Analysis of Welding of Dissimilar Metal by Using Process of Resistance Spot Welding

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Abstract- **In the present situation welding of different metals is vital on the grounds that one metal can't give ideal compound, physical and mechanical properties required for an application. Like Al-Steel or Mg-Al welding for lessening the heaviness of the transportation vehicles, for example, train, car, and ship, high composite material-low amalgam steel or treated steel-low carbon steel for quality and erosion obstruction, Al-Cu for electronic segments. Such a significant number of looks into have been completed on joining of Fe-Al by RSW utilizing distinctive components as interlayer however streamlining of cladding proportion for progress material isn't finished. Here in this paper condition for ideal execution is resolved in the terms of impact of parameters on the ductile shear quality of the weld, enhance the procedure parameters without the Silver interlayer, streamline the procedure parameters with the Silver interlayer, and examine the method of disappointment of these welds.**

Index Terms- Resistance Spot Welding, Shear Strength, Cladding Ratio, Transition Material.

I. INTRODUCTION

Resistance spot welding (RSW) is a noteworthy sheet metal joining process in numerous businesses, for example, the vehicle, household machines, air art and space create manufactures. It is a productive joining process broadly utilized for the manufacture of sheet metal congregations. There are 3000-6000 spot welds in any vehicle, which demonstrates the dimension significance of the opposition spot welding. RSW has incredible techno-monetary advantages for example, minimal effort, high creation rate and versatility for robotization which settle on it an alluring decision for auto-body congregations, truck lodges, rail vehicles and home machines. It is one of the most seasoned of the electric welding forms being used by industry today [1]. Moreover, other metal-to-metal associations, for example, wire-to-wire joints in the hardware industry, are practiced by obstruction spot welding. Application-explicit measures, for example, the distance across of the welding spot, decide the nature of the joint. The weld is made by a mix of warmth, weight, and time. As the name infers, it utilizes the opposition of the materials to the stream of current that makes limited warming between the parts be joined. Comprehension of physical systems for effectively controlling and controlling weld characteristics ahead of time is vital. Obstruction spot welding is the most generally utilized type of the electric obstruction welding process in which faying surfaces are participated in at least one spots. The RSW procedure on a very basic level comprises of four phases which are press cycle, weld cycle, hold cycle and off cycle.

1.1 Resistance spot welding for dissimilar metal joints

Resistance welding for dissimilar metal weld required proper heat balance. Heat balance plays a very important in dissimilar metal welding to obtain the good quality weld. As different metal have different properties like thermal conductivity, electrical conductivity, thermal coefficient of expansion and contraction. Due to that heat generation and heat lose will be different for different metal. Proper heat balance is done by several methods depend upon the situation. If we are welding two dissimilar metal and sheet having equal thickness then we can do the heat balance by adjusting the contact area of electrode and sheet interface.

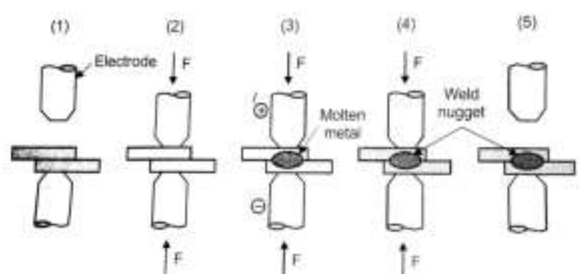

Fig. 1 Working [19]

II.LITERATURE REVIEW

This chapter presents a comprehensive review of literature related to various types of welding process, welding materials, welding parameters, various behaviours of welding. A comprehensive overview of the earlier research work carried out in the area of welding process and optimization of various welding process is presented in detail in this chapter. The literature that laid a platform for the successful completion of the present investigation is mainly aimed to focus on the studies involving synthesis and mechanical behaviour, metallurgical properties, welding temperature, Taguchi method, Design of Experiments, Welding parameters for stainless steel sheets. Welding is the joining of materials in the welding zone with the use of heat and/or force, with or without filler metal. It can be facilitated with the help of, for example, shielding gases, welding powders, or pastes. However the energy required for welding is supplied by an esteemed source (M. Vural 2014)

Dissimilar metal joints of TiNi shape memory alloy wire and stainless steel wire were welded by laser welding method with and without Cofiller metal. Comparative microstructure and properties of laser welded joints with and without Co filler metal have been investigated in detail. The effects of Co filler metal thickness on joint microstructure and properties were also discussed. The results indicated that the addition of Co filler metal had great effect to improve joint microstructure and properties. When 20 mm thick Co filler metal was used, the joint tensile strength and elongation reached the maximum values (347 MPa and 4.2%), and the corresponding joint fracture mode changed from pure brittle feature to mixture of cleavage and dimples due to decreasing brittle intermetallic compounds such as $TiFe_2$, $TiCr_2$, etc. But excessive Co addition resulted in decreasing the joint properties because of forming more Co–Ti intermetallic compounds (Hongmei Li et al. 2013).

