Resistance Spot Welding of CRCA Steel sheets using surface modified electrodes.

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Abstract*— Resistance spot welding has established itself across a wide range of industries as a cost-effective method for welding. One of the problems of Resistance Spot Welding is the lifetime of welding electrode tips which affects the quality of the welds formed. An innovative way to prevent the electrode wear is to plate the surface of the electrode with suitable material. The material chosen in this study is Nickel and Chromium. Plating of these materials is inexpensive and easily available. The increase in resistance due to plating the electrodes is measured. The metals are plated on the surface with varying thicknesses separately and their effect on ultimate load, shear stress and nugget diameter is observed by varying welding current and keeping the weld time and welding pressure constant. It is investigated from the study that Ni plating with 35 microns thickness and Cr plating with 25 microns thickness requires less current to weld spots of higher strengths compared to non plated electrodes. This is due to increase in resistance of the weld system due to plating which requires less current as resistance of the weld system is increased.

Keywords*— *Chromium plating, Nickel plating, Resistance, Resistance spot welding, ultimate load.

I. INTRODUCTION

The term welding is used to cover a wide range of bonding techniques. Now-a-days many processes of welding have been developed and probably there is no industry which is not using welding process in the fabrication of its products in some form or the other. This is the most easiest and fast way of fabrication and assembly of metal parts. The research carried out in this field has given various ways and methods to weld practically all metals. Even dissimilar metals can be welded. One beauty of welding in comparison to other processes of joining metals is that by this process we can have more than 100% strength of joints and it is very easy process.

Resistance Welding is a group of welding processes where a heavy electric current is passed through the metal to be joined over a limited area, causing them to be locally heated to plastic state and the weld is completed by the application of pressure for a prescribed period of time. No additional filler metal is used. In this process two copper electrodes are used and the metal to be welded is pressed between the electrodes. The current is passed through the electrode which incorporates very low resistance in the circuit and the resistance at the joints of the metal is very high. The maximum heating is produced at the point of contact of contact where weld is to be made. [1]

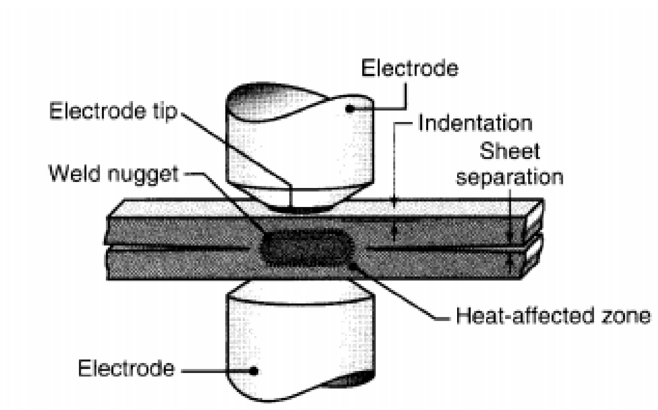

Fig 2.1: Cross section of a spot weld, showing the weld nugget and the indentation of the electrode on the sheet surfaces.

The magnitude of the current, the resistance of the current conducting path, and the time for which the current is made to flow account for the heat generated in the workpiece. This can be expressed in terms of Joule heating, by the simple application of Ohm's law the voltage (V) required for a current flow (I) is given by the relationship

$$V = IR \quad (2.1)$$

Where, R = Resistance offered by the workpiece to the flow of current.

Therefore the Heat generated is expressed by the formula,

$H = IVt$

$H = I\,(IR)\,t$

$H = I^2Rt$

Where, H = Heat generated, Joules
I = Current, Amperes
R = Resistance, Ohms
t = Time of current flow, seconds

The heat generated is therefore directly proportional to the resistance offered by any point in the circuit. The interface of the two sheets forming a lap joint is the point of greatest resistance, and is therefore the point of greatest heat generation. Low voltage high amperage current is made to flow from one sheet to another sheet until the metal at the interface is heated to a temperature high enough to cause localized fusion which under the applied pressure squeezes the molten metal from the two parts to a homogeneous mass called the weld nugget. [2] The amount of current needed for welding is inversely proportional to the duration of time and directly proportional to the area in contact.

