IOSR Journal of Engineering (IOSRJEN) **www.iosrjen.org**
ISSN (e): 2250-3021, ISSN (p): 2278-8719
PP 45-50

Effects of Input Parameters in Resistance Spot Welding of Dissimilar Automobile Steel (DP 600 with AISI 304L)

M. C. Katharotia[1], S.U. Ghunage[2], B. B. Ahuja[3]
[1,2,3](*Department of Production Engineering & Industrial Management, College of Engineering Pune, India)*

Abstract : *Welding of dissimilar materials is an emerging area as it finds different applications in the fields of manufacturing sector. In recent days, dual-phase steels are getting attention of the researchers and manufacturers worldwide as it possesses high strength, high ductility and excellent formability. These steels are having unique microstructure which consists of ferrite and martensite. In this study focuses on characterization of the process parameters in Resistance Spot Welding of AHSS type Dual phase 600 steel with austenitic stainless steel-AISI 304L. To understand the effects of input process parameter and its relation with weld load carrying capacity and micro hardness of weld area, Design of experiment (DOE)methodology was used. From the results of the design of experiments, set of suitable welding parameters were obtained. The effect of different input parameters like welding current, electrode pressure, welding cycles on the weld nugget size are also analyzed.*
Keywords - *Resistance spot welding, Dissimilar materials, Dual Phase steels, Failure modes, Shear tensile test*

I. Introduction

Resistance spot welding (RSW) has been gaining wide acceptance in automobile welding and for research area for recent years. While almost for a century, the sheet materials (steels) for automobiles did not undergo big changes. Structural and functional elements/parts were made of mild steels that were required to be as soft as possible to ensure formability, repairability, weldability, paintability etc.

Government's environment and safety organizations are making strong rules and regulation to reduce harmful gasses to deal with Global warming. To address global warming issues and to reduce fuel consumption, design engineers are required to reduce the weight of vehicle without compromising any strength of vehicle and safety of occupants. In order to minimize the vehicle weight and improve its crashworthiness, amongst other metals, Advanced High-Strength Steels (AHSS) is found most promising material. This is due its higher strength (600-1000 MPa) and excellent formability. For modern vehicle constructions, structures (chassis, pillars etc) should be capable of withstanding higher crash loads. This requirement necessitates increases weight of vehicle if conventional materials are used. However, weight of vehicle can be greatly reduced if conventional steels are replaced by AHSS steels. As AHSS steel usage for manufacturing of structural components is gaining momentum, there is scope to reveal the joining performance of combinations of different grades of AHSS.

The Resistance Spot Welding suitable process for vehicle construction and joining of body panels. It is a phenomenon, which involves the thermal, electrical, mechanical and metallurgical factors. It requires investigation of complex interaction between the process parameters to obtain the optimum quality of weld. This study focuses on the effect of input parameters on Resistance Spot Welding of dissimilar automobile grade steels.