According to Seyedeh Nooshin Mortazavi et al. who has perform an experiment on low carbon0steel and A52500aluminium alloy by using RSW, there is formation a brittle intermetallic layer who deteriorate the tensile strength of the weld. The formation of intermetallic0compound layer is due to limited0solubility of Iron in Aluminium and vice versa. Only small amounts of iron0can be dissolved0in aluminium, and only small amounts of aluminium can be0dissolved in0iron. Iron and aluminium form various intermetallic phases of low0strength and low0toughness. The intermetallic compounds "which are available on it" are gathered as Fe-rich mixes (FeAl and Fe_3Al) and Al-rich mixes ($FeAl_2$, Fe_2Al_5, and $FeAl_3$). Along with these stable compounds, metastable compounds ($FeAl_6$, Fe_2Al_9, and $FeAl_x$) have been also form in Al/steel interface.

2.1 Gaps in Literature Review

After doing the detail study of the literature, the following gaps are found:

1. Few literature is available on joining of Fe-Al by RSW using different elements as interlayer.
2. In the literature cladding ratio optimization for transition material is not clear.
3. In the joining of Fe-Al by using 4047 AlSi12 interlayer the effect of electrode force and weld time is not explained properly.
4. Joining of Fe-Al by using interlayer with the cover plate has not been tried.
5. Different materials (Ti, Ag, Cu, Ca, Mg) as interlayer has not been used.

2.2 Objective of this research

1. To study the influence of parameters on the tensile shear strength of the weld.
2. To optimize the process parameters without the Silver interlayer
3. To optimize the process parameters with the Silver interlayer.
4. To investigate the mode of failure of these welds.

III.METHODOLOGY

3.1 Material selection

A 1.0 mm thick Stainless steel (304) sheet with yield0strength and ultimate tensile strength of 215 and 505 MPa, and 1.5 mm thick aluminium(A5052) sheet with yield strength and ultimate tensile strength of 89.6 and 193 MPa was used in the research work. A Silver interlayer of 100µm thickness was also used. The thickness of stainless steel sheet was taken different due to the heat balance during welding.

Table 1 Composition of SS 304

SS(304)	C	Cr	Ni	Mn	P	S	Si	Fe
Wt%	.04	18.3	9.1	1.2	.03	.01	.5	60.82

Table 2 Composition of Aluminium 5052 alloy

5052	Al	Cr	Cu	Fe	Mg	Mn
Wt%	97.24	0.16	.02	.2	2.5	.08

3.2 Welding Machine

Spot welding was performed using a 150KVA AC Pedestal type Resistance Spot Welding Machine. Welding was done using a 45° truncated cone RWMA class 2 electrode. The face diameter of Electrode was 10mm as shown in fig 3.1. The Electrode was made by tapper turning on the lath machine.

Fig.2 Resistance spot welding machine

3.3 Sample Preparation

Static tensile shear test samples were prepared according to ANSI/AWS/SAE/D8.9-97 standard [Fig. 3]. The samples were prepared with the help of shearing Machine. Firstly samples were polished up to 1200 grit size and then cleaning was done by acetone. Fig 3.3 shows the sample before the cleaning and Fig. 4 shows the sample after the cleaning.

Fig. 3 Weld Samples before the cleaning.

Fig. 4 Weld sample after cleaning.

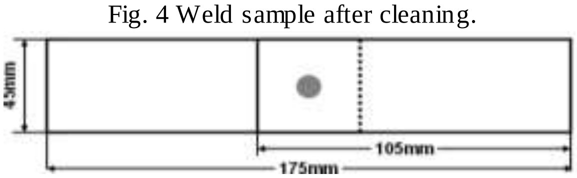

Fig. 5 Static tensile shear test sample

3.4 Welding Parameters

Taguchi technique involves five steps these are as follows:

1. Find out the best parameters which affect the shear strength.
2. Design the Experiment according to partial/ full fraction design.
3. Conducts the experiments.
4. Analyse the results with the ANOVA to determine the optimum conductions and significant parameter.
5. Run a confirmatory test using the optimum conditions.

