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Real Time Force Monitoring in Resistance Spot Welding

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***Abstract*— Resistance spot welding has vital applications; its main function is for joining the sheets in automobile companies. Resistance spot welding process parameters are optimized to improve spot weld quality. Real Time Force Monitoring is all about monitoring the actual force during the time of spot welding and to set the required amount of weld force. Resistance spot welding is necessary to improve the quality of spot welds and to measure the force during welding. Experimental studies are conducted under varying force of electrode, welding current flow and its time duration. The resistance spot welding is studied and the spot welding gun used for welding purpose is optimized. The spot welding gun is integrated with the customized high capacity compression load cell. A regular automobile includes more than 3000 spot welds. When the current is passed through the metal sheets, heat is generated due to resistance. This heat is used for melting the metal sheets and to join them together. Resistance spot welding is a high speed process; whereas the actual welding process occurs within the fraction of seconds. It is simple and clean method. It also joins multiple metal sheets together at same time. It has wide application for joining purpose in manufacturing industries, car batteries, utensils and dental purpose respectively.**

Keywords*— Electrode Force, Expulsion, Real Time, Resistance Spot Welding, Spatters

I. INTRODUCTION

In the automobile industry, and the transportation industry, the resistance spot welding (RSW) has been used for decades for the main joining purpose. The method has a low cost, highly reliability, higher time efficiency, high ability for robot atomization and high accessibility compared to all other joining methods, it made an ideal for the automotive production companies. A conventional modern automobile has around 3000 – 5000 resistance spot welds, while other joining methods, such as arc welding, mechanical fastenings and laser welding is used in a much more limited scale. Resistance spot welding in manufacturing industries results highly important for product and their properties, including with the critical properties such as vehicle safety, fuel efficiency and crashworthiness. To ensure robustness in resistance spot welding the applications, variations of process result is minimized. To measure the process robustness and weld quality of RSW, the main measurements are nugget weld size (the lateral size of the solidified joint zone) and the occurrence of weld expulsion. Expulsion is the phenomenon which occurs when molten metal is subjected from the weld. While, the two measurements do not fully measure all aspects of weld quality, they indicate several important factors and are relatively easy to attain them.

Zygmunt Mikno [1] the article presents the process of resistance welding in relation to the expulsion of liquid metal from the weld nugget. The related tests involved the synchronic recording in research of welding process parameters like welding current and electrode force. Xiaodong Wan et al [2] our study aims at developing an effective quality monitoring system in small scale resistance spot welding of titanium alloy. The measured electrical signals were interpreted in combination with the nugget development. Shaik Shafee [3] Resistance spot welding process parameters are optimized to improve spot weld quality. The experimental studies are arranged for varying force of electrode, its time duration and welding current flow. Fan Qiuyue [4] the effects of different expulsion conditions on the dynamic resistance and weld tensile-shear strength under shop expulsion conditions in resistance spot welding were investigated. S. Chen [5] Resistance spot welding is an important branch of the welding subject, and has been widely used in aviation, aerospace, automotive and other industrial areas due to its high efficiency, low cost and small deformation. The improvement due to online monitoring the product quality, of welding has become an urgent issue. Kang Zhou [6] Resistance spot welding (RSW) is frequently employed in current industrial occasions. This paper presents process analysis. It advances the quality control of the RSW operations. High capacity compressive load cell is customized and integrated inside the gun and display unit is attached to monitor the readings during the actual time of resistance spot welding.

II. PROCEDURE

Resistance spot welding is considered as good method for joining the metal parts. These method results expulsions spatters and bad quality of spot weld due to default changes in electrode force. To know the electrode tip force during the time of resistance spot welding it is decided to optimize the gun design with the help of load cell by integrating inside the Nash gun and with the help of digital indicator to display the electrode force. The exact required electrode force during the time of spot welding is obtained. And continue with monitoring the electrode force results gained by display unit and comparing them with previous results obtained by the force gauge.

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A. Customised Load Cell for integrating inside the Nash Gun.

