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Process Parameter Selection for Resistance Spot Welding Through Thermal Analysis of 1mm Stainless Steel

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Abstract - *Resistance welding process is applicable for joining electrically conducting aerials, the joint s are made by raising the temperature of the weld zone and the parts together during the plastic stage. Spot welding projection welding seam welding and upset butt welding are all basically resistance welding, the difference are mainly in the geometrical arrangement of parts. In all these cases the heat required to raise the temperature of the metal is generated due to the passage of electrical current through the joint. 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. The difficulty of RSW parameter setting leads to inconsistent quality between welds are the welding current, electrode, force, and welding time. No fillers are required therefore the process is cheaper, neater and faster than most of the other methods of metal joining. For this simulation performed 3 Cases in Ansys.*

Key Words: Welding Time, Hold Time, Squeeze, Current Source.

1. INTRODUCTION

Resistance spot welding (RSW) might be a plan where arriving at metal surface centres are joined by the warm got from protection from electric flow. It could be a subset of electric obstruction welding. Work-pieces are held together underneath weight applied by anodes. Customarily the sheets are inside the 0.5 to 3 mm (0.020 to 0.118 in) thickness expands. The technique occupations two shaped copper amalgam cathodes to pack welding current into a bit "spot" and to simultaneously brace the sheets together. Obliging a colossal current through the spot will condense the metal and structure the weld. The charming feature of spot welding is that a piece of essentialness can be passed on to the spot in a terribly short time (around 10–100 milliseconds). That licenses the welding to occur without over the top warming of the extra segment of the sheet [1]. The aggregate of warm (imperativeness) passed on to the spot is chosen by the obstruction between the terminals and the significance and term of the current. The whole of essentialness is picked to arrange the sheet's texture properties, its thickness, and kind of cathodes. Applying too little imperativeness won't mellow the metal or will make a dejected weld. Applying also much imperativeness will relax too much metal, release fluid texture, and make a hole rather than a weld. Another feature of spot welding is that the imperativeness passed on to the spot can be controlled to convey strong welds [2].

2. Seam Welding

For manufacturing leak tight drums and similar items the method used is seam welding. Electrodes are rotating wheels the speed of which is adjustable. A series of overlapping welds are made. Typical timings are 2 cycles on followed by 2 cycles off and periods. Heavy current 100-500 amps are therefore required to be switched at the rate of 10-20 times a second and an electronic device is absolutely necessary. There are several products which are produced by this type of welding.

2.1 Weld Time

A very important requirement of spot welding is that the welding current is delivered to the job only for a very short time, typical timings are only about 0.1sec to 3 sec. Precision welding of highest quality are done with a timing less than 1sec therefore the unit of time preferred by the industry is the cycle. One cycle corresponds to 1/50th of a second when referred to the power supply frequency of 50 cycles per second. In simple machines an electromagnetic contactor is kept energized or a time period suited to each requirement. The contacts of this contactor connect the primary of the welding transformer to the power supply. The timing period is determined by the settings of a variable resistor through which a capacitor is charged to a predetermined level [3].

2.2 Current Source

The source of current is in general a special step-down transformer. The primary side of this fed from the power supply. In small machines up to about (5kva) the transformers are designed to work from 220 volts ac. In case of larger machines, the power is fed from 2 lines of a three phase 440 volts system. Another type of power source employed consists of a regulated dc supply which is momentarily connected to a pulse transformer. Since any machine should be adaptable for different jobs, normal type of resistance welding transformer is provided with a number of taps on its windings. The secondary voltage is thus adjusted depending upon the job to be weld [2].

3. Literature Review

D. W. Dickinson et. al. [1] A symptomatic thermoelectric model has been made to foresee improvement of the piece geometry, similarly as to analyze the temperature scattering in the weldment. It considers the effect of the thermoelectric collaboration at the weldment interface on the internal warmth age, which has been a critical hindrance in spot welding warm assessment. Considering this model of time direct of the temperature field in the weldment, piece broadness advancement and lump invasion have been numerically gained by methods for ADI and SOR plans. To affirm these descriptive results, a movement of examinations was performed under a comparative welding" conditions used in the assessment.

