

STATE OF ART IN MODERN RESISTANCE SPOT WELDING

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Abstract:

This paper presents the current scenario of resistance spot welding. It also expresses the gradual improvement of RSW. Which focus the importance of spot welding. Obtaining the satisfactory weld is also explained in this paper. Here we also compare the resistance and temperature distribution. Also the advance spot welding highlighted where dissimilar metals, simulation, automation takes place.

Keywords: resistance spot welding, automation, simulation, electrodes, electrode life etc.

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. [1] 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.[2]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 a localized heating in the part to be joined.

Understanding of physical mechanisms for easily manipulating and controlling weld qualities in advance is important. This seminar report accounts for force, heat generations due to contact resistances at the electrode-workpiece interface and faying surface between

workpieces, and temperature-dependent bulk resistance of the workpiece. The contact resistances are functions of hardness, temperature, electrode force, and surface condition.

Spot welding is a commonly used process for joining metals. Under nominal operating conditions, existing weld controllers can produce high quality welds. In practice, however, the process can significantly deviate from the nominal condition, and thus compromise the quality of the weld. This report also presents an overview of the main contributing factors to the process variation and suggests methods.[3]

WHAT IS RESISTANCE SPOT WELDING?

Spot welding is a process in which laying surfaces are joined in one or more overlapping spots by the heat generated by resistance to the flow of electric current through the work pieces that are held together under force between the electrodes. The contacting surfaces in the region of current concentration are heated by a short-time pulse of low-voltage, high-amperage current to form a fused nugget of weld metal in between the plates being joined. When the flow of current ceases, the electrode force is still retained while the weld metal rapidly cools and solidifies (see fig1). The electrodes are retracted after each weld, which usually is completed in a fraction of a second. Example of resistance welding configuration is shown in

figure.1[4]

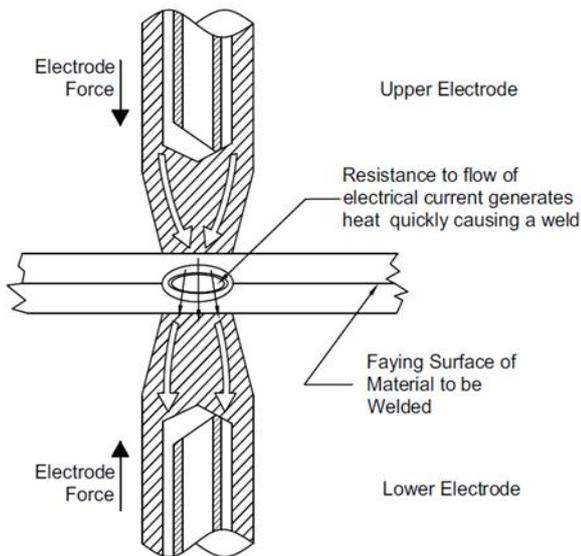


Figure.1 Diagram of resistance spot welding working

HISTORICAL BACKGROUND

The principle of resistance welding was discovered by the English physicist, James Joule, in 1856. In his experiments he buried a bundle of wire in charcoal and welded the wires by heating them with an electric current. This is believed to be the first application of heating by internal resistance for welding metal. It remained for Elihu Thompson to perfect the process and develop it for practical applications. In 1877 Thompson invented a small low-pressure resistance welding machine. Welding was accomplished with this machine by causing the internal resistance in the work piece to generate the heat required to reach its plastic stage. For several years, little was done with this development, since it seemed to have little commercial value. Nevertheless, resistance welding was introduced commercially in the early 1880s as incandescent welding.

REVIEW OF MODERN WELDING PRACTICES

Modern resistance welding is still achieved using pressure and heat. The electrical current creates the heat required to make the welds. Secondary voltage and current are controlled with tap switches mounted remotely or on the transformer. The welding current is controlled by turning a solid-state switch (silicon-controlled rectifier or SCR) on and off. The current is passed through copper secondary conductors, welding arms, and the welding electrodes. In the past, ignitron tubes were used before the invention of SCRs. Today's modern mid frequency DC welding machines use diode packs built into the transformers and insulated gate bipolar transistors in the controls to control the current and convert it into direct current.

