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Optimization of Process Parameters of Spot Welding of CRCA Steel

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Abstract- **Spot welding or specifically resistance spot welding is one of the most popular welding in sheet metal sector in automobile industry. It is one of the oldest of the electric welding processes in use by industry today. Furthermore, other metal-to-metal connections, such as wire-to-wire joints in the electronics industry, are accomplished by resistance spot welding. The main advantage of this welding is that the material joined by spot welding has smooth appearance and strength as compared with other welding process. The problem associated with spot welding is weakening of weld spot that is the strength of the weld get reduced due to some input parameters. The aim of this research is to determine the most significant parameter that affect the strength of the welded joint or spot. In this research work, Stainless steel is used as working material. In this research work, total 9 samples are prepared and their strength is measured on universal Tensile Machine. The significant parameter is found out by using response surface methodology and the optimized parameters are validated by taking confirmatory test. All the spotting work is conducted on KIRTI spotting machine (SPM) with a copper electrode.**

Keywords- **Spot Welding, Electrode, Resistance, Tensile Machine, Optimized Parameters.**

I. INTRODUCTION

Resistance spot welding is getting significant importance in car, bus and railway bodies' etcetera due to automatic and fast process. The major factors controlling this process are current, time, electrode force, contact resistance, property of electrode material, sheet materials, surface condition etc. the quality is best judged by nugget size and joint strength. A general introduction for principle working and parameters of spot welding is given below.[1]

The amount of heat (energy) delivered to the spot is determined by the resistance between the electrodes and the magnitude and duration of the current. The amount of energy is chosen to match the sheet's material properties, its thickness, and type of electrodes. Applying too little energy will not melt the metal or will make a poor weld. Applying too much energy will melt too much metal, eject molten material, and make a hole rather than a weld. Another feature of spot welding is that the energy delivered to the spot can be controlled to produce reliable welds. Projection welding is a modification of spot welding. In this process, the weld is localized by means of raised sections, or projections, on one or both of the work pieces to be joined. Heat is concentrated at the projections, which permits the welding of heavier sections or the closer spacing of welds. The projections can also serve as a means of positioning the work pieces. Projection welding is often used to weld studs, nuts, and other screw machine parts to metal plate. It is also frequently used to join crossed wires and bars.[2]

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. 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.[3].The electrodes are retracted after each weld, which usually is completed in a fraction of a second. Spot welding is the most widely used joining technique for the assembly of sheet metal products such as automotive assemblies, domestic appliances, home furniture's, building products, and enclosures and, to a limited extent, aircraft components.

The attachment of braces, brackets, pads, or clips to formed sheet metal parts such as cases, covers, bases, or trays is another common application of RSW. Major advantages of spot welding include high operating speeds and suitability for automation or robotization and inclusion in high-production assembly lines together with other fabricating operations. With automatic control of the current setting, timing, and electrode force, sound spot welds can be produced consistently at high production rates and low unit labour costs using semi-skilled operators. Most metals can be resistance spot welded if the appropriate equipment is used coupled with suitable welding conditions. This is particularly true for thin sheet or strip steel products, whether uncoated or coated.

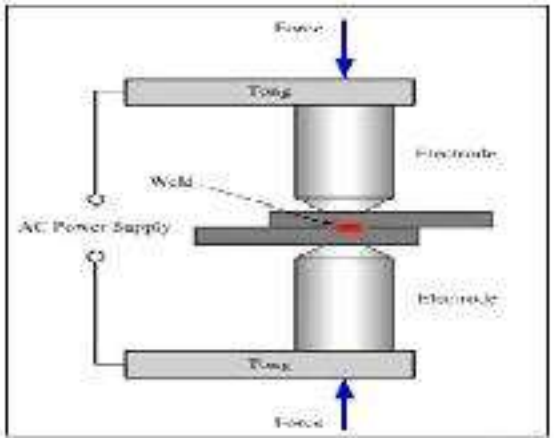

Fig.1. Spot welding operation

Spot welding is a resistance welding procedure and is a method that does not require shielding gas. The workpieces to be joined are placed on top of each other precisely in the first step. Two electrodes press the two workpieces together mechanically and fix the parts to be welded. By supplying a strong voltage, a flow of current is generated between the two electrodes. The workpieces represent a resistance for the flowing current. This causes the metal to heat locally sufficiently to liquefy. The mechanical pressure of the electrodes causes the two workpieces to fuse together and after cooling they are inseparably joined. Resistance spot welding (RSW) is a process in which contacting metal surface points are joined by the heat obtained from resistance to electric current. It is a subset of electric resistance welding.[4]

II. MECHANISM OF SPOT WELDING

The objective of the RSW process is to generate heat rapidly in the joints of the material being welded while minimizing conduction of heat to cooler adjacent material. This heat generation can be expressed by,

$$Q=I^{2}Rt.$$

Where Q is the heat energy in joules, I is the current in amperes,

R is the resistance in ohms, and t is the time in seconds.