Euiwhan Kim and Thomas W. Eagar [2] Constrained part showing and examination can give keen information regarding the weld piece advancement process, yet what's more the relations between weld quality, welding conditions and anode movement traits. The weldability window subject to the augmentation movement qualities gives a consistent control basis. For example, piece discharge or little lump can be foreseen by the dynamic migration history, most extraordinary anode dislodging, or expansion evacuation rate. This has involved a base for in process weld quality watching.

H. S. Cho and Y. J. Cho [3] A 2D logical model of RSW process has been made to think about the transient warm lead and to predict the temperature scatterings as a segment of time and territory for any circumstance in the weldment using the FEM. The model considers electric and warm conduction in the solid, convection of cooling water and encompassing air, inert warmth of blend on account of solid liquid stage change, and material properties as components of temperature.

C. L. Tsai et. al. [4] The lump sizes of restriction spot welding for three bits of top-notch steel Sheets are assessed by investigates various roads in regards to differing welding streams and unmistakable welding current cycles. Piece advancement process is repeated with an OK precision for various spot-welding conditions. Least welding current cycles for lump improvement and weld proficient conditions can be definitely foreseen by FEM re-enactment.

H. Zhigang et. al. [5] The trial results show that the correct segment of the info parameters are: medium current, medium weight and high holding time. The reaction of S/N proportion as for elasticity demonstrates the welding current to be the most noteworthy parameter that controls the weld rigidity where's the holding time and weight are nearly less critical in such manner.

Piyush Jain et. al. [6] System parameter decision of impediment spot welding through warm examination for 2 mm CRCA sheets is finished using SYS weld. The effect of current and time is focused on the nature of weld joints. It is seen that the perfect idea of weld quality for 2mm CRCA sheet is looked for 3928 and 0.3 seconds. Piece width regard from entertainment and preliminary path are in palatable range. From multiplication it will in general be seen that HAZ remains around 5mm from the point of convergence of the rotate. Metal vacillating is found in preliminary path of PSet05 and PSet06 as a result of overheating of the joint.

M. Hamedi, H. Pashazadeh [7] This test relied upon the smoothing out of spot-welding process parameters to find the best flexible shear nature of the spot welded joint. The smooth steel sheets of 0.8 mm and 1 mm of estimations 25 mm × 150 mm have used as the work piece. The Taguchi Method of L18 balanced bunch has used to play out the assessment. All the models are spot welded using the taguchi plan of assessment. By then the flexible shear nature of work pieces is found using a tractable testing machine. A perfect parameter blend for the most outrageous malleable shear quality was gotten by using the examination of Signal-to-Noise (S/N) extent.

MA Ninshu and Murakawa Hidekazu [8] Check Spot welding process mainly depends upon process parameters (e.g., welding current, weld time, terminal force) , material parameters (for instance types, thickness). Most of the parametric assessment has been done by thinking about the three system parameters, for instance, weld time, applied force and squash time and weld quality has been evaluated with respect to the individual properties, for instance, flexible shear quality, versatile strip quality, etc.

Yanjun Xiao et. al. [9] In this work the strip test is performed to understand the spot weld quality and constrained segment assessment is cultivated for different mix of various materials (copper-aluminium, treated steel-aluminium, tempered steel-copper, solidified steel-delicate steel) stress regards are procured .tempered steel-aluminium have low weight regard. From the warm examination treated steel-smooth steel have low temperature.

Jan Vinas et. al. [10] The work presented here is a diagram of progressing works of Resistance Spot Welding (RSW) technique and future references. From above discussion it will in general be deduced that the block welding process is particularly rely upon the methodology parameter, for instance, welding current, weld time, terminal force. Some investigation papers in like manner contemplated that with usage of Taguchi system and ANOVA there is augmentation in versatility. In spot weld extending welding current, forms the lump size and at any rate growing welding current doesn't extend the hardness appointment. The weld time and welding current augmentations have come about separations across increment at the welded zones.