1.1 LITERATURE SURVEY

P.P Choughule et al.[1] have worked on welding of grades of dissimilar metals (mild steel and stainless steel) to obtain maximum tensile strength of the weld components. An empirical relationship developed by the authors in terms of welding current, welding force and welding time, has been proposed for maximizing the weld strength by the use of ANOVA. These experiments were performed by using factorial design concepts. B. S. Gawai et al.[2] optimized the spot welding parameters using Response Surface Methodology. They have studied the fishbone diagram governing Tensile Shear Strength of welded components. S.T. Wei & J.Y. Guo et al.[3] studied similar and dissimilar combinations of a galvanized dual phase (DP) steel and a transformation induced plasticity (TRIP) steel. These samples were welded using Resistance spot welding for different welding conditions like DP/DP, TRIP/TRIP and DP/TRIP welds. Y. J. Chao et al.[4] studied different failure mode of spot welds i.e. interfacial (IF) and nugget pullout (TF). These samples were studied using fracture mechanism. For each sheet metal thickness, values of required minimum nugget diameter of the weld was obtained. Mehdi Mansouri Hasan Abadi et al.[5] investigated dissimilar resistance spot welding of AISI304 and low carbon steel AISI1008. Both sheets of steel have different physical and mechanical properties because of that sheet-sheet interface shifted to higher resistivity side of AISI 304 and hence asymmetrical nugget is formed and it is also observed that lower electrical resistance and high thermal conductivity leads to smaller fusion zone in carbon steel side. S. Aslanlar et al.[6] studied the effects of welding time (cycles) on the tensile-peel strength and tensile-shear strength of welded joints using resistance spot welding. Materials used for this study were chromate micro-alloyed steel sheets having 1.2 mm thicknesses. International Stainless-Steel Forum ISSF[7] described the various grades of stainless steel used in automotive applications. It has been written primarily from a European perspective and does not take account of the practice in other countries. General formulas for Spot Welding[8] describes the relation for deciding the Electrode Force, Weld Current, Weld Time & Tip Face Diameter for given thickness of sheet. Steve Westgate et. al. [9] have provided the practical guidelines and standard tables for selecting the Electrode Tip Diameter, Weld Time Cycles, Electrode Force & Nominal Welding Current for given thickness of sheets.

Requirement of dissimilar metal spot welding is essential for OEM and automobile manufacturers. The spot weldability for dissimilar strength steel is quite difficult but it possible by selecting proper parameters using experimental studies. Various grades of Dual phase steels are used in chassis of automobile and various grades of Austenitic stainless steels are used in exhaust systems of automobile. Also the combination of both steel is used in door hinge and other structural elements of a vehicle. This necessitates need of study of weld behavior of different grades of dissimilar steels.

II. Experimental work

In the present work, dissimilar grades of steels like Dual Phase steel and AISI 304L steel has been welded using Resistant Spot Welding machine (KEJE make, 25 TSP). Welding has been carried out as per the designed weld schedules for dissimilar spot welding. The dimensions of weld specimens are 140mm(Length)*40mm(Wdith)*1mm(thickness). According to AWS standard, overlap was kept 40 mm. For every weld schedules, the values of parameters like Hold time, Squeeze time and Off time were 10 cycles, 20 cycles and 20 cycles respectively. The input parameters, weld schedules and output parameters were mentioned in Table 1 & 2. After performing spot weld, the samples were tested for measuring nugget diameter (in mm), electrode indentation (in mm) and UTS (ultimate tensile strength in N/mm^2) of weld joints. Universal testing machine was used to find out tensile shear strength. Vickers micro-hardness tester was used to find out micro-hardness and metallographic tests were conducted to find out microstructure of nugget zone. Microhardness testing and metallographic testing were performed after completing the tensile shear testing of weld schedules. Austenite, Martensite and Ferrite grain structure were analyzed using optical microscope.

Table 1 Input parameter settings for spot welding of DP600 with AISI304L.

Parameters	Levels		
Electrode pressure (kg/cm^2)	1.5	2	2.5
Weld Cycles	5	10	15
Current in kA	6	8	10

Current	TAP	% Energy
6000	5	48
8000	5	64
10000	5	80

Pre-weld Cycles	Weld Cycles	Post weld Cycles
2	5	2
5	10	5
7	15	7

An attempt has been made to correlate different types of failure regions and weld strength. Following three different modes of failure were observed when welded samples are subjected to tensile shear test.

A. Interfacial Failure (IF): The joint failure occurred in weld nugget due to poor joint and welding parameter values.
B. Partial Failure (PF): It is observed that it is moderate good weld, and tearing has occurred from either side of base metal resulting into partial failure (PF) on AISI304L side.
C. Tear Failure: A better-quality weld was obtained between sheets and therefore higher shear force was required for its failure. In these cases, failure has occurred at relatively high load and so there was button pull-out that is tear failure (TF).