RESISTANCE SPOT WELDING PRINCIPLE, CROSS-SECTION & CYCLE

In resistance spot welding, two or more sheets of metal are held between electrodes through which welding current is

supplied for a definite time and also force is exerted on work pieces. The principle is illustrated in Figure 2

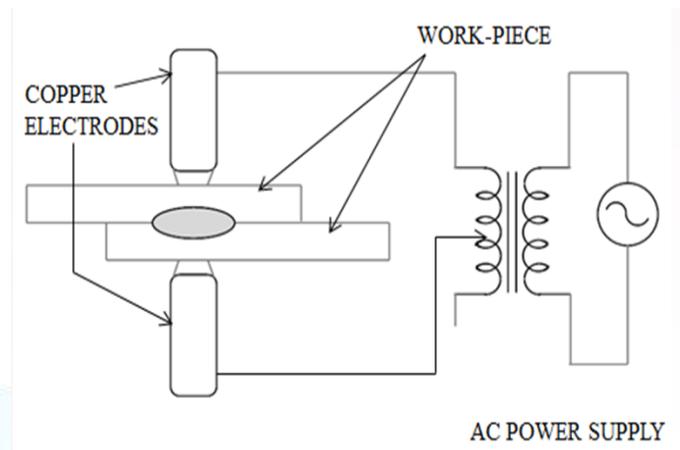


Figure.2 Diagram of resistance spot welding working principle

The welding cycle starts with the upper electrode moving and contacting the work pieces resting on lower electrode which is stationary. The work pieces are held under pressure and only then heavy current is passed between the electrodes for preset time. The area of metals in contact shall be rapidly raised to welding temperature, due to the flow of current through the contacting surfaces of work pieces. The pressure between electrodes, squeezes the hot metal together thus completing the weld. The weld nugget formed is allowed to cool under pressure and then pressure is released. This total cycle is known as resistance spot welding cycle and illustrated in Figure 3.[6]

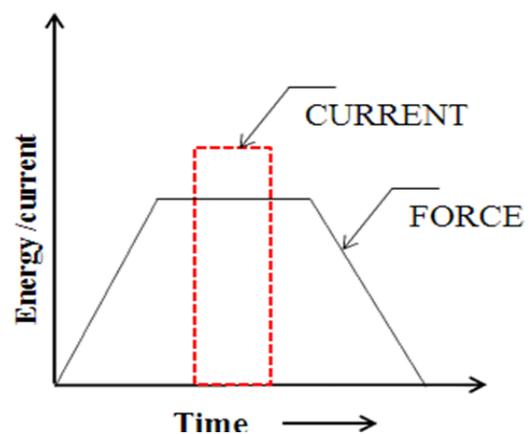


Figure.3 welding cycle

TEMPERATURE DISTRIBUTION

There are, in effect, at least seven resistances connected in series in a weld that account for the temperature distribution. For a two-thickness joint, these are the following:

(1) 1 and 7, the electrical resistance of the electrode material.

(2) 2 and 6, the contact resistance between the electrode and the base metal. The magnitude of this resistance depends on the surface condition of the base metal and the electrode, the size and contour of the electrode face, and the electrode force. (Resistance is roughly inversely proportional to the contacting force.) This is a point of high heat generation, but the surface of the base metal does not reach its fusion temperature during the current passage, due to the high thermal conductivity of the electrodes (1 and 7) and the fact that they are usually water cooled.

