# REDUCE LEAKAGE IN CRCA FUEL TANK MANUFACTURED BY SEAM WELDING

***Kuldip Patel[1]*, Piyush Mandaliya[2], Dr. G. D. Acharya[3]***

[1]PG Scholar, AITS, Rajkot, India

[2]Prof. Mech. Engg. Dept., AITS, Rajkot, India

[3]Principal, AITS, Rajkot, India

***Abstract***

*The seam welding is one of the most popular welding techniques used in industries for leak proof welding joints. This basically uses a non-consumable welding electrode in the form of wheel. The input parameters in seam welding plays a significant role in deciding the weld quality, strength, cost and speed. In one of the company manufactured fuel tank by seam welding faces a leakage problem due to overheating. In this paper a leakage will be reduced by using full factorial design of experiment method and by using analytical method to find optimum parameter to eliminate leakage.*

***Keywords:*** *RESISTANCE SEAM WELDING, CRCA, LEAKAGE, RESISTANCE WELDING, FULL FACTORIAL DOE*

---

****Author for Correspondence*** E-mail: patelkuldip909@gmail.com, Tel: +918140604747

## 1. INTRODUCTION:

### 1.1 RESISTANCE WELDING:

Metal joining process is considered as major manufacturing and fabrication process. Manufacturing industries drive for cost reduction and productivity improvements have landed in the use of resistance welding for joining metal sheets predominantly. The need of localized joint, continuous joint developed resistance spot and resistance seam welding respectively. Major advantages of resistance welding are high working speed, suitability for automation and inclusion in high production lines with other fabrication operations. Resistance welding is most widely used in the sector of automobile industry where metal sheets are to be joined with high precision, high strength as well as quality. [10]

## 1.2 RESISTANCE SPOT WELDING:

Resistance spot welding (RSW) is a welding process in which sheet metal pieces are joined together with application of pressure and passing a large current through localized area while the sheets are fixed together. Thin sheet materials up to 6mm are joined together by overlap joints and is used mostly in the automotive industry. A typical car can have up to 5 000 spot welded joints.

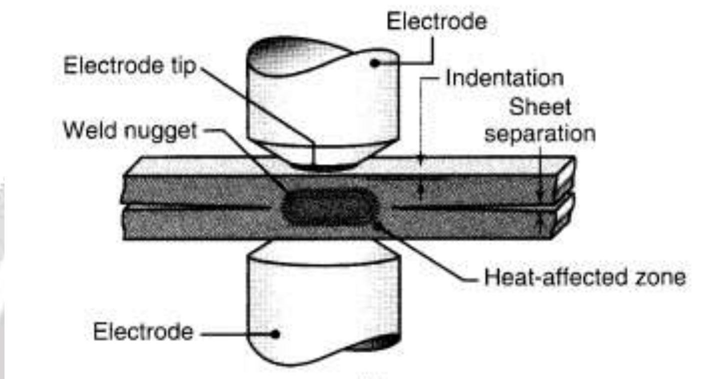


*Figure 1: Spot Welding [9]*

The high current when combined with a rapid heating time, shows efficiently used thermal energy input and very little is conducted away to the surrounding metal. Thus, spot welding has several advantages and that is why it is preferred over various other methods of welding sheet metal.

## 1.3 RESISTANCE SEAM WELDING:

Resistance seam welding (RSEW) is used for the fabrication of automotive gas tanks which require water or air tightness. Reliable welding procedures giving better quality results are required, as leakage within the system makes the tank unsafe for its desired applications. In general, the weld quality is strongly dependent on the maintenance of the RSEW machine and optimum welding parameters' selection. Originally a modification of resistance spot welding (RSW), a continuity of overlapping spot welds is produced by RSEW with the help of rotating wheel electrodes. Usage of this process gives a continuous, leak-tight joint.

