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EFFECTS OF PROCESS PARAMETERS AND OPTIMIZATION OF MECHANICAL AND METALLURGICAL BEHAVIOUR FOR DISSIMILAR MATERIAL BY ELECTRICAL RESISTANCE SPOT WELDING.

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ABSTRACT

Electrical resistance Spot Welding is a pressure welding used for joining of sheet metals or wires. The welding heat is produced at the desired location by electrical resistance through the metal pieces. ERSW is highly used due to its fast rate of production, less maintenance, free from smoke etc… ERSW is experimented in dissimilar materials (Stainless steel –Mild steel) to analyze the effect of process parameters such as welding current, welding time and electrode force. The welded parts were applicable to tensile test and hardness test .Thus the influence of parameters on weld quality was categorized.

Keywords: ERSW,Stainlesssteel –Mild steel,Stainless steel –Aluminiumtensiletest, hardness test

1.INTRODUCTION

1.1. ELECTRICAL RESISTANACE SPOT WELDING

ERSW is a familiar method in joining thin work pieces in several manufacturing, automobile, aerospace and packaging industries. The work pieces are closely pressed by two water cooled copper electrodes which breaks up the surface oxides on the faying surfaces by exerting force to provide a contact. When passing current the heat is developed on the work piece due to the resistance. Thus melting begins at the faying surface. The molten nugget grows until the current flow stops, and solidifies due to cooling through the electrodes.

It is practicable to weld aluminum alloy through Resistance spot welding. With increasing welding current and welding time increase in tensile shear load was obtained [1]. In car body manufacturing galvanized steel welded by RSW provides a non linear relationship between the welding parameters and the tensile shear strength [2].On welding low carbon steel with austenitic steel in RSW the heat affected zone (HAZ) of the low carbon steel sheet was broader than that of austenitic steel also there is an increase in iron content and decrease in Cr, Mn towards low carbon steel [3].The welding parameters have a immense effects on the microstructures and also on fatigue life of the welded joints. The welding current has a great effect on nugget diameter and lap joint mechanical characters. [4].RSW is the major manufacturing processes in automobile industries for assembling bodies. Increase in electric current flow and electric cycle causes rapid growth of nugget [5].Tensile shear and tensile peel strength of Galvanized chromided steel sheets of 1.2mm thick can be observed in Electrical resistance spot welding [6]. A conventional FEM model for RSW with two sided electrodes to a model of single sided electrode and a feasible numerical analysis of the single sided RSW for a real chassis structure was schemed[7]. The effect of local contact resistance including constriction and film resistances on resistance spot welding experiencing heating, melting, cooling and freezing was investigated [8].For good surface quality the depth of electrode indentation into material should not exceed 20% of sheet thickness[9].Small scale resistance spot welding (SSRSW) is a necessary method to join titanium and its alloys [10].Resistance spot welding (RSW) can be used to join thin strips of Vitreloy 101 ($Cu_{47}Ti_{34}Zr_{11}Ni_{8}$) successfully.

1.2 PRINCIPLE OF WORKING

It is attained when current flow through electrode tips and the pieces of metal to be joined.Resistance of the base metal to electrical current flow causes localized heating in the joint and the weld is formed.

1.3. SCHEMATIC DIAGRAM OF ERSW

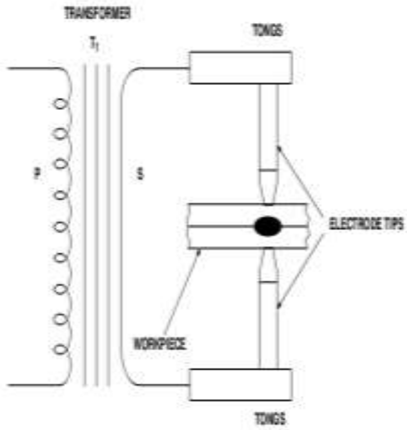

Fig 1.Schematic Diagram

2. MATERIALS SELECTION

Electrical resistance spot welding is deviced on Stainless steel – Mild steel combination.

The detailed dimension of the specimen is described table 1.

2.1.CHEMICAL COMPOSITION

The tables2,3, and 4liststhe chemical compositions of the selected materials.