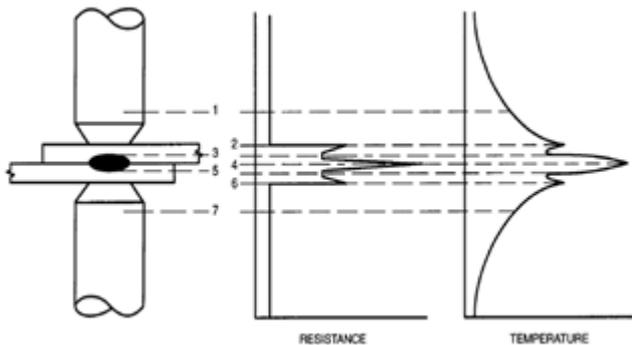


Figure. 4 Resistance and temperature distribution

(3) 3 and 5, the total resistance of the base metal itself, which is directly proportional to its resistivity and thickness, and inversely proportional to the cross-sectional area of the current path.

(4) 4, the base metal interface resistance at the location where the weld is to be formed. This is the point of highest resistance and, therefore, the point of greatest heat generation. Since heat is also generated at points 2 and 6, the heat generated at interface 4 is not readily lost to the electrodes.[7]

WELDING ELECTRODES

Materials for RSW electrodes should have sufficiently high thermal and electrical conductivities and sufficiently low contact resistance to prevent burning of the workpiece surface or alloying at the electrode face. In addition, the electrode should have adequate strength to resist deformation at operating pressures and temperatures. Because the part of the electrode that contacts the workpiece becomes heated to high temperatures during welding, hardness and annealing temperatures must also be considered. Electrode materials for RSW have been classified by RWMA and in International Standards Organization (ISO) standard ISO 5182.

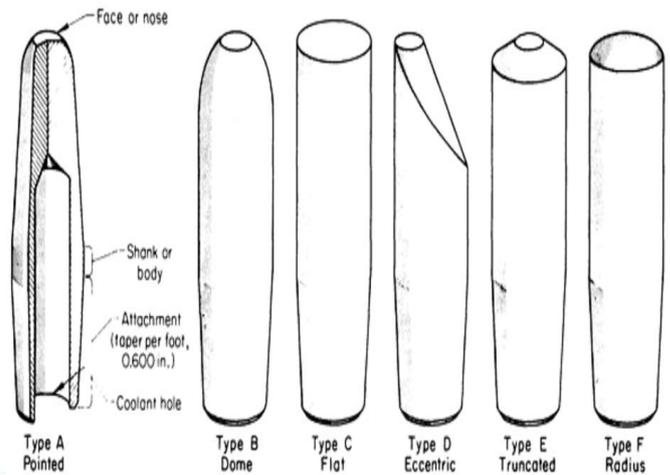


Figure.5 standard welding electrodes

Figure shows the six standard faces or nose shapes, identified by letters A through F. Electrodes with type A (pointed) tips are used in applications for which full diameter tips are too wide. Type D (eccentric, formerly called offset) faces is used in comers or close to upturned flanges. Special tools are available for dressing the electrode faces, either in or out of the welding machine.[9]

ELECTRODE LIFE

The electrode life obtained may be lower than that derived using optimized welding conditions. For example, the electrode life obtained can depend greatly on the type of welding gun used (Fig. 6) or the angle of approach of the electrode. For multiple spot welders, it is essential that all welding stations are balanced electrically and that the same air pressure is supplied to each station. Electrode shape and configuration, water cooling arrangements, and electrode dressing schedules need to be optimized. The last item is most important because satisfactory weld quality can only be provided when the necessary electrode condition and shape are maintained over a production run.