Table 2 Taguchi L27 for spot welding of DP600 with AISI304L.

Run order	Electrode pressure (kg/cm^2)	Weld Cycles	Current (A)	Nugget Diameter (mm)	Avg. Indentation (mm)	UTS (N/mm2)	Failure Mode
1	1.5	5	6000	3.49	0.0935	227	IF
2	1.5	5	8000	3.79	0.125	359.5	PF
3	1.5	5	10000	4.1	0.1525	361.5	PF
4	1.5	10	6000	4.71	0.161	344.75	TF
5	1.5	10	8000	4.79	0.1755	399.25	PF
6	1.5	10	10000	5.3	0.1855	434.75	PF
7	1.5	15	6000	4.4	0.167	372	PF

8	1.5	15	8000	5.05	0.1865	431.75	PF
9	1.5	15	10000	5.88	0.1995	438	TF
10	2	5	6000	3.58	0.097	241.75	IF
11	2	5	8000	3.96	0.132	325	PF
12	2	5	10000	4.3	0.1555	370	PF
13	2	10	6000	4.92	0.1625	342.5	PF
14	2	10	8000	5.03	0.202	411.75	PF
15	2	10	10000	5.57	0.2215	431	PF
16	2	15	6000	4.93	0.174	366.5	PF
17	2	15	8000	6.02	0.2055	453.25	PF
18	2	15	10000	6.04	0.227	463.25	TF
19	2.5	5	6000	3.77	0.105	262.5	IF
20	2.5	5	8000	4.04	0.142	315	PF
21	2.5	5	10000	4.87	0.1635	345.25	PF
22	2.5	10	6000	4.98	0.167	368.75	PF
23	2.5	10	8000	5.15	0.174	409.5	TF
24	2.5	10	10000	5.74	0.224	441.25	TF
25	2.5	15	6000	4.81	0.173	318.25	PF
26	2.5	15	8000	5.73	0.2095	427.5	TF
27	2.5	15	10000	6.08	0.2495	457.25	TF

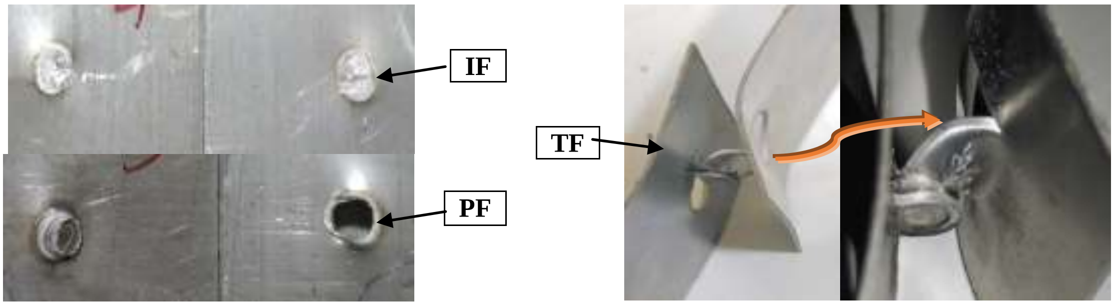


Fig. 1 Types of failure mode

III. Results and Discussion

Output parameters of dissimilar spot welding of DP600 with AISI 304L are tabulated in table 2. It contains nugget diameter, electrode indentation, UTS of weld joint and failure mode.