Table.1 Dimension of the specimens

Length (mm)	Width (mm)	Thickness (mm)	Overlap (mm)
75	25	2	30

Table 2.Composition for Stainless steel

Element	Content
Cr	17-19%
Ni	8 – 11%
Fe	Balance

Table 3 Composition for Mild steel

Copper (%)	Min	---
	Max	0.10
Silicon (%)	Min	----
	Max	0.5
Iron (%)	Min	
	Max	0.6
Manganese (%)	Min	
	Max	0.1
Aluminium(%)	Min	99
	Max	

Table 4 Composition for Aluminium

Carbon	0.16-0.18%
Silicon	0.40% max
Manganese	0.70-0.90%
Sulphur	0.040% Max
Phosphorus	0.040% Max

3.EXPERIMENTAL PROCEDURE

The materials of 75mm x 25mm x 2mm were welded by ERSW by the welding condition in the table4.The figure 2shows the welded specimen.

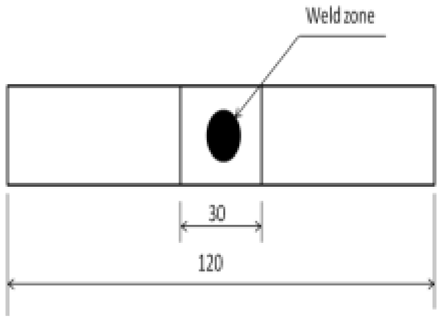

Fig.2

Thus parts are welded as per the parameters detailed in the Table6.All the welded specimens were supposed to Tensile test on universal testing machine(UTM) and hardness test on Rockwell hardness testing machine.
The selected materials of 75mm x 25mm x 2mm were welded by ERSW as per the varying parameter condition from TAGUCHI method.
For three varying conditions (Welding Time, Welding Current, and Electrode Force) and for three level orthogonal array L9 was selected on Taguchi method. The Table.5shows orthogonal array L9.

Table.5. Taguchi L9 Orthogonal Array

Experiment	P1	P2	P3
1	1	1	1
2	1	2	2
3	1	3	3
4	2	1	2
5	2	2	3
6	2	3	1
7	3	1	3
8	3	2	1
9	3	3	2

The varying parameters and the level of experiments are illustrated in the following table.6.

Table.6. Range of Parameters

Material	Parameters	Min	Intermediate	Max
SS-Al	Welding Current (KVA)	3	4	5
	Welding Time (Cycles)	200	300	400
	Electrode Force (Kgf)	125	150	175
SS-MS	Welding Current (KVA)	4	5	6
	Welding Time (Cycles)	400	500	600
	Electrode Force (Kgf)	150	175	200

The above table provides condition that produces weakest weld as minimum value and the strongest weld condition as maximum value have to be selected from trial and error method. For experimental work an intermediate condition was selected.

4. EXPERIMENTAL RESULTS ANDISUSSIONS

4.1. INTRODUCTION

The tensile load and the hardness were experimentally evaluated using universal testing machine (UTM) and hardness onRockwell hardness testing machine andthe weld nugget diameters were also evaluated the experimented results are given below. The obtained results are tabulated in the following tables.

4.2. STAINLESS STEEL – MILDSTEEL

The results for several conditions on SS-MS combinations are listed in the following table 7.

Table: 7 Experimental results for SS-MS

Material	Trials	Welding Current (KVA)	Welding Time (Cycles)	Electrode Force (Kgf)	Tensile shear load (kN)	Hardness (at nugget)	Nugget diameter (mm)
SS-MS	1	4	400	150	8.2	80	3
	2	4	500	175	14	76	7
	3	4	600	200	14.6	95	7
	4	5	400	170	14.1	97	6
	5	5	500	200	14.7	95	8
	6	5	600	150	15.8	97	5
	7	6	400	200	16.6	94	5
	8	6	500	150	14.3	98	6
	9	6	600	175	16.7	96	5