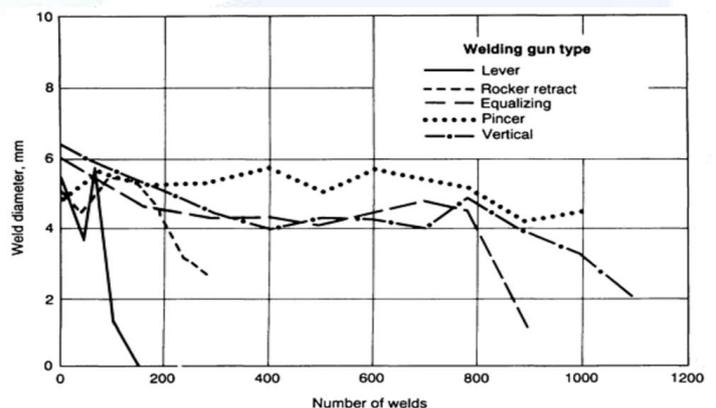


Figure.6 weld diameter and number of welds

ADHESIVE BONDING IN COMBINATION WITH RESISTANCE WELDS AND MECHANICAL FASTENERS

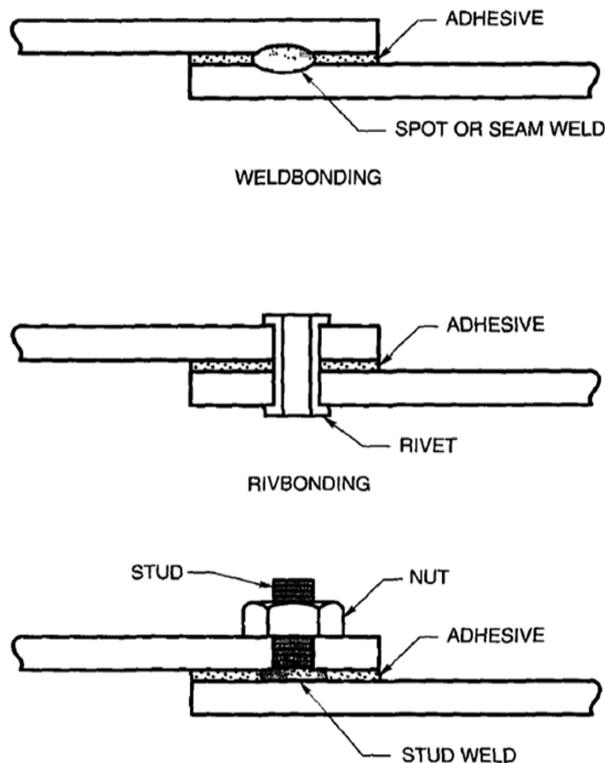


Figure.7 adhesive bonding in combination with resistance welds

Adhesive bonding has several advantages for joining metals when compared to resistance spot welding, brazing, soldering, or mechanical fasteners such as rivets or screws. Adhesive bonding is also capable of joining dissimilar materials, for example, metals to plastics; bonding very thin sections without distortion and very thin sections to thick sections; joining heat sensitive alloys; and producing bonds with unbroken surface contours. The adhesive that bonds the component may serve as a sealant or protective coating. Adhesives can provide thermal or electrical insulating layers between the two surfaces being joined, and different formulations of the adhesive can make the bonding agent electrically conductive. These properties are highly adaptable to mass-produced printed circuit boards, and to the electrical and electronic components industry. Smooth, unbroken surfaces without protrusions, gaps, or holes can be achieved with adhesive bonding. Typical examples of applications are the vinyl-to metal laminate used in the production of television cabinets and housings for electronic equipment. Other examples are automotive

trim, hood and door panels, and roof stiffeners. The ability of flexible adhesives to absorb shock and vibration gives the joint good fatigue life and sound-dampening properties. A specific example is the improved fatigue life of adhesive-bonded helicopter rotor blades.[10]

HOW TO CREATE A SATISFACTORY RSW

Most basic controls set the time and welding amps and the air pressure is set with the remote regulator on the welding machine. An option for most modern weld controls is a built-in force monitor, and with the addition of a programmable regulator, the weld force can be set apart of the weld schedule. Controls can be set to fire based on time, or for fast production times and with the force option, they can be programmed to fire when the weld force is reached. The four elements required to make a satisfactory weld are heat (H) in the work piece, electrical current (I) in the work piece, resistance (R) of the metal being welded, and time (T). The common formula for weld development is $H = I^2RT$. You can vary the heat by changing any of the elements in the formula