Nachimani Charde [11] This contains the assessment and smoothing out of welding parameters during spot welded SS 304 on steel sheet. The level of noteworthiness of the welding parameters during malleable test is directed by ANOVA procedure. This gives the results of various incredibly feasible parameters similarly as connection between them, while Pressure was observed less ground-breaking factor. Improvement has been done on the parameters for the most outrageous tractable shear quality by using the examination of sign to-uproar (S/N) extent.

Ladislav Kola et. al. [12] The idea of spot welding depends on the proportion of versatility required to break the joint or to break the piece. This preliminary moreover achieves the perfect system parameters to stimulate the most outrageous tractable shear of spot welded joint. To play out a blend of different parameters, the Taguchi L9 balanced show has been gotten to play out the investigation. The delicate steel case of 1.2mm*25mm*250mm and 1.5mm*25mm*250mm are used as a work piece. By then tractable shear quality is controlled by the comprehensive testing machine of each test. The perfect parameters blend is found using S/N extent. The result got shows that it is possible to augment flexible shear quality by using suitable parameters. At different parameters, there will be various versatility regard. With the objective that perfect mix of parameters is basic to achieve most extraordinary flexible shear quality.

Matsushita Muneo et. al. [13] In this paper, we portrayed the activities to build up a profoundly accurate spot-welding FEM investigation framework dependent on a steadily coupled examination technique between the electric, temperature, and stress fields considering the stage change and stage change. The innovation accomplished high precision forecast of the chunk development for any sheet get together under any welding conditions.

Carlos Frederico et. al. [14] The goal of the survey article has been expected to report crafted by different specialists for improving Nugget width and Tensile Strength during Resistance Spot Welding and to overcome any issues between the immaculate regions. The work introduced here is a review of ongoing works of Resistance Spot Welding procedure and future references. Material like hardened steel and aluminium. Be that as it may, the work has been done distinctly for restricted materials not for other material. The writing above uncovers that the parcel of endeavors was taken so as to defend the RSW procedure. RSW process trial work has been done by scientists for process parameters like welding current, welding time and crushes time and hold time, Electrode Pressing power, terminal geometry, the decision of cathode material.

Yanhua Ma et. al. [15] This assessment reviewed the moulding, viewed the blend furthest reaches of obstacle spot welds on a press setting steel 22MnB5, using stage field showing and test recognitions. Microhardness mapping parts with a from of a mellowed territory at as far as possible, yet metallographic assessments and hardness estimations don't allow us to evidently perceive _-Fe and martensite, and thusly further preliminaries using transmission electron microscopy are essential to probably check possible this theory. No proximity of aluminium could be perceived by EDX estimations in the lump or at as far as. Along these lines, it doesn't accept any activity in the _-Fe course of action at the blend furthest reaches of Al– Si-secured steel.

4. Result

Using filtered articles and authentic data of construction industry we got data. Collected authentic data like materials properties, boundary conditions, loading conditions, resistance spot welding machine specifications, 3D Modelling data, analysis data from the articles

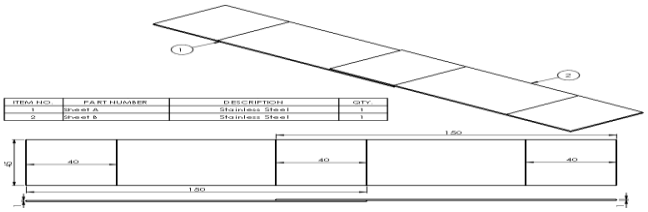

Fig -1: Work piece Dimensions.

Solidworks software mostly used software in industry [16-17]. In software available commands for creation of 3D model such as line, arc, trim, rectangle, circle, smart dimension, extrude boss and extrude cut etc. Using these commands created 3D model of Setup for resistance spot welding analysis of 1mm stainless steel sheet metal as shown.