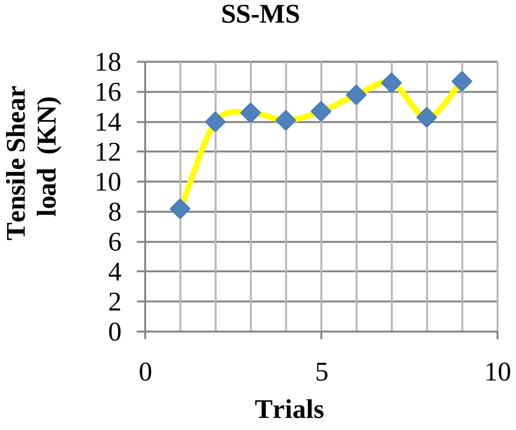

Fig:3 Trials Vs Tensile Shear

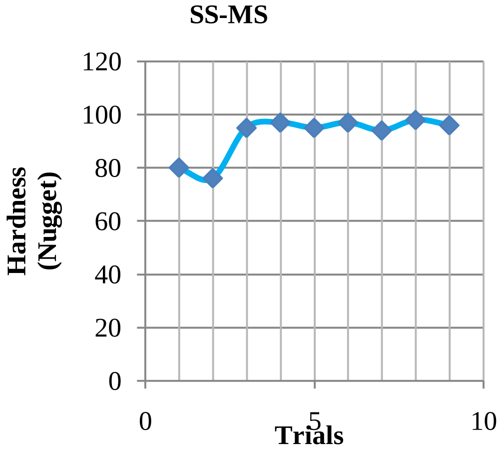

Fig: 4 Trials Vs Hardness

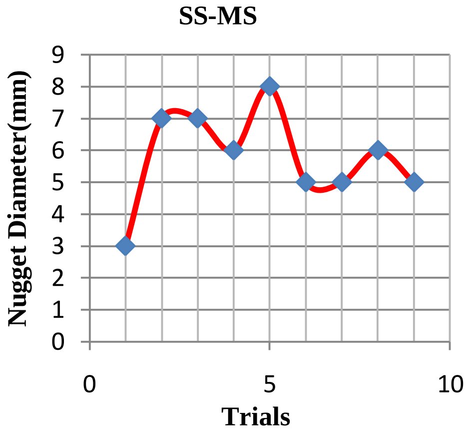

Fig: 5 Trials Vs Nugget

From the above figure 3 it is observed that the maximum tensile shear load capacity of the specimen is 16.7KN obtained under 6 KVA of welding current, 600 cycles of welding time and 175Kgf of electrode force.

Figure.4 shows the maximum hardness 97 is obtained under the condition of 5KVA of welding current, 200 cycles of welding time and 175 Kgf of electrode force.

4.3. STAINLESS STEEL – ALUMINIUM

The results for various conditions on SS-MS combinations are listed in the following table 7

Table: 8 Experimental results for SS-Al

Material	Trials	Welding Current (KVA)	Welding Time (Cycles)	Electrode Force (Kgf)	Tensile shear load (kN)	Hardness (at nugget)	Nugget diameter (mm)
SS-Al	1	3	200	125	0.7	65	7
	2	3	300	150	1.4	68	5
	3	3	400	175	1.9	90	4
	4	4	200	150	0.5	87	4
	5	4	300	175	2.2	62	7
	6	4	400	125	1.8	54	7
	7	5	200	175	1.2	97	6
	8	5	300	125	1.9	91	6
	9	5	400	150	2.4	92	4