Table 3 Spot welding Parameters for with and without Silver layer and there levels for DOE

Factors	Process parameter	Levels			Unit
		1	2	3	
1	Welding Current	13	14	15	kA
2	Weld Time	15	16	17	Cycle

Table 4. L9 Orthogonal array for spot welding with and without silver interlayer.

S.N.	Welding Current	Weld Time
1	13	15
2	13	16
3	13	17
4	14	15
5	14	16
6	14	17
7	15	15
8	15	16
9	15	17

Same array was used for the spot welding with silver interlayer and the comparisons have been done between them.

Fig. 6 Sample after weld

3.5 Metallography Preparation

Metallography observation was performed on the cross section structure of the weld zone. For this weld was cut from the centre and then cross section was polished up to 2000 grit size. After that cloth polishing with MgO powder. The etchant for steel was aqua regia and for aluminium was Keller's etchant. (190ml Distilled Water, 5ml Nitric Acid, 3ml Hydrochloric Acid, and 2ml Hydrofluoric Acid). The etching time was 12 second for aluminium and 1.5 minute for steel. After etching FESEM, EDX and stereoscopy were performed.

3.6 Shear Strength Testing

Shear strength testing was performed on the Universal Testing Machine.

3.7 Metallographic Observation

Metallographic Observation was performed by using the Stereoscopic microscope, Scanning Electron Microscope and FE-SEM.

3.8 X- Ray Diffraction

XRD of fracture surface was performed to know the type of intermetallic formed at the interface of the joint.

IV.RESULTS AND DISCUSSIONS

4.1 Influence of welding current on nugget diameter of weld.

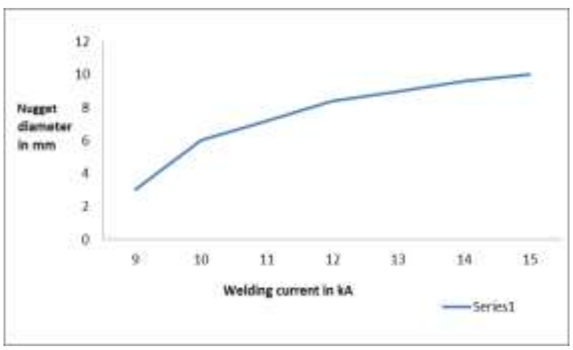

Fig. 7 Influence of welding current on nugget diameter of weld.

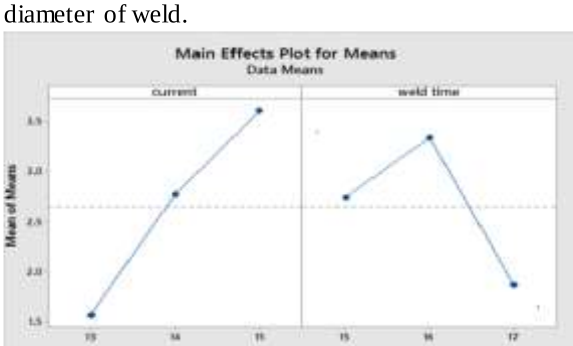

Fig.9 Effect of input parameters on SN ratio

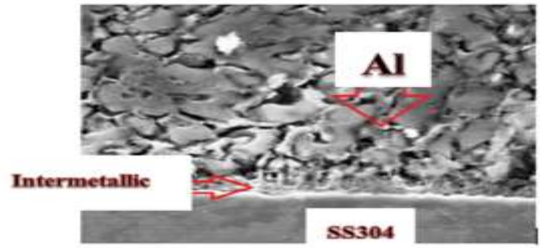

Fig. 10 FESEM Micrograph of weld cross section at 15 kA current and 16 cycles weld time.

Fig. 11 Fracture of weld during cross sectional cutting of weld.

Table 5 Elements and their weight % at the interface of the weld.

S.N.	Element	Weight%	Atomic%
1	C	11.15	26.17
3	Al	26.76	27.95
4	Si	0.63	0.64
5	Cr	8.56	4.64
6	Fe	34.90	17.62
7	Ni	4.67	2.24
8	Ag	1.83	0.48

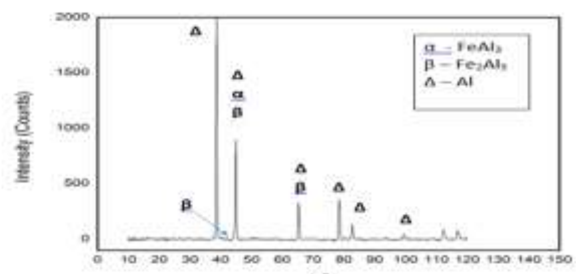

Fig. 12 XRD Graph of aluminium side fracture surface.