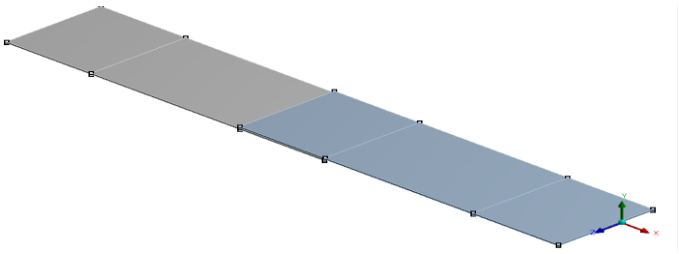

Fig -2: Work piece Dimensions.

Ansys so for that this file converted in .iges format. IGES can be importing any 3D modeling and any FEA software as shown.

After converted in IGES format imported in Ansys Workbench 15.0. After imported in Ansys applied meshing using fine relevance center quality of element. Meshing means a complex body divided in known formula body that is simple. This meshing created using 10 node tetrahedral elements. This type element has 10 nodes and each node 3 degree of freedom it means this type have 30 degree of freedom

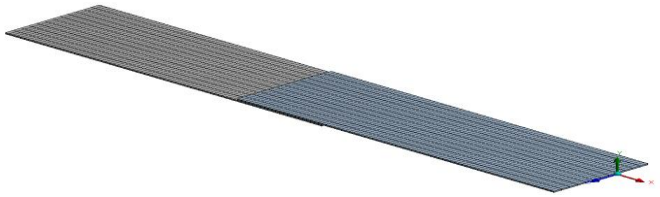

Fig -3: Work piece Dimensions.

4.1 Boundary Condition

After applied meshing proceed to apply boundary conditions and load conditions according to resistance spot welding standard parameters. In loading conditions comes force and pressure. In boundary conditions comes type of support applied on work piece such as fixed, roller and pin support etc. Applied temperature of work piece according to resistance spot welding machine for 1mm stainless steel work piece. Atmospheric temperature applied 27º C and also applied atmospheric convection parameters.

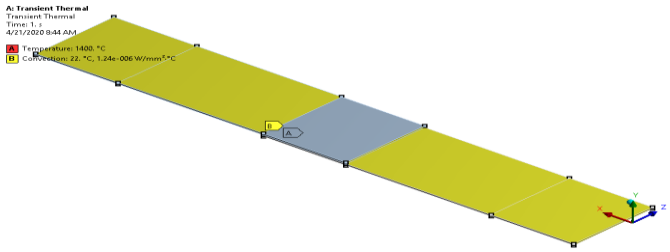

Fig -4: Loading Conditions.

4.2 Experimental Investigations

Simulation done using Solidworks and Ansys, after this process got results. For the validations did same analysis physically using spot welding machine. This physically testing completed with all same data as used in software simulation. System need to meet all our above specification from Clause 1 to 19 and bidders have to grant factor-to-point replies in opposition to all of the points of our above specification enclosed failing which their provide might not be taken into consideration. For this analysis created two sheet of stainless steel. Each plate have 105mm length, 45mm width and 1 mm thickness. These plates assemble with 35mm distance as lap joint. After these all mates and relations between plates, total length of assembly will be 175mm. 3D model created using Solidworks. Solidworks developed by Dassault systems company in 1993. Dassault systems is USA based company. Solidworks is very user-friendly software, this software can also use beginner.

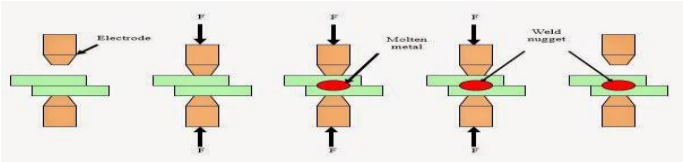

Fig -5: Steps of Resistance Spot Welding Process.

5. RESULTS

For thermal analysis there is no need to apply any type support for stability of body. After applied all boundaries and loading conditions proceed for solution so for the solution applied solve command. After solve Ansys generate results such as temperature distribution with time and thermal flux with time. Numerical Calculations are carried out for evaluating nugget diameter, area, volume and mass. The calculations are for 1mm sheet metal only. The material properties of the selected Stainless-Steel sheet are obtained according AISI 304, which is provided in Table 1 below.