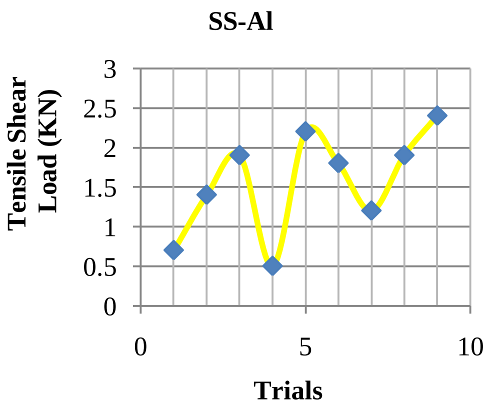

Fig:6 Trials Vs Tensile

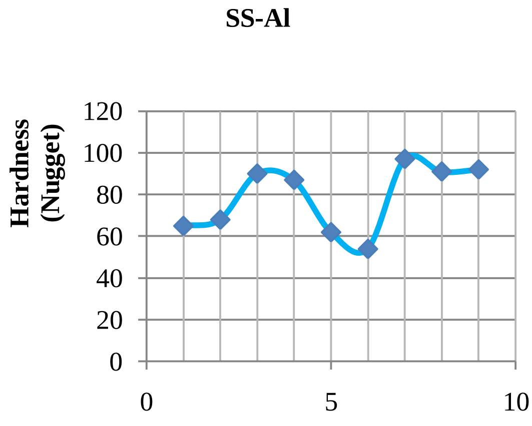

Fig. 7 Trials Vs Hardness

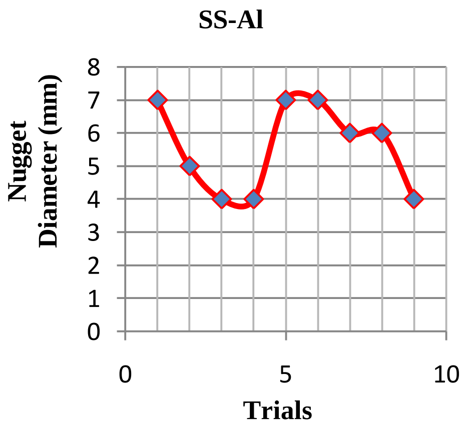

Fig. 8 Trials Vs Nugget

From the above figure.6 it is observed that the maximum tensile shear load capacity of the specimen is 2.4KN obtained under 5 KVA of welding current, 400 cycles of welding time and 150Kgf of electrode force.

Figure7 shows the maximum hardness 97 is obtained under the condition of 5KVA of welding current, 200 cycles of welding time and 175 Kgf of electrode force.

Figures9.a,b,care the samples before weld has been made and the figure 9. d, e are the specimens after the test has been experimented such as tensile shear and hardness test.

(a) (b) (c) (d) (e)

Fig .9 a)Aluminium b) Mild steel c) Stainless steel d) Tested specimen [SS-MS]e)Tested specimen [SS-Al]

4.4. INFLUENCE OF NUGGET DIAMETER ON TENSILE SHEAR LOAD

From this study it was clearly known that the nugget diameter of the weld has a great influence on the shear load barring capacity. The following figures show the allied graphical representations of the nugget diameter with the tensile shear load.

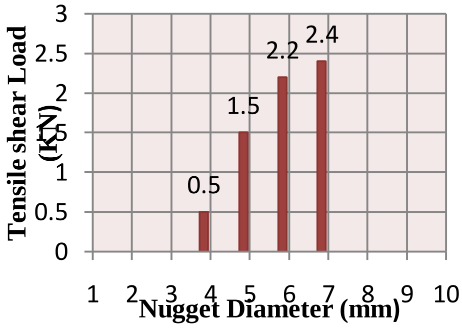

Fig.10 Nugget diameter Vs Tensile Shear Load

As per the results tabulated in the table.8the figure.10 was plotted betweennugget diameter (mm) and tensile shear load (KN) for Stainless steel – Aluminium combination andsimilarly as per the results mentioned in the table.7the figure.11 was plotted between nugget diameter (mm) and tensile shear load (KN) for Stainless steel – Mild steel combination

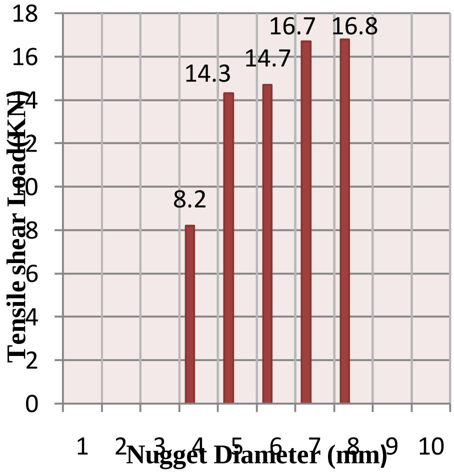

Fig.11 Nugget diameter Vs Tensile Shear Load

In both the combinations the tensile shear load gets increased for increasing nugget diameter. That is I have obtained the maximum tensile shear load for maximum nugget diameter. From this result we can say that the nugget diameter plays a vital role regarding mechanical properties of the welded materials.

4.5. MACROSCOPIC AND MICROSCOPIC EXAMINATIONS OF THE WELD NUGGETS

A set of welds with various strength and different nugget diameters have been prepared for examining their macro and microstructures. The macroscopic structure examinations of the nuggets have been done to valuetheir size and shape. The samples were cut approximately at the center of the weld nugget in the thickness and were mounted,grounded,polished and etched in a manner that described in macro and micro structural analysis were carried out using a light optical microscope united with an image analyzing software.

In the following section 4.5.1.and 4.5.2.we can see the macroscopic and microscopic images of strong and weak weld obtained in the selected combinations of dissimilar materials.