Fig. 1 Customized Load Cell

In above image we can see the high capacity compression load cell is customized in such a manner that it is easily fitted in welding gun. The compression load cell is at the top and copper metal is attached with the help of welding process. This type of arrangement is fitted inside the gun. The requirement behind the customization of load cell is to make the load cell fit inside the area where the linkage of movable shank and piston rod is connected with the help of knuckle joint. After studying and taking the dimension it is observed that the load cell requires particular amount of dimensions to make a proper arrangement inside the gun. The cross sectional area of piston rod hitting the load is calculated. Hence, some amount of clearance is added in the diameter of customized load cell around 15 mm approx. The same dimensions are used for the copper block below the load cell and it is chamfered around 2 mm from all four sides.

B. Optimize the gun design.

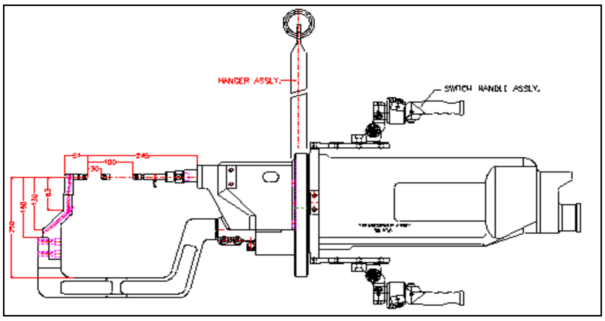


Fig. 2 Gun Design

The Nash Gun is most commonly used for the resistance spot welding in automobile industries. The customized load cell is integrated inside the cover box in between both the shanks where the upper one is fixed and lower one is movable. The gun operates on two phase 415 volts AC supply. Green and Red tubes are connected to electrodes from inside for water in and out for cooling purpose. 5/2 solenoid valve is used as it has two independent exhaust port as it helps to return back the piston rod back to rest position and it is connected with blue wire for air supply with high pressure for the movement of the piston rod which helps the movable shank to move.

C. Experimental Setup

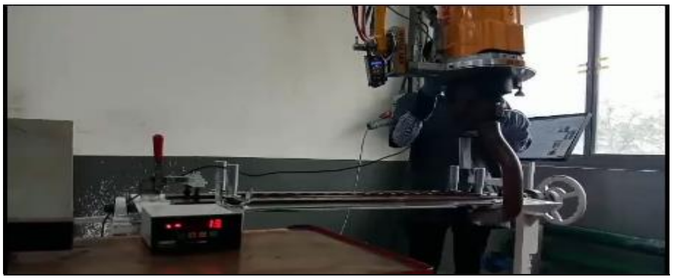


Fig. 3 Experimental Setup

The experimental setup is arranged using two dual phase steel sheets which are kept on each other and held together with the help of C clamps from both sides. The Nash gun is placed perpendicular over the sheet where the spot welding is required. The digital display unit is connected to the Nash gun with the help of connecting wire and placed within the operational area. And the electrode force generated is calculated by using formula,

$$F = PA = P\frac{\pi d^2}{4}$$

Where F is Force, P is pressure, A is area

Table I Results for Electrode Force for Thickness (T-1)

Pressure (N/mm^2)	Diameter (mm)	Force (kgf)
3.77	30.2894	277
3.92	33.4340	351
3.63	35.9139	375
4.45	22.3350	178
3.77	28.9475	253
3.92	28.2166	250
3.63	33.3318	323

From the above table it is seen that at different pressure and different diameter, we get the values of electrode forces thickness (T-1). These values obtained are compared with the previous data available of the process.

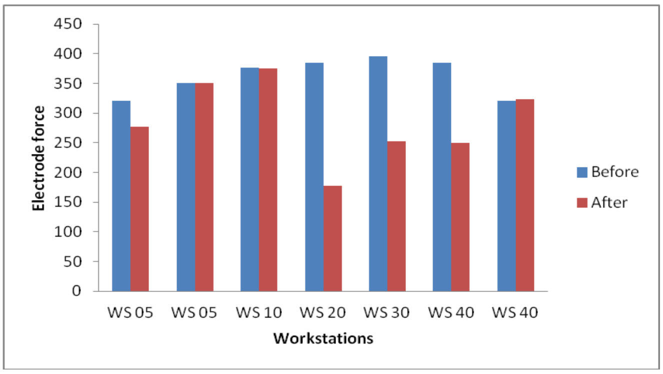
Table II Results for Electrode Force for Thickness (T-2)

Pressure (N/mm^2)	Diameter (mm)	Force (kgf)
3.26	30.2894	240
3.35	33.4340	300
4.24	35.9139	438
4.38	22.3350	175
3.81	28.9475	256
4.36	28.216	278
3.72	33.3318	331