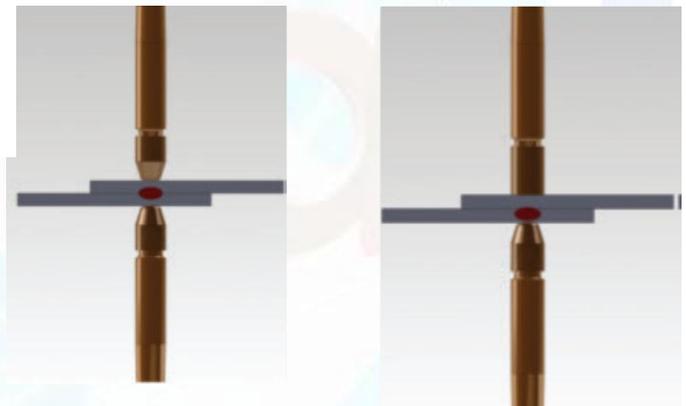


Figure.8 satisfactory weld for ac current

Direct welding, where the current passes from the transformer to a top electrode directly through the material into a bottom electrode and back to the transformer, is the most commonly used process — Fig. 9. When we are unable to back up the work piece or the size or shape of the work piece dictates using a flat backup shunt bar, it is suggested the series welding process be used — Fig. 8. In this case, the two electrodes are connected to the opposite poles of the transformer, and the current passes through the transformer, the one electrode through the work piece into a copper backup shunt bar, then back out to the second electrode and back to the transformer. Series welding is recommended for joining only 18-gauge and thinner materials.[11]

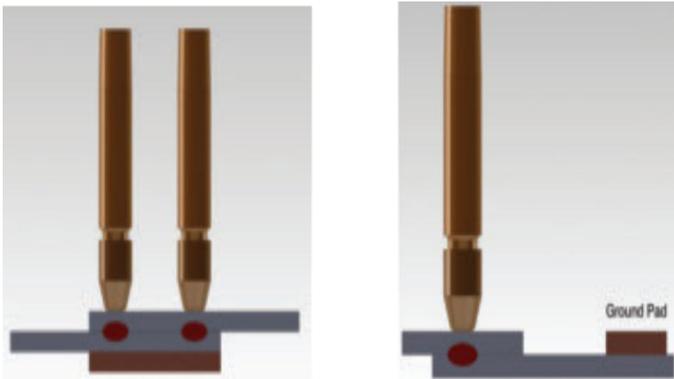


Figure.9 satisfactory weld for dc current

Thicker materials may not allow the current to reach the weld interface and can cause undesirable surface heating. When the material thickness is over 16 gauges, indirect welding is recommended. With indirect welding, the two electrodes are connected to the opposite poles of the transformer, and the current passes through the transformer to one electrode through the work piece into a copper backup shunt bar and back out to a contact gun and back to the transformer.

RESISTANCE SPOT WELDING SIMULATION

Unlike other welding processes, resistance spot welding (RSW) is difficult to directly monitor on the weld nugget development, since melting and solidification processes primarily happen between the workpieces. A common practice is to control the input, such as welding parameters, and monitor the output, such as the attributes of a weld and process signals. However, little is known about the nugget formation process from the input and output. Complexity rises due to the interacting electrical, mechanical, thermal, and metallurgical processes. Numerical simulation (such as finite element analysis) is a powerful tool in this situation. Detailed thermal profile, stress and strain distributions, as well as distortion at various stages can be revealed by numerical simulations. Welding process parameters, such as electrode force, current and welding machine stiffness, can be easily altered using the finite element method to study their influence. To perform a similar study experimentally would be extremely difficult if not

