International Journal of Scientific Research in Mechanical and Materials Engineering
© 2019 IJSRMME | Volume 3 | Issue 3 | ISSN : 2457-0435

Defect Assessment of Spot Welding

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ABSTRACT

Spot welding is the welding method that uses the heat generated by the resistance of the material to the electrical current together with the gripping pressure simultaneously. There is no extra external heat source. Heat is produced only on the parts to be welded and pressure is applied by the rocker arms or electrode arms. The high current density is provided by the transformations and the pressure is provided by the hydraulic and pneumatic equipment's. It is the most common form of electric resistance welding as its method is very easy, practical and easeful. Although it is seemed to be very basic, its process is very complex and requires the continuous control of specified parameters. The method may be used for joining sheet to sheet, sheets to rolled sections or extrusions, wire to wire, for sundry special applications using combinations of the above. By far the widest application in industry is the spot welding together of sheet-metal parts, as in the hollow-ware industry (handles to kettles and saucepans) or the automotive industry. For example, the typical car body contains about 5000 spot welds joining a mixture of sheet metal material types and thicknesses. This welding method is very advantageous corresponding to its high speed of operation, hence its adaptability to mass production, its cleanliness, no need for welding rods, and its high degree of control possible by electrical means (i.e., reducing the necessity for a degree of operational skill). The process spot welding involves the joining of two or more pieces of sheet metal in localized areas (spots) where the melting and coalescence of a small volume of material occurs from heating caused by resistance to passage of an electric current. The electric current is carried to the sheets via electrodes that are also used to clamp the work pieces together.

Keywords: Forge and Resistance Welding, Fusion Welding, molten metal cools down, electrode skidding

I. INTRODUCTION

Spot welding is the welding method that uses the heat generated by the resistance of the material to the electrical current together with the gripping pressure simultaneously. There is no extra external heat source. Heat is produced only on the parts to be welded and pressure is applied by the rocker arms or electrode arms. The high current density is provided by the tranformators and the pressure is provided by the hydraulic and pneumatic equipment's.

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II. LITERATURE REVIEW

Donders S. et al studied the effect of spot weld failure on dynamic vehicle performance. The impact of spot weld quality and design for vehicle functional performance also an industrial robustness study is presented that assess the effect of spot weld failure on dynamic vehicle characteristics. The FEA body in white (BIW) structure of vehicle is introduced in the study.

Zhang X. et al 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 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. The total stain life equation is used to predict the fatigue life. 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.

They introduced penalty function to prevent the close spot welding and the boundaries of the plate, which cause effect on optimal characteristics of spot weld.

Moshayedi H.et al investigated the two dimensional finite element simulation of resistance spot welding process is performed using fully coupled electrical, thermal and incrementally coupled thermal and mechanical analysis on steel sheets to predict weld nugget formation through temperature distribution at different welding cycles and current intensities. Finite element modeling is used for investigation of effect of welding current and temperature.

Nacy S.M.et al investigates the study of vibration analysis of stiffened conical shell. Experimental and FEA study is performed for this investigation. The effect of conical shape stiffeners considering its stuffiness, mass, damping factor are studied in details. They described structural and modal analysis of conical shape stiffeners considering effect of spot weld.

Prasad K. et al investigates the study of spot welded stiffeners. This study focuses on effect of spot weld pattern and profiles of stiffeners under the vibration analysis of structures. Both FEA and experimental study are carried out for vibration analysis of plates with spot welded stiffeners. In FEA study, modal analysis method is used to find the natural frequencies of all test structural models. Ls-Dyna and HYPERMESH software are used for FEA study.

To back up the results obtained by FEA study, experimental analysis is done to find frequencies of the same models using FFT analyzer. From the above FEA and experimental results, it is revealed that, the profile of stiffener and weld pattern having much more influence on natural frequencies of the structural model. The structures having less frequency are useful for the application where high excitation frequency and the structures having high frequency are useful for the application where less excitation frequency.

Rusinski E. et al investigates briefly the effect of diameter of spot weld on structural characteristics. The strength of spot welded structures is studied under compression considering effect of diameter and pitch of spot weld. FEA study is also carried on same structures taking into account physical and geometrical nonlinearities.

The strength of spot welded structure is precisely determined under the test of compression. The information regarding structural details including all the parameters of the spot weld are referred for the study of vibration analysis of plates with spot welded stiffeners.

Palmonella M. et al studied two types of the spot weld structures are CWELD and ACM-2. It is shown in this paper that natural frequencies of proposed structures are very sensitive. These structures are mainly useful for many sheet metal applications to optimize the design. In this paper the techniques of model updating in structural dynamics are used to analysis and to improve CWELD and ACM-2 model. Guidelines are given for the model updating and implementation mainly in application of an automotive body in white (BIW) model. It has thousands of spot welds and major influence on the structural dynamics of the whole body. They also studied the effect of spot weld diameter on the dynamics of the spot welded sheet metal structures using FEA and experimental analysis.