From the above table it is seen that at different pressure and different diameter we get the values of electrode forces for thickness (T-2). These values obtained are compared with the previous data available of the process

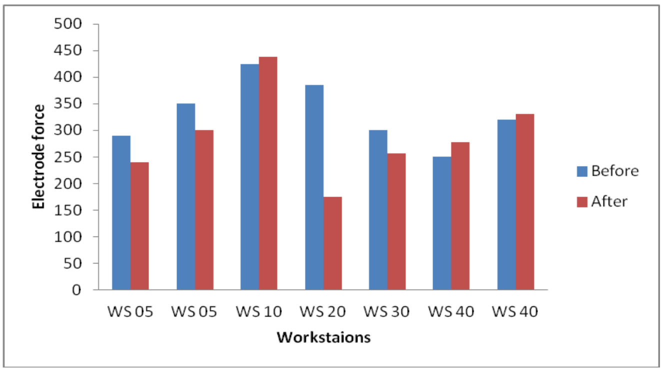
III. Results and Discussions

A. Weld Force Results



Graph 1 Weld Force Comparison for One-T

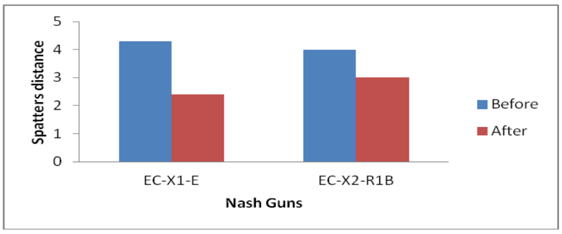
Weld force comparison before & after integration of load cell of ONE-T (sheet thickness) without load cell the weld force we noted was high later after integrating load cell less force is enough at some workstations which results less expulsion and spatters too.



Graph 2 Weld Force Comparison for Two-T

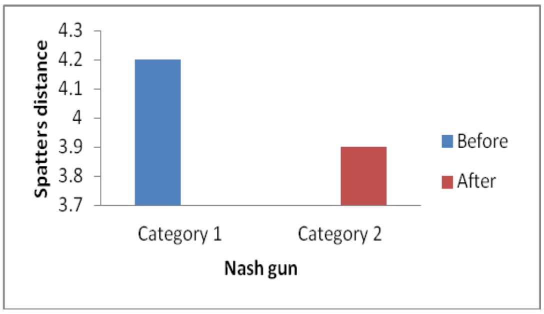
Weld force comparison before & after integration of load cell of TWO-T (sheet thickness) without load cell the weld force noted was high and less on some workstations later after integrating load cell some workstation needs much force and some needed less weld force.

B. Spatters Results



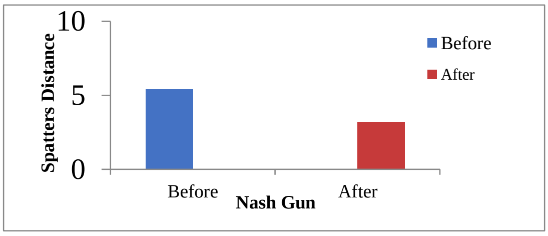
Graph 3 Spatters Result at Workstation 05

These readings are the distance of spatters from the origin of spot welding in which we can see that they are reduced 52% in first gun & 25 % in second gun.



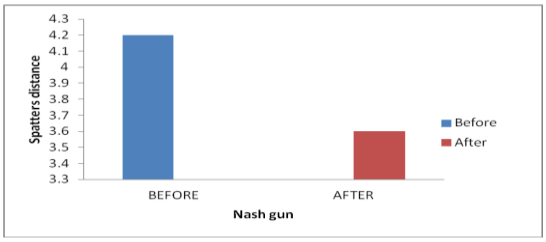
Graph 4 Spatters Results at Workstation 10

These readings are the distance of spatters from the origin of spot welding in which we can see that they are reduced 8%



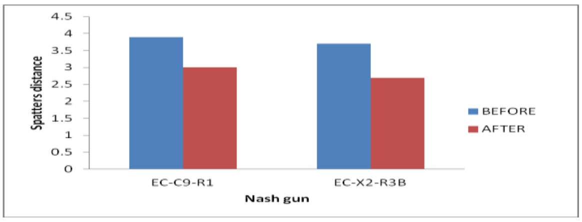
Graph 5 Spatters Results at Workstation 20

