence of the welding parameter for each mode on the dimensions and shape of the welds and on their ferrite contents is investigated.

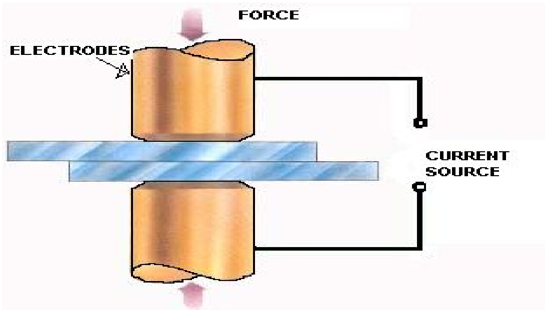
Sachin K Jadavet. al.,[5] conducted the literature review on "Experimental Investigation of Resistance Spot Welding" in 2014. The main emphasis of this review is to study the effect of different input parameter of resistance spot welding on the weld quality. The experimental studies have been conducted 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. DariuszUlbrichet. al.,[6] carried out "The analysis of spot welding joints of steel sheets with closed profile by ultrasonic method" in 2015. The article presents the methodology and the results of non-destructive ultrasonic testing of resistance spot welded joints of thin steel sheet with closed profile. Non-destructive test results were verified on the basis of welded joint area after destructive testing. The obtained results were used to develop an assessment technique for spotwelded joints of closed profile with steel sheet, which could be used in factories employing such joints. Zhang X. et al [16] investigated the strength of multiple spot weld joint. They also studied its automobile application i.e. vehicle chassis having many spot welds. Analyses of these structures are based on finite element study and experimental study. They have studied the finite element model for multiple spot weld joint under tensile shear load by experimental method. The effect of multiple spot weld joint strength is analyzed considering spot weld spacing, edge distance, weld size and thickness using FEA. The conclusion of this study is weld parameters like weld size and thickness are primary factors affecting the strength of the joint of materials.

Ertas A H. et al [17] studied the optimum locations of spot weld and the optimum overlapping length of joined plates. Minimum weld-to-weld and weld-to-edge distance recommended by the industry are considered as side constraints for optimum design of spot weld. They suggest that number of spot welds significantly affects the strength of structure. The distance between two spot welds, arrangement of spot weld and diameter of spot welds, these are the parameters considered for optimum design of spot weld. Spot weld is studied by using FEA and under different loading conditions. Dipak V. Patilet. al, [18] conducted a review on Effect of Spot Weld Parameters on Spot Weld Strength. The aim of this study is to find out the effect of spot weld parameters on the strength of spot weld. The effect factors of multiple spot-welded joints strength are analyzed including spot weld arrangement, distance between two spot welds, spot weld diameter and thickness based on finite element analysis (FEA) and experimental results. The study shows that weld diameter and thickness are primary factors affecting the strength of the joints for a given material. From the review conducted, we will interpret the effect of various input parameters on the physical and chemical properties and the primary factors affecting the strength of spot weld joints. The study also helps to understand basics regarding the complicated behaviors of the process which in turn will help one to develop a system to optimize spot welding parameters for maximizing joint strength and efficiency. The study shows that, quantity of heat delivered to the welding spot is dependent upon the duration of current and resistance between the amplitude of electrodes.

III. SPOT WELDING - A JOINING PROCESS

Spot welding is one form of resistance welding, which is a method of welding two or more metal sheets together without using any filler material by applying pressure and heat to the area to be welded. Spot welding is used in a wide range of industries but notably for the assembly of sheet steel vehicle bodies. This is a type of resistance welding where the spot welds are made at regular intervals on overlapping sheets of metal.

It is primarily used for joining parts that are normally up to 3 mm in thickness. The strength of the joint depends on the number and size of the welds. Spot-weld diameters range from 3 mm to 12.5 mm. A current is then passed between the electrodes, sufficient heat being generated at the interface by resistance to the flow of the current that melting occurs, a weld nugget is formed and an autogenous fusion weld is made between the plates. The heat generated depends upon the current, the time the current is passed and the resistance at the interface. The resistance is a function of the resistivity and surface condition of the parent material, the size, shape and material of the electrodes and the pressure applied by the electrodes.