III. RESULTS AND DISCUSSION

Evaluating the spot welding parameters and the inspection results for the specimens, i.e. Table 3.1 would take us to many statistical consequences about the spot welding process supporting the theoretical basis. The most considerable ones are given graphically and in brief below.

As seen from the Fig. 3.1, there is a linear relationship between the machine efficiency and the welding current for constant welding pressures and welding times, i.e. the welding current increases linearly with the spot welding machine efficiency (machine performance). Note that, here welding current is determined value, i.e. the output value, measured with a special multimeter capable of measuring the current for a very short time period. On the other hand, welding time do not affect the weld current significantly for constant welding pressure and machine efficiency values (Fig. 3.2).

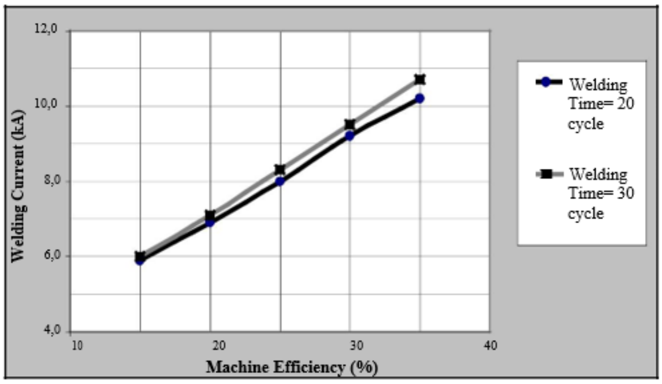


Figure 3.1 Welding current vs machine efficiency for constant welding times (for welding pressure= 4.8 kN)

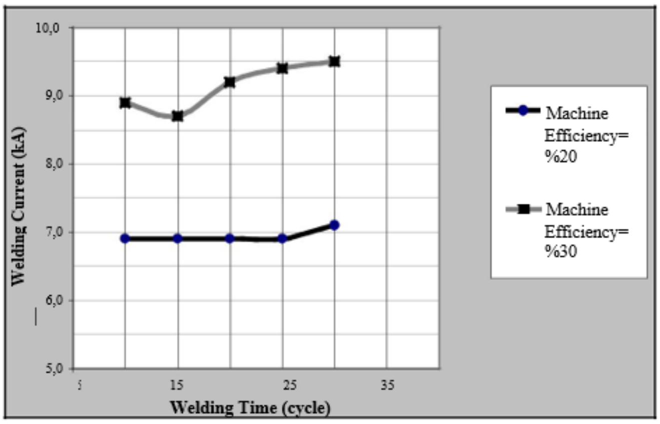


Figure 3.2 Welding current vs welding time for constant machine Efficiencies. (for welding pressure= 4.8 kN)

Furthermore, welding pressure also do not affect the determined weld current value significantly for constant welding time and machine efficiency values as seen in Fig. 3.3.

Consequently, it can easily be understood that the welding current is strongly dependent on the machine efficiency not on the welding time or welding pressure, i.e. one can easily predict the output welding current by assigning the machine performance value, or by other words, machine efficiency is the control mechanism of the output welding current. Hence some of the weld defects resulting from the low or high welding currents can be avoided by means of the machine performance control.

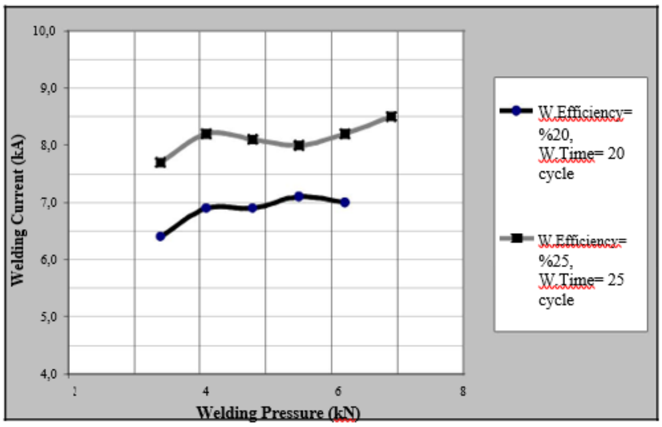


Figure 3.3 Welding current vs welding pressure

In order to understand the effect of welding pressure to quality of spot welding specimens, the statistical study shown graphically in Fig. 3.4 was made. Six different welding pressure values were used during the manufacturing of the spot welding specimens : 3.4, 4.1, 4.8, 3.5, 6.2 and 6.9 kN (Table 3.1).