These readings are the distance of spatters from the origin of spot welding at workstation 20 in which we can see that they are reduced 23%



Graph 6 Spatters Results at Workstation 30

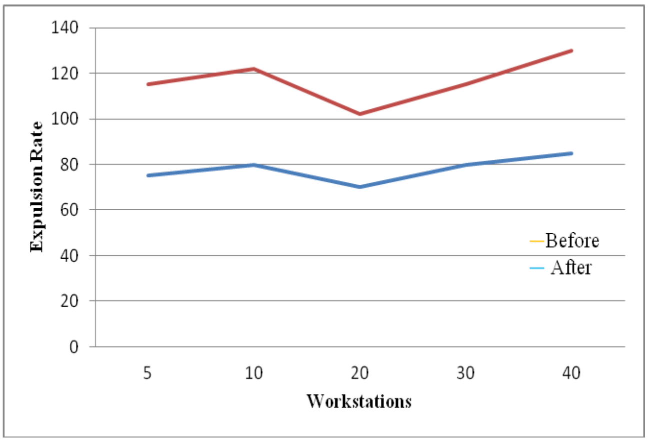
These readings are the distance of spatters from the origin of spot welding at workstation 30 in which we can see that they are reduced 15%



Graph 7 Spatters Results at Workstation 40

These readings are the distance of spatters from the origin of spot welding at workstation 40 in which we can see that they are reduced 15% & 10%

C. *Expulsion Results*



Graph 8 Expulsion Rate

These are the results of expulsion rates in which they are reduced certainly more than 50% at workstation 05, 10, 20, 30 & 40 respectively.

D. *Spot Weld Quality Results*

Fig. 4 Spot Weld Quality before Integrating Load Cell

The work piece used for the trail shows the spot quality before integrating the load cell with the shunting effects and darker region around the spot weld.

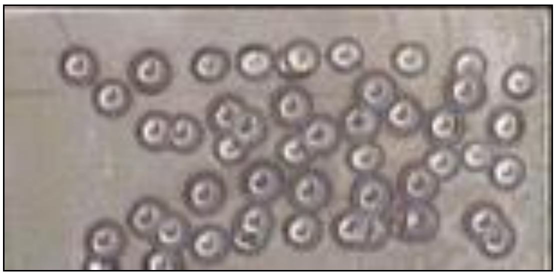


Fig. 5 Spot Weld Quality after Integrating Load Cell

The work piece used for the trail shows the spot quality before integrating the load cell with the shunting effects and dark region around the spot weld.

IV. CONCLUSION

As per the studies and results related to resistance spot welding gun it was necessary to make the changes to overcome the issues which are related during required operating time for the resistance spot welding gun. The idea of integrating the load cell inside the spot welding gun gives successful results regarding electrode force and the spatters and expulsion were reduced. The studies and investigation of welding gun in a proper way to customize the load cell and to integrate the same in proper way so that accurate results during experimental trails are observed.

The experimental results were the first priority to the team. The earlier parameters were noted and new parameters were introduced and we found the changes at the particular workstations and the results were compared with the previous parameters. It was found that the changes in previous parameters has the positive effect on work piece and the digital display unit was introduced so that we can see the exact electrode force during the time of spot welding which reduces the NVAs (Non Added Values Activities) and also the successful results in reducing the expulsions and spatters during spot welding where achieved. Good quality of spots during resistance spot welding is observed.

Table III Conclusion of Electrode Forces at Engine Compartment Section

Work station	WS 05	WS 05	WS 10	WS 20	WS 30	WS 40	WS 40
Forces Before	277	351	375	178	253	250	323
Forces After	240	300	438	175	256	278	331

These are results of electrode forces at Engine compartment section where the experiment was carried out and comparison shown in above Graph 1 & 2 respectively. There are five workstations in this section with two Nash guns at workstation 05 & 40 and one Nash gun at workstations 10, 20 & 30 each. The experiment was carried out in this section because two or more child parts are joined together at this section. There are less expulsions and spatters as shown in expulsions rate Graph 8 and spatters results Graphs 3, 4, 5, 6 & 7. Good qualities of spots are shown in the above Fig. 5 as compared to Fig. 4 respectively.

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