Table -1: Material Properties

Sl. No.	Property	Description
1	Specific heat	502 kJ/kg-°C
2	Density	7896 Kg/m^3
3	Melting Temperature	1534ºC
4	Sheet Thickness	1mm
5	Elastic Modulus	193 Mpa
6	Poisson's Ratio	0.25

It is observed from the literature and simulations, is that shorter weld time and current will not have sufficient time to heat up the interface region between the sheets to achieve the melting temperature, thereby reducing the weld strength at the joints. And when welding current is too high due to overheating at weld joints it will results in strength at the joints. And when welding current is too high due to overheating at weld joints it will results in expulsion. Considering these two limitations, a full factorial DOE is designed for conducting the numerical analysis.

DOE techniques enable to determine simultaneously the individual and interactive effects of many factors that could affect the output results. DOE also provides a complete insight of interaction between variables. DOE helps to pin point the sensitive parameters which causes problems in experiment. The number of variables selected for the DOE are current and weld cycle. To have a wider range, weld cycle of 3 set i.e. 0.3, 0.4 and 0.5 seconds are selected; along with 3 set of secondary current i.e. 1886A, 2075A, 2234A, 2371A.

A full factorial method of DOE covers all combination of input variable which affect the output process. In this study 3 sets of full factorial DOE are constructed. It can be notice from Table No. 2 four set is available with 0.3, 0.4, 0.5 seconds. As taping 1,2,3 qnd 4 have 1886, 2075, 2234 and 2371 A currently respectively. Thus 4th taping from the Table No.2 is not considered for generating DOE table.

5.1 Simulation

Spot welding module of Ansys Workbench 15.0 is used for simulating the spot welding. These simulations help in analysing the effect of input variable on output results. In particular, the effects of input variable such as current, electrode force, holding time are studied through thermal analysis. Using Ansys completed analysis of 3 cases as those in Table 2. In this analysis, the following outputs are available.

Table -2: Final Outcomes

Description	Case A	Case B	Case C
Current (A)	2234	2234	2234
Frequency (Hz)	50	50	50
Force (N)	2000	2000	2000
Application Cycle (Seconds)	.3	.4	.5
Each Sheet Thickness (mm)	1	1	1

5.2 FEA Result

According standard applied all input for FEA analysis using Solidworks and Ansys. After solve results generated results by Ansys such as temperature distribution and thermal flux. These results have maximum values and minimum values with magnitude. Ansys workbench have so many of modules for analysis. Using Transient Thermal analysis completed this study. In this modules available temperature, convection, radiation, heat generation etc. option for apply inputs. Ansys Workbench software also standard inputs that can be use for any analysis these all inputs are authentic by Ansys company. Ansys is also known as Analysis of systems. This is full form of Ansys software. This company is USA based company.

5.3 Experimental Result

After applied all available and required inputs by Spot Welding machine on workpiece same as Ansys simulation. For CASE A applied inputs for .3 sec, for CASE B applied inputs 0.4 sec and for CASE C applied inputs 0.5 sec respectively shown. CASE A spot area generated proper not more and not less but in CASE B and CASE C generated more spot area. Due to big Spot area material got extra melt as in CASE B and CASE C, due to this material got improper joint.

5.3 CONCLUSIONS

After simulations using Ansys workbench 15.0 results has been generated. In simulation analysis done for 3 cases after comparison and discussion some conclusions comes by this study that are following:

- Observed that the optimum quality of weld strength for 1mm stainless strain sheet metal is observed for 2234A and 0.3 seconds.
- Design tools like Ansys is very helpful to do like this study.
- In Experimental results CASE A gave proper results as compared to CASE B and CASE C.
- During Covid 19 Lockdown, Normal Researcher or student can not use laboratory and Mechanical workshop for testing and inspection of welding setup but using Ansys this is very easily complete analysis.
- Maximum temperature generated in welding 1550 ºC and minimum temperature 22.021 ºC.

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