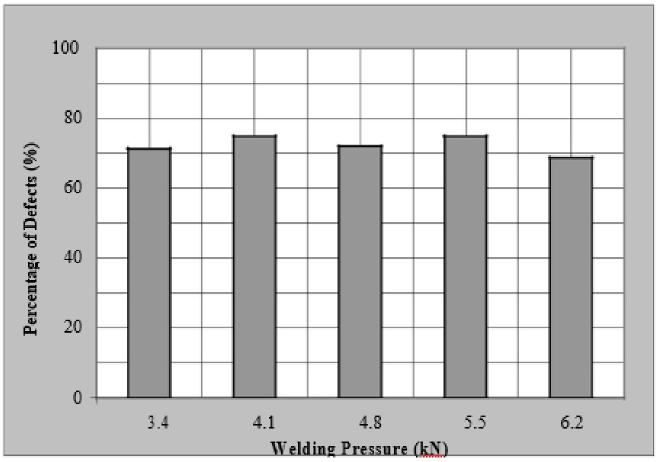


Figure 3.4 Percentage of defective specimens vs welding pressure

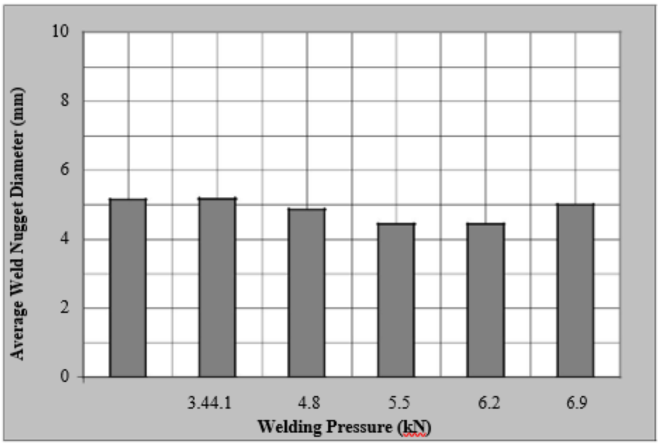


Figure 3.5 Average weld nugget diameter vs welding pressure

The weld nugget diameter slightly decreases with the increasing welding pressure. Here it should be noted that, for lower welding pressure values, the average weld nugget diameter is slightly less than the expected values because of the expulsion of the metal from the weld nugget.

The decrease in the average weld nugget diameter as the welding pressure increases is also due to the effect of welding pressure on the resistance and by the way the heat generated. As lower welding pressures leads to an increase in the heat generated, an increase in the volume of the metal, the weld nugget, that has undergone heating, melting, fusion and solidification is expected. But, this effect is not strict as the effect of the welding current, because of the equation $H = I^2 R t$. In this equation heat is directly proportional to resistance itself but to the square of the current. Hence, as the welding current increases, there is a sudden rise in the average weld nugget diameter. This situation is easily seen in Figure 3.6. But, it should be noted that for the welding current range of 11.1 to 12.0 kA, there is a decrease in the average weld nugget diameter due to the expulsion that is most probable for such a high welding current range. Because of the expulsion of the re solidifying material from the weld nugget, the average weld nugget diameter decreases rapidly.

In order to understand the effect of welding current on the quality of spot welded specimens, the statistical study shown graphically in Fig. 3.7 was made. Seven different output welding current ranges were used during this statistical approach. Note that, here the lower and upper limit output welding current values of a range are included to that range when calculating the number of defects for this ranges from Table 3.1.

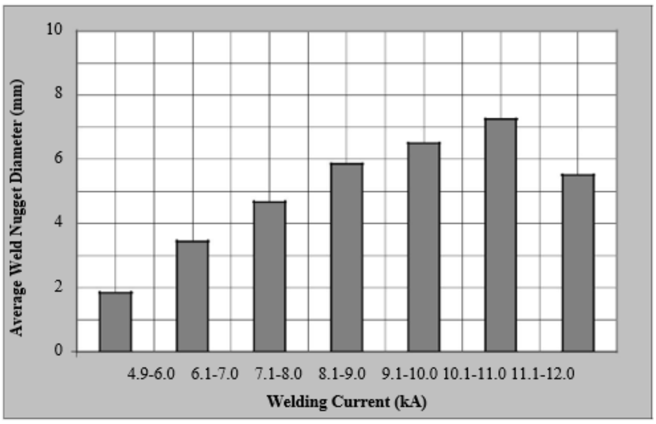
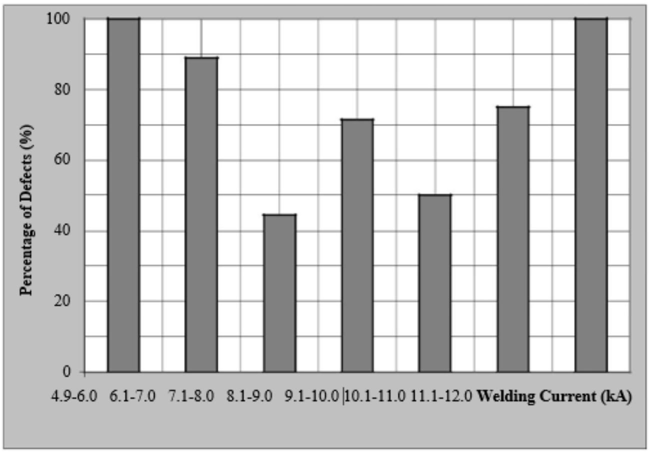