The working principle of RSEW is similar to spot welding but with different electrode geometry. Two roller type electrode wheels are used to apply current and force. [6]

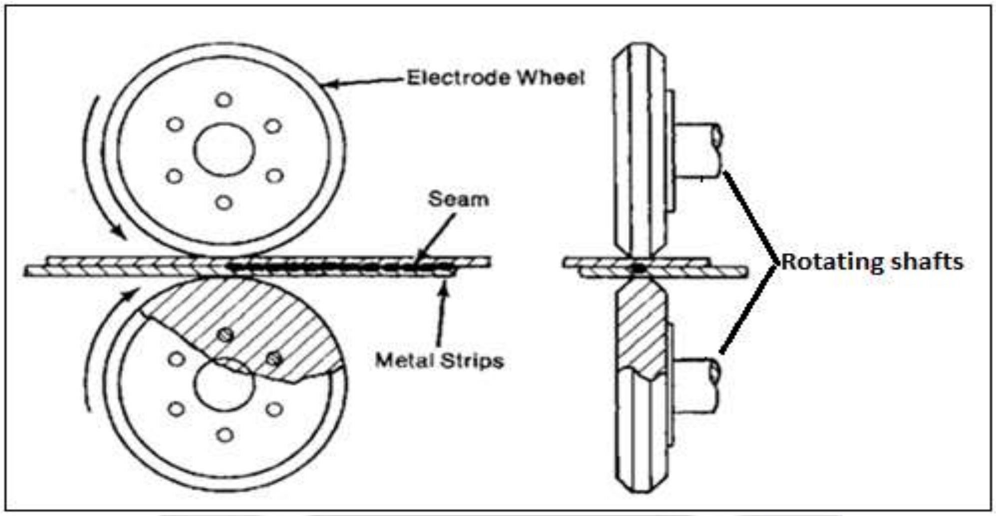


*Figure 2: Seam welding [10]*

Overlap of nugget in seam welding = (1 – b / l) * 100%

Where, b = the part of nugget outside the overlap

l = length of the last nugget in the seam weld

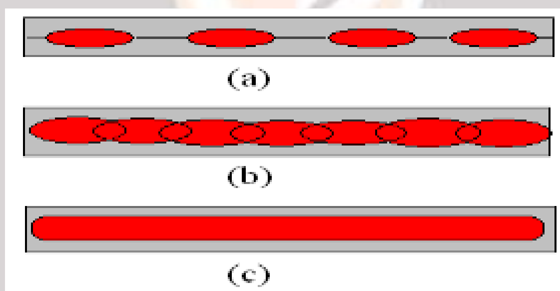


*Figure 3: Types of Seam Welding Joints [11]*

The weld joints produced by the seam welding machines have three types as shown in above figure 4. In the roll spot joint, as shown in Fig. 4(a), the weld schedule is fired at a constant repetition rate in order to form weld nuggets with distinct separation.

If the linear velocity of the circular electrodes is maintained and the firing rate of the current supplied is increased, then the spots of the weld become closer together until they overlap forming the overlap joint as shown in Fig. 4(b).

The overlapping of the nugget may vary from 10% to 50%. For gas tight joints the overlapping is from 40% to 50% and for a liquid tight joint it may vary from 10% to 40%. When the overlap is more than 50% then there is a continuous seam weld as shown in Fig. 4(c), and for which a continuous stream of energy is applied to the welding electrodes.

The velocity of the circulating electrodes in the seam welder depends on the material being welded, the sheet thickness and also on the mode of current being applied. [11]

## PROCESS PARAMETER OF RESISTANCE SEAM WELDING

- Welding Current
- Weld Time
- Electrode Force
- Welding Speed
- Sheet Thickness