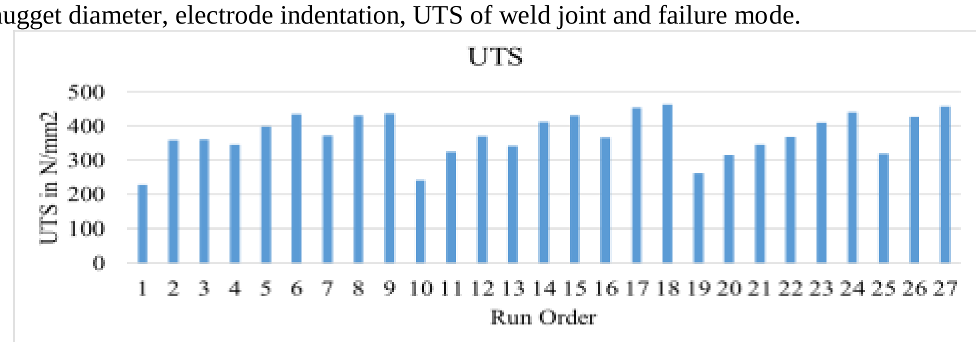


Fig. 2 Graphs on output of DOE for dissimilar spot welding of DP600 with AISI 304L

From fig. 2, it is observed that for each of the weld schedules i.e. 1 to 9 runs, 10 to 18 runs & 19 to 27 runs, as weld cycles (weld time) increases, ultimate tensile strength of weld joints increases proportionately.

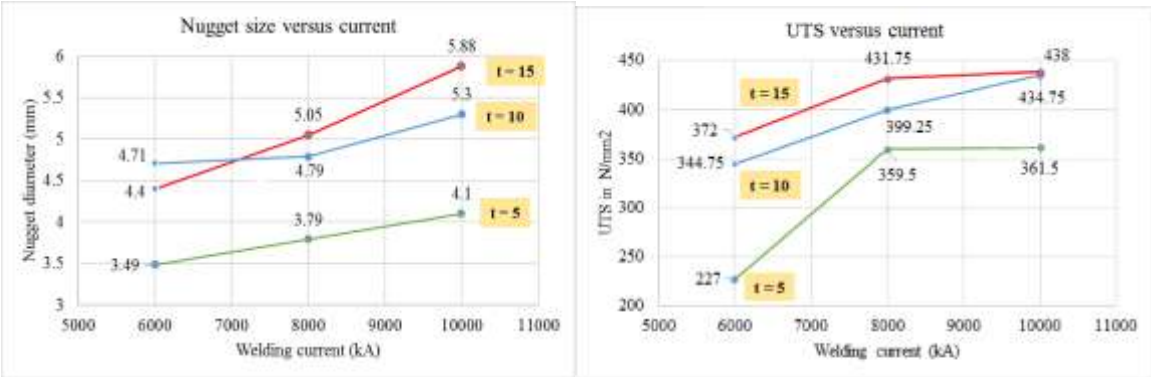


Fig. 3 Graphs on output of DOE for dissimilar spot welding of DP600 with AISI 304L.

Also, the above charts indicate that the UTS of weld joint and nugget size is increased with increase in weld cycles and weld current. It is observed that Ultimate Tensile strength of welded specimen was highest for run 9, 18 and 27. Therefore samples of these run order were re-welded to obtain micro hardness and metallographic test. Microhardness was measured using Vickers microhardness tester where hardness was measured across the nugget diameter as shown in figure. Metallographic study was carried out using optical microscope.