Figure 3.6 Average weld nugget diameter vs welding current (for welding pressure= 4.8 kN)

A high welding current will generate more heat as explained with the Eq. 1.1, resulting in weld issues such as excessive indentation, cracks and holes and expulsion/burn-through. On the other hand, lower welding currents will give rise to the weld issues such as stick welds, undersized welds and poor weld shapes. Thus, looking at the Fig. 3.7, higher percentages of defects are certain for the lower and higher welding pressures as expected by the theory.

Although the least probability of defects is expected for the output welding current range 8.1 to 9.0 kA, a rapid rise in the percentage of defective specimens is seen in for the is seen in Fig. 6.7. This is due to the higher welding times. But, from Table 3.1, it is experimentally shown that expulsion is more severe for higher welding currents (2 of 2 specimens, i.e. 100 % for the range 11.1 to 12.0 kA) as in the theory. On the other hand, stick welds are more probable for lower welding currents (5 of 6 specimens, i.e. 83.3 % for the range 4.9 to 6.0 kA and 5 of 9 specimen, i.e. 53.6 % for the range 6.1 to 7.0 kN).



From the results from Table 3.1, it is clear that the consistency of the ultrasonic test with G15MNX8.0 probe is less than that of the ultrasonic test with G20MNX3.6. This condition arises from the following facts:

- The frequency of G15MN8.0 (15 MHz) is less than the frequency of the G20MNX3.6, i.e. it provides less sensitivity than the other.
- The element diameter and hence the sound beam of the G15MN8.0 probe is wider than the expected nugget size of the weld (5-6 mm), leading to some false indications.

- The coupling of the probe is more difficult and needs more attention to place on the right position of the spot weld indication due to wider diameter.

IV. CONCLUSION

In this study, a procedure which is actually a guideline to the non-destructive inspection of spot welds is aimed to be constituted in order to use the non-destructive inspection methods in a correctly, effectively and perfect manner for different kinds of industries. This study is conducting by using commercially available instruments supporting last technologies.

Various technical approaches have been investigated for non-destructively inspecting spot weld quality. The first method is the visual inspection, the oldest one, which is also used in the application of the other approaches.

It is very efficient for the visible surface of the spot weld, but cannot be used for determining the quality of the weld nugget, alone. Excessive indentation, distortion, surface fusion, surface cracks can be detected visually. But, visual inspection is not sufficient for a reliable defect assessment of the spot welds as seen with the 42 % inconsistency with the torsional test in our study.

For the radiographic testing, its reliability was not found too malicious with 66 % consistency with the torsional test, but it is not economical, practical and easily adaptable solution for spot welding lines. It requires film processing which is expensive and takes long time for film treatment. Nowadays, a new radiographic technique called “real-time radiography” introduced using the real-time images instead of film processing. But this method is not efficient in parts having complex shapes and in spot welding production lines.

Among the others, the leading non-destructive method was found to be ultrasonic pulse-echo technique with at least 70 % consistency (for ultrasonic with the transducer having element diameter of 8.0 mm) with the torsional test. If we add the percentage of spot welded specimens for which torsional and ultrasonic tests give different kinds of defects but both rejects the part, then the consistency will rise to 82 %. Here, it should also be noted that more reliable results can be taken by using a transducer having an element diameter of the desired nugget diameter.

Ultrasonic pulse-echo technique is based upon the transit time and attenuation of the ultrasonic energy. It enables detection of the presence and size adequacy of a weld in the weld zone. Early works point toward the probable success of the ultrasonic pulse-echo method applied through the thickness of the weld nugget. Recent work on transducers will permit extending the method to inspection of thinner spot welds.

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Cite this article as :

Swati, "Defect Assessment of Spot Welding", International Journal of Scientific Research in Mechanical and Materials Engineering (IJSRMME), ISSN : 2457-0435, Volume 3 Issue 3, pp. 01-08, May-June 2019.

URL : http://ijsrmme.com/IJSRMME19331