The series of resistances is contributed by the secondary circuit resistance. The resistance transformation of the material work piece affects the melting temperature in the spot weld in the RSW process and the weld ability of the material. Optimal electrode force is needed for the explosive solutions during material smelting, while the intensity of the electric welding current is an important factor that affects heat generation leading to smelting. When the electric intensity is high the spot weld will also have intensive heat. This will affect the nugget size and strength of the weld joint. The nugget size and weld joint strength depends on the resistance and welding time, so the welding duration influences the mechanical properties of the weld joints. Melting occurs as a result of the relationship between welding current, welding time, and electrode force, is welding current, is welding time, and is electrode force. Researchers have studied the relationship of the RSW parameters and confirm that the welding process parameters have a great influence on the weld quality. In addition, the resistance of the material due to the thickness of the work piece is also important, as can be seen in greater nugget growth in thicker pieces than thin pieces. In different materials, a satisfactory nugget will be generated in high resistance materials or materials with lower thermal conductivity. [5]

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. The equipment used in the spot welding process consists of tool holders and electrodes. The tool holders function as a mechanism to hold the electrodes firmly in place and also support optional water hoses that cool the electrodes during welding. Tool holding methods include a paddle-type, light duty, universal, and regular offset. The electrodes generally are made of a low resistance alloy, usually copper, and are designed in many different shapes and sizes depending on the application needed. The two materials being welded together are known as the work pieces and must conduct electricity. The width of the work pieces is limited by the throat length of the welding apparatus and ranges typically from 5 to 50 inches (13 to 130 cm). Work piece thickness can range from 0.008 to 1.25 inches (0.20 to 32 mm). After the current is removed from the work piece, it is cooled via the coolant holes in the center of the electrodes. Both water and a brine solution may be used as coolants in spot welding mechanisms.

III. EXPERIMENTAL SET UP

Initially the levels are set by pilot experimentation. In the pilot experimentation, the levels of voltage & current are selected by trial & error method. For minimum voltage & current.i.e, (22KV & 15KA) the weld joint get detached easily by hand. For Maximum voltage & current (24KV & 20KA) the joint get stronger & it get burning mark sign on the weld joint which is not aesthetic & it causes spatter in weld which is considered as rejection as per customer requirement.

From the above condition an average middle level is taken & the array is prepared as per the response surface method. The parameters & levels in the tabular form are as shown below

Table1. Levels & parameters Details

Parameter	Lower	Middle	Higher
Voltage in KV	22	23	24
Current in KA	15	17.5	20

The array is prepared by the use of Minitab software as shown below.

Table 2. Array for response surface method.

Std Order	Run Order	PtType	Blocks	A	B
13	1	0	1	0.0	0.0
11	2	0	1	0.0	0.0
8	3	-1	1	0.0	1.4
3	4	1	1	-1.0	1.0
10	5	0	1	0.0	0.0
12	6	0	1	0.0	0.0
6	7	-1	1	1.4	0.0
9	8	0	1	0.0	0.0
5	9	-1	1	-1.4	0.0
2	10	1	1	1.0	-1.0
1	11	1	1	-1.0	-1.0
7	12	-1	1	0.0	-1.4
4	13	1	1	1.0	1.0

From the above array, the experiments are conducted and the results are obtained and tabulated as follows. In the response surface method, it creates an additional level in the upper 7 the lower side that is if upper level of the parameter is 1 middle level as 0 & the lower level as -1, then response surface method array creates an additional level as +1.4& -1.4.so we have to take an additional upper level for voltage as 250KV & lower level for voltage as 210 KV. In the same manner the upper additional level for the current. The experiments are conducted and the results are plotted in the tabular format as shown in following table.

Table 3. Results of experimentation

A	B	Voltage	Current	Strength
0.0	0.0	23	17.5	71
0.0	0.0	23	17.5	70
0.0	1.4	23	22.5	95
-1.0	1.0	22	20	87
0.0	0.0	23	17.5	68
0.0	0.0	23	17.5	68
1.4	0.0	25	17.5	84
0.0	0.0	23	17.5	68
-1.4	0.0	21	17.5	68
1.0	-1.0	24	15	74
-1.0	-1.0	22	15	72
0.0	-1.4	23	12.5	68
1.0	1.0	23	17.5	71

IV. RESULTS

After the completion of experimentation, the data which is obtained by the experimentation is given as input for the Minitab software. From the software we have received the equation which shows the relationship between the Strength, voltage & current i.e. output & input.