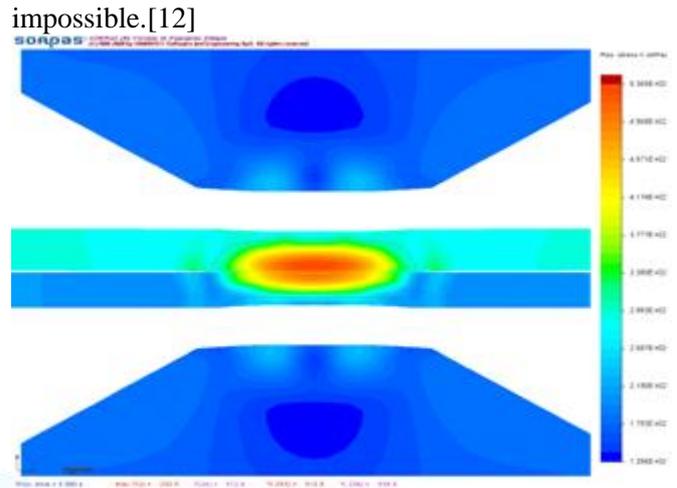
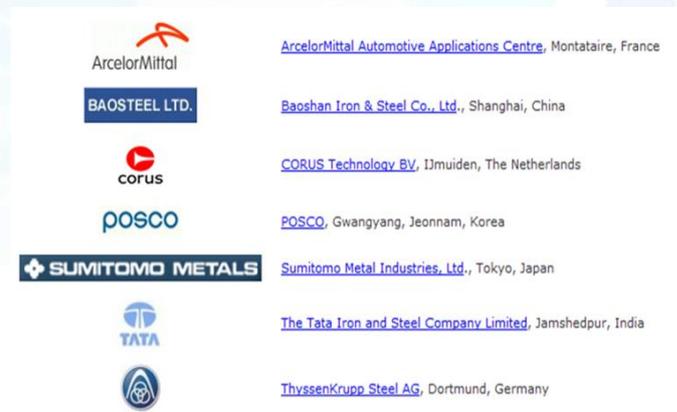


Figure.10 simulation of spot welding

Finite element simulation of resistance spot welding has been attempted by many researchers, and most of the work has been on resistance welding steel. For instance, a commercial finite element simulation package, ANSYS™ was used for simulating resistance spot welding of steel by sequentially coupling electrical-thermal and thermal mechanical processes (Nied2; Tsai et al.3). A small portion of the existing work is on aluminum welding. Computational models were also proposed to study effects of electrode geometry, electrode wear, and thermoplastic constitutive relationship.[13]

There are numbers of software's are used in the simulation of resistance spot welding ie: weldworks by techmatrix, sorpas by swantec, ANSYS etc. which is used by world top automobiles companies.



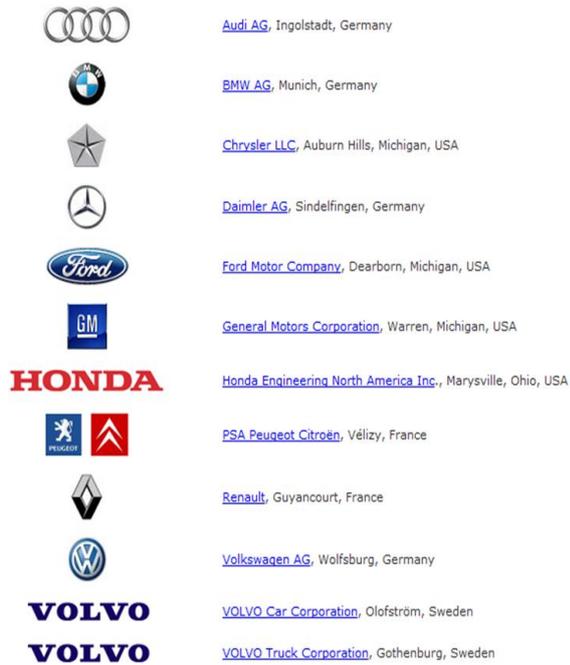


Figure.10 list of few companies who use resistance spot welding simulation

This animated picture shows the simulation result of a complete spot welding process including the compression during squeeze time, the heating and weld nugget development during weld time, the cooling during hold time and off time, the eject of electrodes during off time, and the finally achieved weld nugget size and shape.[14]