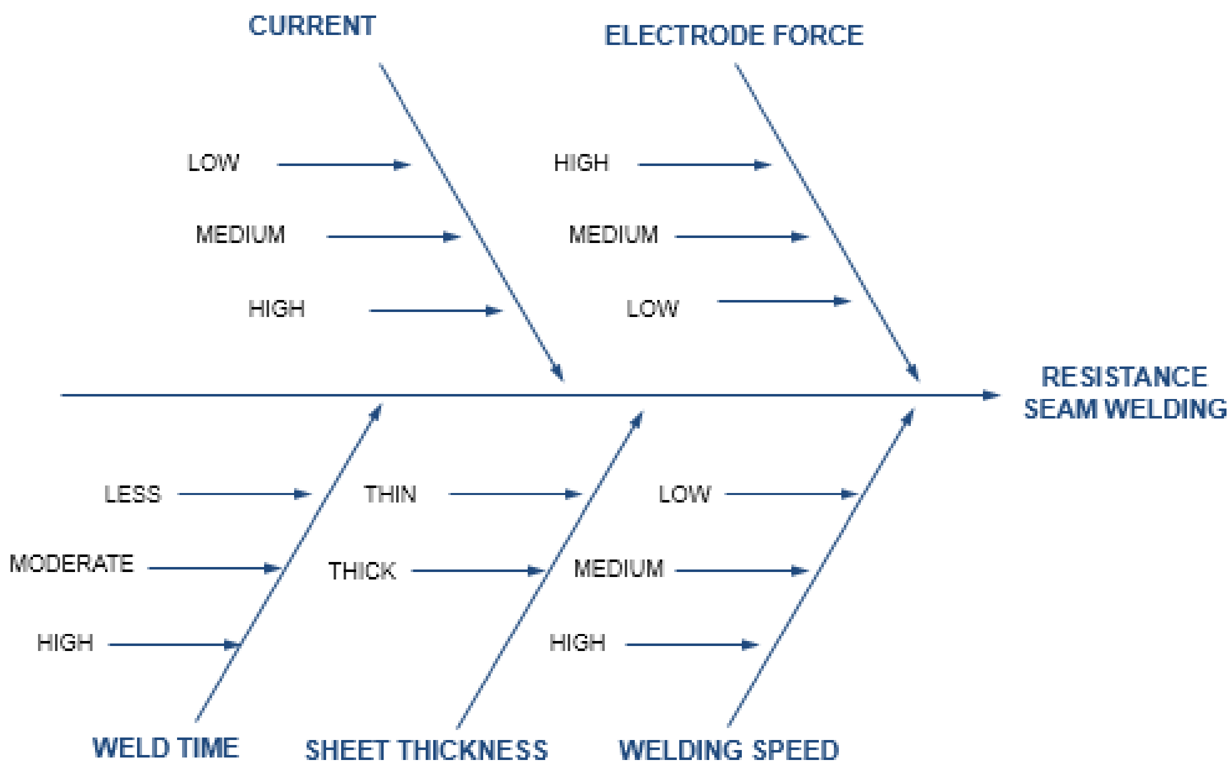


*Figure 5: Cause and Effect Diagram*

Welding current and welding speed has high effect on nugget overlap and overheating problem.

Optimum range of current and wheel speed is required to reduce leakage in fuel tank

### Seam welding machine

- Sheet thickness: 0.9 mm
- Welding Current Range : 60 – 80 A

- Welding Speed or Feed motion : 3 – 4 m/min
- Welding pressure or Air pressure : 4.5 $Kg/cm^2$
- Roller Electrode material Specification : Cr.Zr.Cu

*Figure 6: Wheel Electrode*

RWMA Class 2, ASTM UNS C - 18150

Electrode: Diameter * Thickness: 203 mm*10 mm

Hardness: 77-83 BHN

**Material Specification**

CRCA Sheet – Cold Rolled Close Annealed Steel

TATA Steelium D Grade

Equivalent to IS 513 D - CR2 D

*Table 1: Chemical Composition*

| CHEMICAL COMPOSITION | | | | | | |
|---|---|---|---|---|---|---|
| Al% | C% | Mn% | N(PPM) | P% | Si% | S% |
| 0.044 | 0.0450 | 0.190 | 22 | 0.020 | 0.006 | 0.007 |
| MECHANICAL COMPOSITION | | | | | | |
| Elongation% | Hardness (BHN) | | UTS (MPa) | | YS (MPa) | |
| 42 | 40 | | 307 | | 172 | |

## 2. BASIC PRINCIPLE OF RSEW:

The general principle of RESW is the Joule heating law. Where the heat Q, is generated depending on 3 basic factors as expressed in the following formula:

$Q_{calc} = I^2 *R *T$

$Q_{act} = 40\%* I^2 *R *T$

Where, $Q_{catc}$ = Heat generated due to current

I = Current Supplied

R = Total Resistance

T = Time Duration of Current Supply

Force is applied before, during, and after the application of electric current to maintain the electrical connectivity and to provide the pressure necessary to produce defect free seam welds. This process involves strong interactions between electrical, thermal, metallurgical, and mechanical fields

## 3. NUMERICAL CALCULATION

### 3.1 Heat required for Nugget Formation

Specific heat of material: 468 KJ/Kg℃

Density of material: 7850 Kg/m³

Melting Temperature: 1480℃

Each Sheet thickness t: 0.9 mm

So, Electrode Thickness = √ t * 5 = √0.9 * 5 = 4.743 mm

Nugget Diameter = √ t * 4 = √0.9 * 4 = 3.79 mm

Area of Nugget = 0.7853 * d² = 1.128e-5 m²

Volume of Nugget = Area of Nugget * Sheet thickness

= 1.128e-5 * 0.9e-3

= 1.0152e-8 m³

Mass of the Nugget = Volume of Nugget * Density

= 1.0152e-8 * 7850

= 0.796e-4 Kg

Heat required to melt Nugget = Mass of Nugget * Specific heat * ΔT

= 0.796e-4 * 468 * 1480

= 55.134 KJ

Thus, 55.134 KJ heat is required for 0.796e-4 Kg mass of Nugget.

### 3.2 FULL FACTORIAL DOE

In the present study the primary current values are collected from OEM and secondary currents are calculated

$$\frac{Vs}{Vp} = \frac{Ip}{Is} = \frac{Ns}{Np}$$

$$Is = \frac{Vp}{Vs} * Ip$$

Where:

Vp = Primary Voltage (Volts)

Vs = Secondary Voltage (Volts)

Ip = Primary Current (Amps)

Is = Secondary Current (Amps)

Np=Primary Turns

Ns= Secondary Turns

This seam welding equipment is used for the study consists of 5 taping. The secondary voltages are calculated from above equation

*Table 2: Voltage and Current Values in Secondary Current*

| TAPPING | 1 | 2 | 3 | 4 | 5 |
|---|---|---|---|---|---|
| Primary Voltage (Vp) | 440 | 440 | 440 | 440 | 440 |

| Primary Current (Ip) | 64 | 66 | 68 | 75 | 77 |
|---|---|---|---|---|---|
| Secondary Voltage (Vs) | 8.2 | 8.25 | 8.30 | 8.35 | 8.40 |
| Secondary Current (Is) | 3434 | 3520 | 3605 | 3952 | 4033 |

A Full factorial DOE is designed for conducting the numerical analysis in Minitab.

The number of variable selected for the DOE are current and Weld cycle. To have a wider range, weld cycle of 3 set i.e. 0.05, 0.06, 0.07 seconds are selected along with 5 set of secondary current i.e. 3434A, 3520A, 3605A, 3952A, 4033A

Resistance for material is 0.147 Ω.

Full factorial DOE for RSEW

*Table 3: Full factorial DOE for RSEW*

| Sr. No | Current(A) | Time(sec) |
|---|---|---|
| 1.1 | 3434 | 0.05 |
| 1.2 | 3520 | 0.05 |
| 1.3 | 3605 | 0.05 |
| 1.4 | 3952 | 0.05 |
| 1.5 | 4033 | 0.05 |
| 2.1 | 3434 | 0.06 |
| 2.2 | 3520 | 0.06 |
| 2.3 | 3605 | 0.06 |
| 2.4 | 3952 | 0.06 |
| 2.5 | 4033 | 0.06 |
| 3.1 | 3434 | 0.07 |
| 3.2 | 3520 | 0.07 |
| 3.3 | 3605 | 0.07 |
| 3.4 | 3952 | 0.07 |
| 3.5 | 4033 | 0.07 |