4.2 FESEM Results with Silver Interlayer

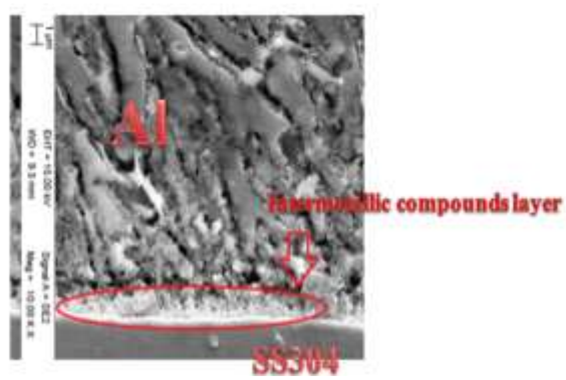

Fig.13 FESEM micrograph of weld cross section with Silver interlayer at 15 kA current and 16 cycles weld time.

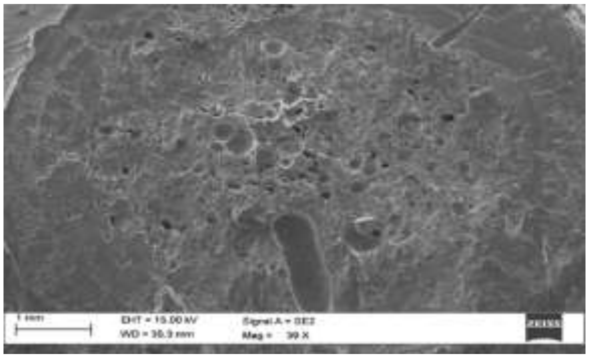

Fig14 Fracture surface of Aluminium SS304 joint with Silver interlayer at 39x magnification.

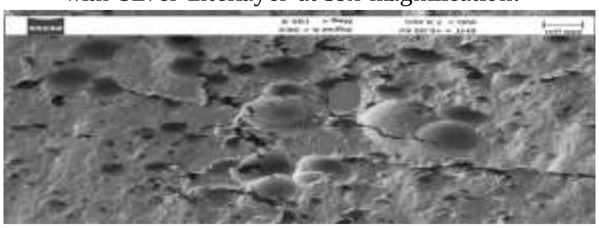

Fig. 15 Fracture Surface of steel aluminium joint with Silver interlayer at 100X

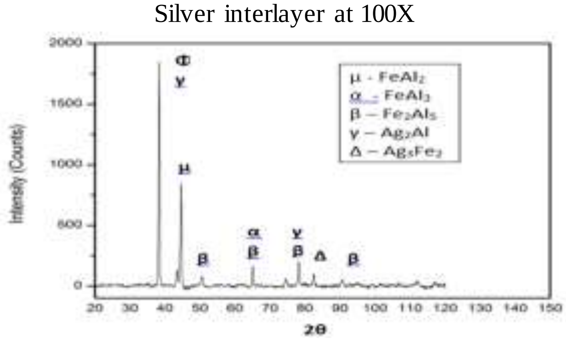

Fig. 16 XRD Graph of aluminium side fracture surface with Silver interlayer.

V.CONCLUSIONS

On the basis of the experimentation and results acquired through analysis of Tensile Shear testing, Metallographic observations, Nugget diameter, EDX, and XRD of fractured surfaces the following can be concluded:

- Welding of Steel and Aluminium is a challenging task. These welds show lower tensile shear strength due to formation of intermetallic compounds at the interface of the weld which are brittle in nature like FeAl3, Fe2Al5.
- Welding current has the maximum effect on shear strength of the weld joint.
- Welding of SS304 with Aluminium 5052 using Silver as an interlayer, Silver reduces the formation of Fe-Al based intermetallic and replace it with Al-Ag based intermetallic, such as Ag2Fe2, Ag2Al, which are ductile in nature.
- FESEM micrographs show a mix mode of fracture.
- Welding of SS304 with Aluminium 5052 without using Silver interlayer shows maximum tensile shear strength 4.2 kN.
- Welding of SS304 with Aluminium 5052 using Silver as an interlayer shows maximum tensile shear strength 4.6 kN which is higher than welding without Silver interlayer.
- The EDX results support the presence of Silver at the weld interface.
- In the XRD analysis, mainly FeAl2, FeAl3, Fe2Al5 intermetallic compound and Ag2Al, Ag3Fe2 ductile phases of Al-Ag and Fe-Ag are found.

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