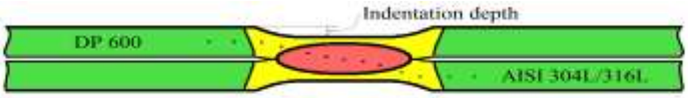


Fig. 4 Micro-hardness testing across the weld nugget

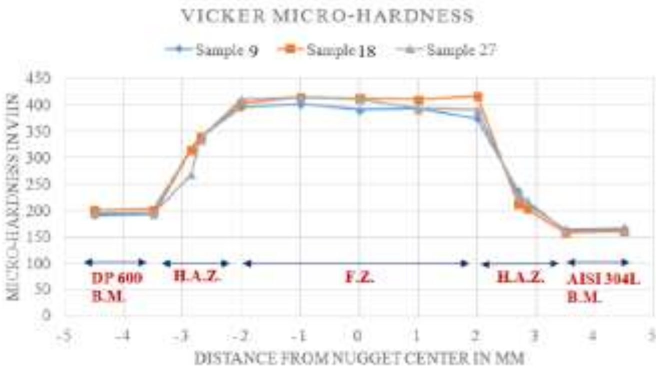


Fig. 5 Microhardness of dissimilar spot welding of DP 600 with AISI 304L

Hardness test was conducted to identify the capacity of resistance to plastic deformation of welded joint. Hardness test was conducted using diamond indentation in which a load of 500gm was applied for dwell time 10s. Across the weld nugget area, 13 different points were selected to observe the hardness variation (fig 4). Among these13 points, 4 points were taken on both side of base metal, 4 points were taken on both side of heat affected zone and 5 points were taken along the fusion zone. Hardness distribution pattern for three samples for three weld schedules was almost same. Electrode pressure does not affect the hardness distribution across the nugget zone. In the fusion zone, Vickers hardness was achieved between 370 to 420 VHN for dissimilar spot welding of DP 600/AISI304L.

Metallographic study used to identify various zones of weld nugget area. It shows the variation in grain size of weld nugget. In this study, there was dissimilar spot welding of DP600 with AISI 304L were observed. Images of samples for dissimilar spot welds are mentioned here.

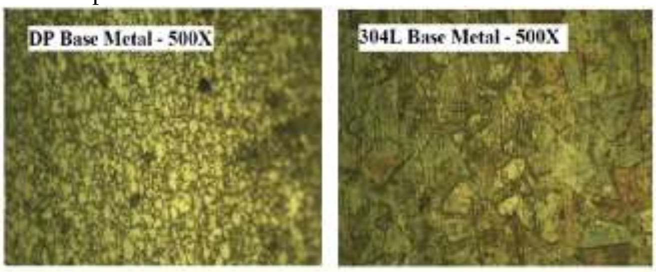
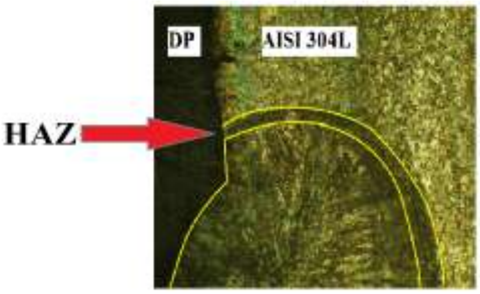


Fig. 6 Grain structure for base metal of DP 600 and 304L

Grain size of ferrite and martensite is smaller than austenite which was clearly identified at 500X magnification. The microstructure DP 600 steels reveals ferrite and martensite composition, while the microstructure of AISI 304L reveals austenite grains.



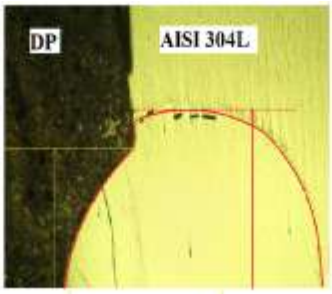


Fig. 7(a) Heat Affected Zone in dissimilar spot welding Fig.7(b) Nugget size in dissimilar spot welding

In a dissimilar spot welding, the nugget was observed to be of elliptical nature between the two adjoining sheets and HAZ was formed around the nugget. Fig 7(b) reveals that the nugget diameter on dual phase side is smaller as compared with the nugget diameter on AISI 304L side. The microstructure of weld nugget shows that grain are columnar in nature. Heat affected zone (HAZ) showed a mixture of ferrite and martensite regions.