*Table 4: Full Factorial DOE values*

| DOE No. | Identification no. | Heat transfer Values |
|---|---|---|

| | | |
|---|---|---|
| DOE-1 | $Q_{1.1}$=0.4*(3434)$^2$*0.147*0.05<br>$Q_{2.1}$=0.4*(3434)$^2$*0.147*0.06<br>$Q_{3.1}$=0.4*(3434)$^2$*0.147*0.07 | 34.669 KJ<br>41.603 KJ<br>48.537 KJ |
| DOE-2 | $Q_{1.2}$=0.4*(3520)$^2$*0.147*0.05<br>$Q_{2.2}$=0.4*(3520)$^2$*0.147*0.06<br>$Q_{3.2}$=0.4*(3520)$^2$*0.147*0.07 | 36.427 KJ<br>43.713 KJ<br>50.998 KJ |
| DOE-3 | $Q_{1.3}$=0.4*(3605)$^2$*0.147*0.05<br>$Q_{2.3}$=0.4*(3605)$^2$*0.147*0.06<br>$Q_{3.3}$=0.4*(3605)$^2$*0.147*0.07 | 38.208 KJ<br>45.849 KJ<br>53.491 KJ |
| DOE-4 | $Q_{1.4}$=0.4*(3952)$^2$*0.147*0.05<br>$Q_{2.4}$=0.4*(3952)$^2$*0.147*0.06<br>$Q_{3.4}$=0.4*(3952)$^2$*0.147*0.07 | 45.917 KJ<br>55.101 KJ<br>64.284 KJ |
| DOE-5 | $Q_{1.5}$=0.4*(4033)$^2$*0.147*0.05<br>$Q_{2.5}$=0.4*(4033)$^2$*0.147*0.06<br>$Q_{3.5}$=0.4*(4033)$^2$*0.147*0.07 | 47.819 KJ<br>57.383 KJ<br>66.997 KJ |

By comparing values in above Table with 55.134 KJ heat is required for 0.796e-4 Kg mass of Nugget.

It is observed that $Q_{3.3}$ in DOE-3, $Q_{2.4}$, $Q_{3.4}$ in DOE-4 and $Q_{2.5}$, $Q_{3.5}$ in DOE-5 has heat transfer value 55.134 KJ, which is required to melt the mass of the nugget.

Thus it is evident that parameters from DOE-3, DOE-4 and DOE-5 are used to carry out for experiment.

## 4. EXPERIMENT WORK:

Overlap of nugget in seam welding = (1 – b / l) * 100%

Where, b = the part of nugget outside the overlap

l = length of the last nugget in the seam weld

For gas tight joints the requirement of overlapping is from 40 % to 50 %.

For liquid tight joint the requirement of overlapping is from 10 % to 40 %.

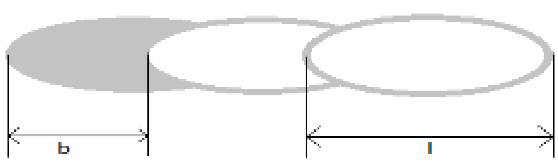


*Figure 7: Nugget overlap*

*Table 5: Experiment on Fuel tank*

| DOE No. | Current (A) | Time (sec) | b (mm) | l (mm) | Overlap (%) | Heat transfer Values | Leakage | Remark |
|---|---|---|---|---|---|---|---|---|
| $Q_{1.3}$ | 3605 | 0.05 | 3.50 | 5.46 | 35.89 % | 38.208 KJ | YES | < 40% |
| $Q_{2.3}$ | 3605 | 0.06 | 3.46 | 5.58 | 37.99 % | 45.849 KJ | YES | < 40% |
| $Q_{3.3}$ | 3605 | 0.07 | 3.42 | 5.89 | 41.93 % | 53.491 KJ | NO | 40-50% |
| $Q_{1.4}$ | 3952 | 0.05 | 3.45 | 5.56 | 37.94 % | 45.917 KJ | YES | < 40% |
| $Q_{2.4}$ | 3952 | 0.06 | 3.41 | 5.98 | 42.97 % | 55.101 KJ | NO | 40-50% |
| $Q_{3.4}$ | 3952 | 0.07 | 3.24 | 7.04 | 53.97 % | 64.284 KJ | YES | > 50% |
| $Q_{1.5}$ | 4033 | 0.05 | 3.43 | 5.62 | 38.96 % | 47.819 KJ | YES | < 40% |
| $Q_{2.5}$ | 4033 | 0.06 | 3.39 | 6.16 | 44.96 % | 57.383 KJ | NO | 40-50% |
| $Q_{3.5}$ | 4033 | 0.07 | 3.21 | 7.29 | 55.96 % | 66.997 KJ | YES | > 50% |