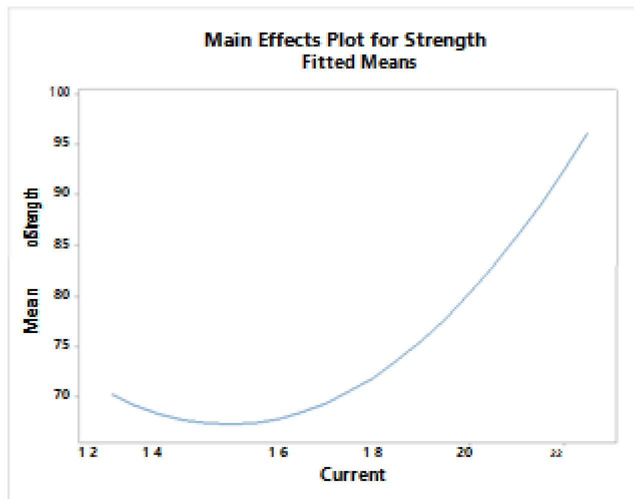

Fig.2. Main Effects Plot between Mean of strength vs. Current.

The figure2 is showing the main effect of plot between mean of strength verses current which is showing the main effect plot for strength for fitted means which is increasing in nature.

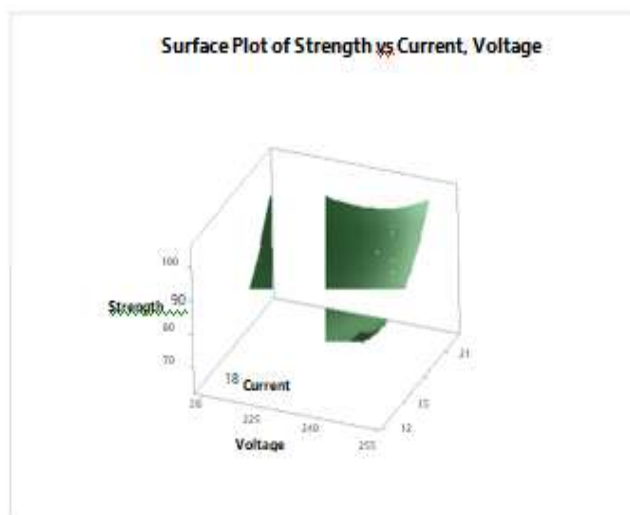

Fig.3. Surface plot of Strength vs. voltage and current

A surface plot can include only two continuous variables. If a model has more than two continuous variables, then Minitab holds each variable that is not on the plot constant. If a model has categorical variables, then Minitab also holds the categorical variables constant. Thus, these plots are valid only for fixed levels of the extra variables. If you change the holding levels, the response surface also changes, sometimes drastically.

In the surface plot obtained after plotting the output against input, it shows that the strength shows higher affinity towards the current.

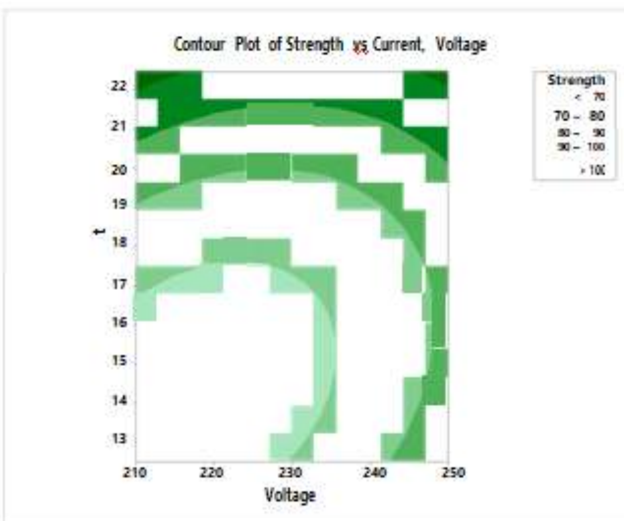

Fig.4. Contour Plot of Strength vs Current, Voltage

The main function of contour plot is that it shows how a response variable relates to two predictor variables. A contour plot provides a two-dimensional view in which all points that have the same response are connected to produce contour lines of constant responses. Contour plots are useful for investigating desirable response values and operating conditions. A contour plot can include only two continuous variables. If a model has more than two continuous variables, then Minitab holds each variable that is not on the plot constant.

V. CONCLUSION

From the analysis obtained from the experimentation conducted in our research work, it is found that the Current is significant parameter in Spot welding of Cold rolled Cold annealed steel. The results are optimized to get strength of the weld joint to a minimum strength of 75 Kilogram. The parameters were optimized & checked analytically.

The optimized setting for CRCA Steel is found to be 21 KV & current of 22.5 KA which gives predicted value of 104 Kilogram. The sample on this setting is spotted& checked for Strength on Universal Testing Machine & the strength was found to be 97 Kilogram. Thus the customer requirement is satisfied by above parameters & spotting is performed on the parameters mentioned above.

VI. FUTURE SCOPE

In our research work we have studied the significant parameters like voltage & current on the strength of the joint. In future, various other factors such as squeeze, hold time, should be taken into account for getting better strength. Also various metals like HRPO, DB series materials can be studied for further investigations.

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