In spot welding, two sharp copper alloy electrodes are used to cluster the welding current to a petite 'spot' as well as fasten the work pieces simultaneously. Inflicting a sizeable current via the two metal pieces eventually melt them a bit for welding. The best part of this procedure is that it occurs very quickly, in just 10 milliseconds and that too to a specific small spot to which the heat generated is not too much to result in warping.

Spot welding involves three stages; the first of which involves the electrodes being brought to the surface of the metal and applying a slight amount of pressure. The current from the electrodes is then applied briefly after which the current is removed but the electrodes remain in place for the material to cool. Weld times range from 0.01 sec to 0.63 sec depending on the thickness of the metal, the electrode force and the diameter of the electrodes themselves.

IV. PROCESS OPTIMIZATION

Optimization is the discipline of adjusting a process so as to optimize some specified set of parameters without violating some constraint. The most common goals are minimizing cost and maximizing throughput and/or efficiency. This is one of the major quantitative tools used in industry for decision making. When optimizing a process, the goal is to maximize one or more of the process specifications, while keeping all others within their constraints. This can be done by using a process mining tool, discovering the critical activities and bottlenecks, and acting only on them. The spot welding process tends to harden the material, causing it to warp. This reduces the material's fatigue strength, and may stretch the material. The physical effects of spot welding include internal cracking, surface cracks and a bad appearance. The chemical properties affected include the metal's internal resistance and its corrosive properties. Optimization of RSW process parameters have traditionally been performed through empirical experimental testing in laboratory environments. Such physical testing is accurate and reliable but it also has its downsides. Physical testing always involves material supply, welding equipment and operator skills, all of which are costly and critical for the results. In many fields of research, numerical modeling has been used partly or fully as a replacement for experimental testing. Numerical models can be used as an effective tool in virtual process planning. The complicated behavior of the process must be analyzed to set the optimum values of parameters to get the optimum weld quality.

V. STUDY OF PARAMETERS

There are three main parameters which control thequality of resistance spot welding:

A. EFFECT OF WELDING CURRENT:

Current controls the heat which generated accordingto the equation Q = I2Rt.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.

B. EFFECT OF WELD TIME:

The rate of heat generation must be such that weldswith 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,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.

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 increases, 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. Contact resistance will be high. As the pressure increases, the high spots are depressed and actual metal-to-metal contact area increases, thus decreasing the contact resistance.

VI. SPOT WELDING JOINTS- QUALITY ASSURANCE

NDT OF SPOT WELDS

Nondestructive testing (NDT) is the process of inspecting, testing, or evaluating materials, components or assemblies for discontinuities, or differences in characteristics without destroying the serviceability of the part or system. In other words, when the inspection or test is completed the part can still be used.Today modern nondestructive tests are used in manufacturing, fabrication and in-service inspections to ensure product integrity and reliability, to control manufacturing processes, lower production costs and to maintain a uniform quality level. Most NDT methods that are used for ordinary fusion welds can be used on spot-welds. The most common NDT-methods are visual inspection (VT), penetrant testing (PT), eddy current testing (ET), ultrasonic testing (UT), magnetic particle testing (MT) and X-ray testing (RT).

DEFECTS IN SPOT WELDS:

All discontinuities in spot-weld could be divided in two groups.
1) Non-Surface breaking discontinuities
2) Surface breaking discontinuities

Some of the NDT methods can only detect discontinuities in one of the two groups and some methods can detect discontinuities in both groups. The discontinuities that exist in spot welds are:

1. Weld with no or minimal fusion
2. Cold or stuck weld
3. Weld nugget size
4. Weld expulsion and indentation
5. Weld cracks

Spot welds can fail completely in two distinct modes namely nugget pull out failure and interfacial failure. Nugget pull out failure is caused by plastic collapse and interfacial failure is governed by crack. Failure of a spot weld occurs when at least the fracture criterion for one of the mechanisms is satisfied first.

VI. CONCLUSION

In the review, it was observed that the common input parameters affecting the strength of multiple spot-welded joints are spot welding pressure, current and weld time. The spot welds withstand much better shearing forces than normal forces. Also the spot weld can rupture in two modes. Nugget pullout failure which occurs in stronger joints and interfacial failure occurs in weaker joints.The survey clearly manifests thatAluminum material is much preferred for spot welding in automotive industries because of its higher thermal and electrical conductivity and a good tensile strength. Due to these properties, spot welding of aluminum requires much higher tip forces and higher welding current but takes one-third the weld time of steel.

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