From experiment, it is concluded that $Q_{3.3}$, $Q_{2.4}$, and $Q_{2.5}$ is the optimum range where no Leakage is found.

As shown in below diagram of heat transfer values to overlap, at points $Q_{3.4}$ and $Q_{3.5}$ burning of faying surface occurs due to its higher value of current and time.

In $Q_{3.4}$ and $Q_{3.5}$ leakage occurs due to high heat transfer values.

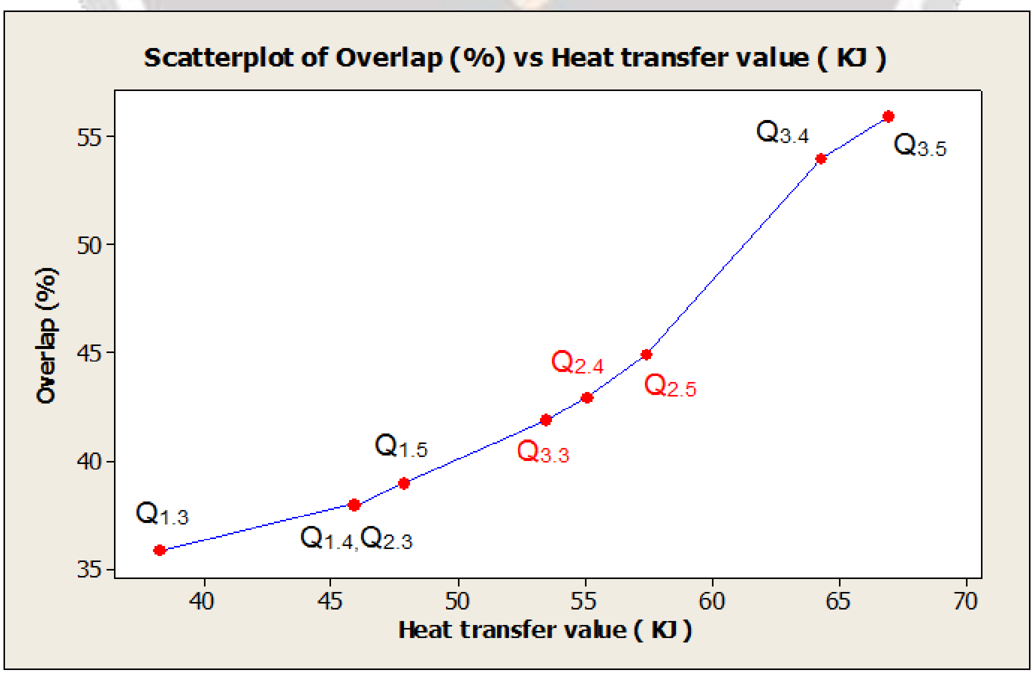

*Figure 8: Graph of Overlap versus Heat transfer value*

## 5. Conclusion:

In this work, RSEW method is used to weld CRCA sheets. Effects of welding parameters on the welding joints were studied. The major results obtained from this study were as following:

1) The resistance seam welding process is greatly dependent on its process parameters like Welding current, Electrode force, Weld time and Welding speed.
2) The most affecting factor among all process parameters is welding current.
3) The optimum range of welding speed and current is required to achieve good quality weld.
4) Materials with electric conductivity, with different thickness can also be joined easily by resistance seam welding.
5) Difficult weldable materials like Aluminum are also weld able by resistance welding with high welding currents.