4.5.1.STAINLESS STEEL WITH MILD STEEL

Stainless steel – Mild Steel (Strong Weld)

Macrostructure

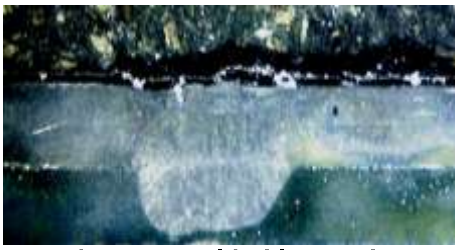

Fig.12. Macro Photograph: Shows the spot welded low carbon steel to the Stainless steel. The top shows the stainless steel sheet and the bottom shows the low carbon steel.

Stainless steel – Mild Steel (Weak Weld)

Macrostructure

Fig.14.Macro Photograph: Shows the spot welded low carbon steel to the Stainless steel. The top shows the stainless steel sheet and the bottom shows the low carbon steel.

4.5.2.STAINLESS STEEL WITH ALUMINIUM

Stainless steel – Aluminium (Strong Weld)

Macrostructure

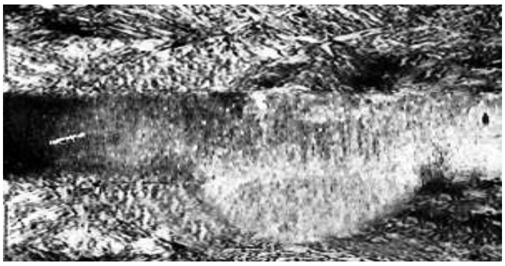

Fig.16.Macro Photograph: Shows the spot welded Aluminium to the Stainless steel. The top shows the s.s. sheet and the bottom shows the Aluminium.

Stainless steel-Aluminium (Weak Weld)

Macrostructre

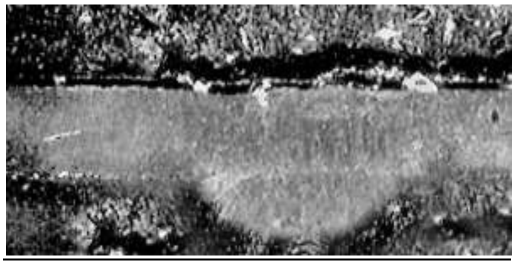

Fig. 18 Macro Photograph: Shows the spot welded Aluminium to the Stainless steel. The top shows the s.s. sheet and the bottom shows the Aluminium.

4.6. SCANNING ELECTRON MICROSCOPE IMAGES (SEM micrographs)

The SEM micrographs have been taken for the strongest and the weakest weld on both the combinations (SS-MS and SS-Al).The SEM structures are shown in the following study.

4.6.1. STAINLESS STEEL – MILD STEEL

STAINLESS STEEL – MILD STEEL (Strong Weld)

The figure.20a and figure.20.b shows the SEM micrograph for the strongest weld made in stainless steel -mild steel combination.The weld condition for this weld is 6 KVA of welding current, 600 cycles of welding time and 175Kgf of electrode force.

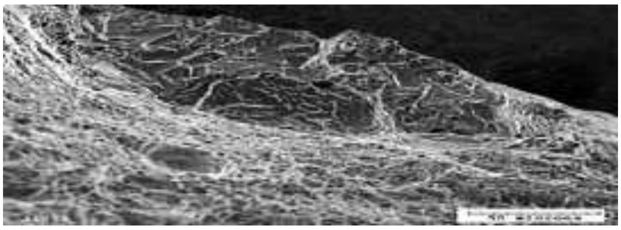

Fig.20.a. SEM micrograph

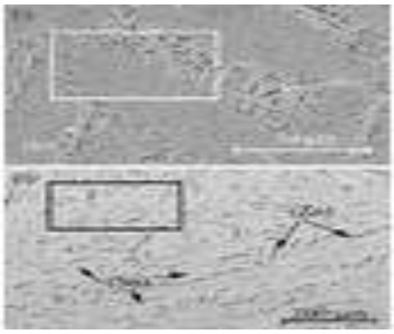

Fig.20.b. SEM micrograph

STAINLESS STEEL – MILD STEEL (Weak Weld)

The figure.21 shows the SEM micrograph for the strongest weld made in stainless steel -mild steel combination.The weld condition for this weld is 4 KVA of welding current, 400 cycles of welding time and 150 Kgf of electrode force.

Fig.21. SEM micrograph

4.6.2. STAINLESS STEEL – ALUMINIUM

STAINLESS STEEL – ALUMINIUM (Strong Weld)

The figure.22.a shows the SEM micrograph for the strongest weld made in stainless steel -Aluminium combination. The weld condition for this weld is under 5 KVA of welding current, 400 cycles of welding time and 150Kgf of electrode force.