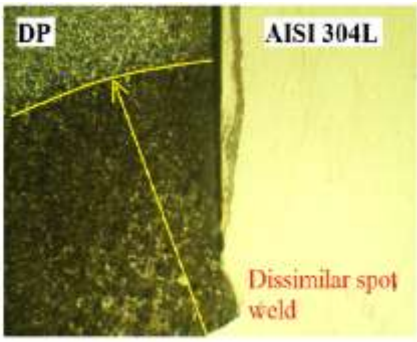


Fig.8 HAZ of Dual Phase steel

Fig.7 and fig. 8 reveals that HAZ on DP 600 steel is of larger size than that of AISI 304L. The nugget of dissimilar spot welding contains the higher percent of austenite grains as compare with ferrite grains and martensite grains. During welding, fusion zone is melted completely and is re-solidified resulting into a cast structure. After cooling , solidified structure shows dendrite morphology in which directional solidification ha occurred towards the center.

IV. Conclusion

In this study, attempts were made to link the quality of weld of DP 600 and AISI 304L steel joints to its parameters. The performance of the welding parameters on the weldments has been found out. Taguchi method was used to understand multivariable nature and its effect in characterizing a spot weld. Key findings can be stated as:

1) Tensile shear strength for DP 600 and Austenitic Stainless Steels AISI 304L was found to be comparatively more than that of for similar sheets (AISI 304L to AISI 304L and DP 600 to DP 600).
2) Tensile shear strength of welded specimen is majorly governed by weld current applied. Proportionate increase in weld nugget was observed for incremental values of weld current within specified limits. This has resulted into increased values of tensile shear strength of weld specimens.
3) Amongst the three input parameters considered for the study, welding current is prime factor controlling the weld strength followed by weld time and electrode pressure respectively.
4) For dissimilar RSW between Dual Phase stainless steels (DP600) and AISI 304L, asymmetric fusion zone was observed from the micrographs. The main reason is differences in mechanical and electrical properties like coefficient of thermal expansion, electrical resistivity. Fusion zone of
5) For the DP steel and AISI 304L joints, fusion zone hardness was observed higher than that of the base metals.

References

[1] P. P Choughule, A.K. Biradar, A.K. Modi, Resistance Spot Weldability Of Dissimilar Materials In 1 Mm Thick Sheet, Journal of Mechanicl Engineering and Technology, JMET, 2016, Vol 4, issue 1.

[2] B. S. Gawai, Dr. C. M. Sedani, "Optimization of Process Parameters for Resistance Spot Welding Process of HR E-34 Using Response Surface Method – A Review", International Journal of Science and Research (IJSR) , 2016, Vol 5, issue 3.

[3] S. T. Wei, D. Lv, R. D. Liu, L. Lin, R. J. Xu, J. Y. Guo and K. Q. Wang, "Similar and dissimilar resistance spot welding of advanced high strength steels: welding and heat treatment procedures, structure and mechanical properties", Science and Technology of Welding and Joining, 2014, VOL-19, NO 5.

[4] Y. J. Chao, "Failure modes of Spot Weld: Interfacial versus Pullout", Science and Technology of Welding and Joining, 2003, Vol. 8, No 2.

[5] Mehdi Mansouri Hasan Abadi, Majid Pouranvari, "Correlation between macro/micro structure and mechanical properties of dissimilar resistance spot welds of aisi 304 austenitic stainless steel and aisi 1008 low carbon steel", Association of Metallurgical Engineers of Serbia – AMES, MJoM Vol 16 (2) 2010 p. 133-146.

[6] S. Aslanlar, A. Ogur, U. Ozsarac, E. Ilhan, "Welding time effect on mechanical properties of automotive sheets in electrical resistance spot welding", Science Direct, Materials and Design 29 (2008) 1427–1431. 2007 Elsevier Ltd.

[7] ISSF – International Stainless Steel Forum, "Stainless Steel Applications – Automotive", International Stainless Steel Forum Rue Colonel Bourg 120 B-1140 Brussels Belgium.

[8] "General Formula's For Spot Welding", Resistance Welding Equipment & Supply Co. 2045 East 46th Street Indianapolis, IN 46205-1472.

[9] Steve Westgate, TWI Ltd., "Setting for Resistance Spot Welding of Steels – Practical Guidelines", Online document.