## 6. References:

[1] Prasant Kumar V.K., “Parameter Selection for Resistance Spot Welding Through Thermal Analysis of 2mm CRCA Sheets”, Elsevier, Procedia Materials Science 5 ( 2014 ) 369 – 378

[2] Avishi Gupta, Dr. K. M. Moeed, “Experimental Analysis of Leakages in Seam Welding by Controlling Seam Welding Parameters”, International Journal of Engineering Technology, Management and Applied Sciences. April 2015, Volume 3 Issue 4, ISSN 2349-4476

[3] Alireza Khosravi , Ayyub Halvaee , Mohammad Hossein Hasannia, “Weldability of electrogalvanized versus galvanized interstitial free steel sheets by resistance seam welding”, Elsevier, Materials and Design 44 (2013) 90–98.

[4] Hessamoddin Moshayedi, Iradj Sattari-Far, “Numerical and experimental study of nugget size growth in resistance spot welding of austenitic stainless steels”, Elsevier, Journal of Materials Processing Technology 212 (2012) 347– 354”

[5] Ali. Moarrefzadeh, “Study of Heat Affected Zone (HAZ) in Resistance Welding Process”, Journal Of Mechanical Engineering Vol. 1, No. 1, January 2012.

[6] N Muhammad and YHP Manurang, “Analysis on Development of Transverse - Sectioned Weld Zone using FEM Verified with Multipulsed Resistance Seam Welding”, TJER 2013, Vol. 10, No. 2, 78-86, 2 March 2013.

[7] V. Jalilvand, H. Omidvar & H. Khorrami, “Effect of welding parameters on the mechanical properties of AA2024 aluminium alloy joints welded by resistance seam welding”, The Canadian Journal of Metallurgy and Materials Science, ISSN: 0008-4433 (Print) 1879-1395.

[8] S. Aslanlar, A. Ogur, U. Ozsarac , E. Ilhan, ”Welding time effect on mechanical properties of automotive sheets in electrical resistance spot welding”,Elsevier, Materials & Design 9 March 2007.

[9] Prajakta Patil, “Resistance Spot Welding of CRCA Steel sheets using surface modified electrodes.”, International Journal of Innovative Research in Advanced Engineering (IJIRAE) ISSN: 2349-2163, Volume 1 Issue 6 (July 2014)

[10] Aditya S. Kulkarni, Dr. K. H. Inamdar, “Effect of Process Parameters on Resistance Welding”, JETIR (ISSN-2349-5162), April 2015, Volume 2, Issue 4 JETIR.

[11] J. Saleem, A. Majid, K. Bertilsson, T. Carlberg, “3 Dimensional Finite Element Simulation of Seam Welding Process”, ISSN 1392-1215, VOL. 19, NO. 8, 2013.

[12] T. Mira-Aguiar & C. Leitao & D. M. Rodrigues, “Solid-state resistance seam welding of galvanized steel”, Int J Adv Manuf Technol, 21 December 2015.

[13] Satish Garg, SS Banwait and Ravneet Kumar, “Optimisation of High Frequency Seam Welding Parameters By Taguchi Method”, Asian Journal of Engineering and Applied Technology, ISSN 2249-068X Vol. 2 No. 2, 2013, pp.78 – 83.

[14] Julio Molleda, Juan L. Carus , Ruben Usamentiaga, “A fast and robust decision support system for in-line quality assessment of resistance seam welds in the steelmaking industry” Elsevier, Computers in Industry 63 (2012) 222–230

[15] Hidekazu MURAKAWA, Hiroyuki MINAMI, Toshihito KATO, “Finite Element Simulation of Seam Welding Process”, JWRI, Vol 30, 2001

[16] A.G.Thakur, T.E.Rao, M.S.Mukhedkar, V.M.Nandedkar, “Application of Taguchi Method for Resistance Spot Welding Of Galvanized Steel”, ARPN Journal of Engineering and Applied Sciences, ISSN 1819-6608, VOL. 5, NO. 11, NOVEMBER 2010

[17] P.S.Wei, T.H.Wu, “Electrical contact resistance effect on resistance spot welding”, Elsevier, International Journal of Heat and Mass Transfer 55 (2012) 3316–3324