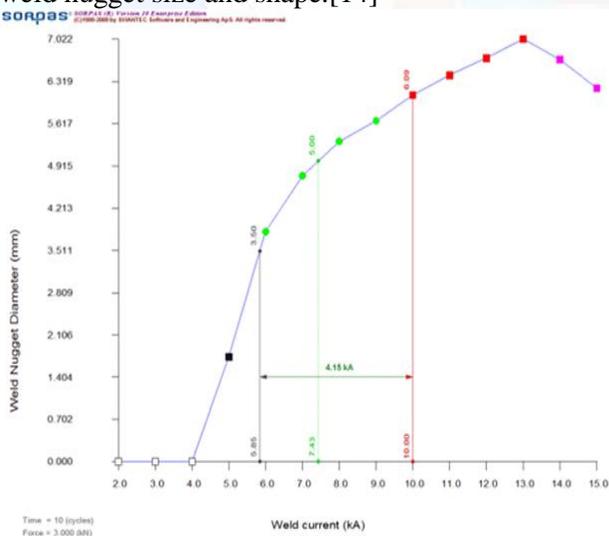


Figure.11 Graph of weld nugget diameter and weld current

AUTOMATION CONTROL

An automated micro/mini resistance spot welding applications in the medical device, aerospace and electronics industries. Which can: Simultaneously weld multiple parts while operator loads/unloads machine

Complete electronic record retention enables Six Sigma Quality Electronic records, data storage, web reports and on-line analysis Precise and repeatable weld head positioning(X, Y, Z axes)



Figure.12 Diagram automation control

CONCLUSION

Resistance spot welding processes are widely used in high production operations, especially in the automobile and in other appliance industries also. It did not required filler material which made it more economic in production field. It is the most suitable for steel & steel alloy but recent researches made it suitable for aluminium and other industrial metals. Modern use of automation, simulation & advance control made it more effective these developments have improved its strength and surface finish characteristic. Computer numeric spot welding machines are able to give high production rate with low cost and reduced manpower. Portable and dc spot welding made it more suitable of any place to perform the welding operation.

REFERENCES

1. Aslanlar S, Ogur A, Ozsarac U, Ilhan E. Welding time effect on mechanical properties of automotive sheets in electrical resistance spot welding. J MaterDes 2008;29:1427–31..
2. Luo Yi , Liu Jinhe ,Xu Huibin, Xiong Chengzhi, Liu lin. Regression modeling and process analysis of resistance spot welding on galvanized steel sheet
3. AWS D8.7: Recommended Practices for Automotive Weld Quality—Resistance Spot Welding, American Welding Society, Miami, FL, 2004.
4. Resistance Welding Pocket Handbook AWS RWPH:2011
5. Jefferson's Welding encyclopaedia 8th addition, ROBERT L. O'BRIEN page no.43
6. Manufacturing Science 2011 M I Khan , Serajul Haque
7. Welding Handbook 8th Edition vol 2 AWS 2000 Welding Processes page no.533-534
8. Resistance welding manual 4th ed., Resistance welder Manufacturing's Association, 1989
9. Recommended practices for automotive weld quality Resistance Spot Welding ANSI/AWS D8.788, American Welding Society,1988
10. Jefferson's Welding encyclopaedia 8th addition, ROBERT L. O'BRIEN page no.8-9
11. Welding Journal September 2012 AWS page no.81-82
12. E Feulvarch et al. Resistance spot welding simulation: a general finite element formulation of electrothermal contact conditions Journal of Materials Processing ..., 2004(Elsevier)
13. DJ Browne et al Computer simulation of resistance spot welding in aluminum. II Welding journal, 1995
14. www.swantec.com/sorpas.php
15. Y Cho, S Rhee New technology for measuring dynamic resistance and estimating strength in resistance spot welding 2000
16. www.techmatrixllc.net
17. ASM Metals Handbook Vol 6
18. Resistance Welding: Fundamentals and Applications 2006, Hongyan Zhang , Jacek Senkara
19. Welding Science And Technology 2009, Md Ibrahim Khan
20. Welding process and technology 2012, R S Parmar
21. CL Tsai, JC Papritan, DW Dickinson, O Jammal Modeling of resistance spot weld nugget growth 1992
22. en.wikipedia.org/wiki/Spot_welding
23. Handbook for Resistance Spot Welding Miller 2012
24. Resistance Welding Manual – Ruukki 2009
25. Resistance Spot Weld CMW-2006