STAINLESS STEEL – ALUMINIUM (Weak Weld)

The figure.23shows the SEM micrograph for the weakest weld made in stainless steel -Aluminium combination.

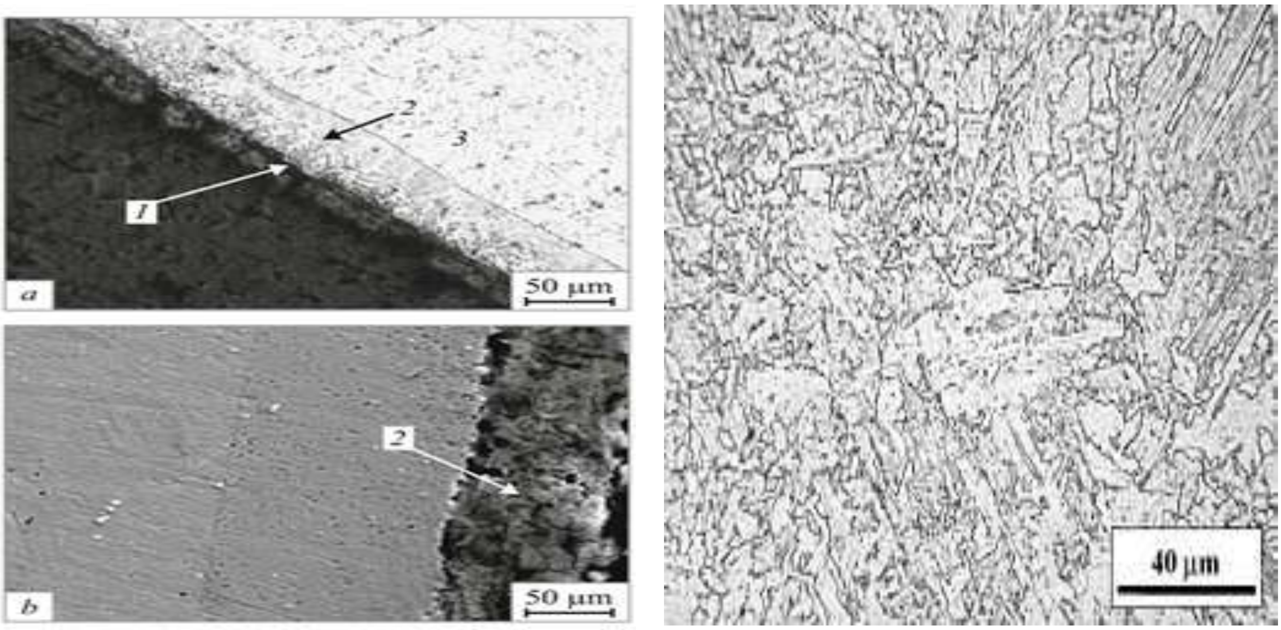

Fig.23.SEM Micrograph

The condition for this weld is under 4 KVA of welding current, 200 cycles of welding time and 150Kgf of electrode force.

CONCLUSION

By experiments on Electrical Resistance Spot Welded Specimens (Stainless steel –Aluminium& Stainless steel – Mild steel) towards Mechanical and Metallurgical properties the followings are concluded. Under the Mechanical testing Tensile shear test in Universal testing Machine (UTM), Hardness test at the nugget in Vickerne's Hardness testing machine and under metallurgical testing Macro and Microstructure were studied. The following conclusions have been made from this study,

(SS-AL)

- The maximum tensile shear load capacity of the specimen is 2.4KN obtained under 5 KVA of welding current, 400 cycles of welding time and 150Kgf of electrode force.
- The maximum hardness 97 is obtained under the condition of 5KVA of welding current, 200 cycles of welding time and 175 Kgf of electrode force.

(SS-MS)

- The maximum tensile shear load capacity of the specimen is 16.7KN obtained under 6 KVA of welding current, 600 cycles of welding time and 175Kgf of electrode force.
- The maximum hardness 97 is obtained under the condition of 5KVA of welding current, 200 cycles of welding time and 175 Kgf of electrode force.
- From the above results it has been concluded that Stainless steel has good weld quality with mild steel than with Aluminium.
- In this study it isseen thatfor maximum nugget diameter maximum tensile shear load has been obtained. From this result we can say that the nugget diameter plays a vital role regarding mechanical characteristics of the welded materials.

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