One of the major challenges in spot welding is the extraordinary short cap life. The electrodes used often require tip dressing or replacement within a fraction of time, which would increase the cycle time and production cost significantly. [3]. Wearing of electrode adversely affects cost and productivity of assembly welding cause of reduced reliability, weld quality, and robustness. This mandates increased inspection rates and greater control of welding parameters. Hence, quality improvements and large potential cost savings are expected from substantial improvements in electrode life. [4]

Generally, the summary of literature review have found that various approaches, such as selecting the proper process variables, electrode designs and materials, and humanizing the cooling system results in improvement of electrode life. But these ways only help prolong the electrode wear and do no good to prevent the electrode wear. In order to enhance the life of electrode, plating the electrode surface with a suitable material will prevent direct contact between the electrode and the sheet that is to be welded.

Mechanical testing is one of the important aspect of weld ability study. Such testing is either for revealing important welds characteristics, such as weld nugget diameter or weld button size, or for obtaining and evaluating the quantitative measures of weld’s strength. Mechanical testing of a weldment can be static or dynamic test and among the static test, tension shear or tensile shear testing is commonly used in determining the maximum load that a weld can sustain before it fails, because it is easy to conduct the test and the specimens for the test is simple in fabrication.

II. EXPERIMENTAL DETAILS

The material used for the experiments is Cold Rolled Close Annealed Steel sheets of 1.6mm thickness. The composition and the properties of the CRCA sheets are given in the table. The material used is a Tata Steel product TDC NO: PN02 Grade: DQ used in electrical Panel fabrication.

Table 4.1: Metal composition of CRCA Steel sheets. [5]

% C	% Mn	% Si	% S	% P	% Al	% B
0.02 -0.06	0.1 - 0.25	0.03	0.01	0.02	0.021 - 0.06	0.002

III. WELDING PROCESS

Set of welding specimens were made as follows: The weld time and electrode pressure were constraints and the welding current was varied to obtain different weld joints. In this work all the specimens were a single weld. Electrode pressure was set to be a constant at 0.8 MPa (8 bar). Welding time was set to be constant at 30 milliseconds. And the welding current varied in the range from 60 Amperes to 100 Amperes in the intervals of 10 Amperes.

The electrode caps were plated with Chromium and Nickel with 15, 25, 35 and 45 microns separately, that makes overall 8 pairs of electrode caps to be used. Therefore for chrome plated electrode caps with varying current range from 60, 70, 80, 90 and 100 Amperes 20 specimens were made. Similarly for nickel plated electrode caps 20 specimens were made. Therefore in this work a total of 40 specimens were made plus 5 specimens with bare Copper electrode caps were made.

IV. WELDING EQUIPMENT

The RSW equipment employed in this investigation is a standard pneumatically operated PRIMA Spot 65, single phase machine with transformer capacity (45Kva) used to weld sheets up to 2mm thickness each (2+2). The Electrode caps used are manufactured at PRECISION Delhi. Class 2 Copper Chromium electrode caps which are domed shape. Specification: RWMA Class 2 Copper USN C18200.

Fig 4.3: Photograph of Class 2 Copper Chromium electrode.

V. RESISTANCE MEASUREMENT

Static resistance of uncoated electrodes with the workpiece material held in between the electrodes was measured using an Ohm meter without passing electric current. Static resistance of electrodes coated with Chromium and Nickel are also to be measured similarly and change in resistance is noted.

VI. MEASUREMENT OF STATIC RESISTANCE

The presence of a thin coating on the electrode surface affects the resistance of the weld system and hence the weld behaviour. Therefore, static resistance of the weld systems of both uncoated and coated electrodes is measured using a milliohm meter. To simulate the resistance experienced during actual welding, measurements are taken with two CRCA steel sheets between the electrodes held together without welding current held under pressure. Average resistance was obtained by three random measurements for uncoated and coated electrodes at different positions, respectively. For uncoated electrodes the average resistance measured is 147 mΩ. The measured average resistance for the Nickel and Chromium plated electrodes of varying thicknesses are shown in the graph below. It clearly showed that the plating on electrode surface increased the resistance of weld system. The lower resistance for non plated electrode system was owing to smooth surface and softness of non plated electrode compared to the plated electrode, resulting in a lower contact resistance. On the contrary, the plated electrode with a hard metal coating corresponded to a relatively high contact resistance.

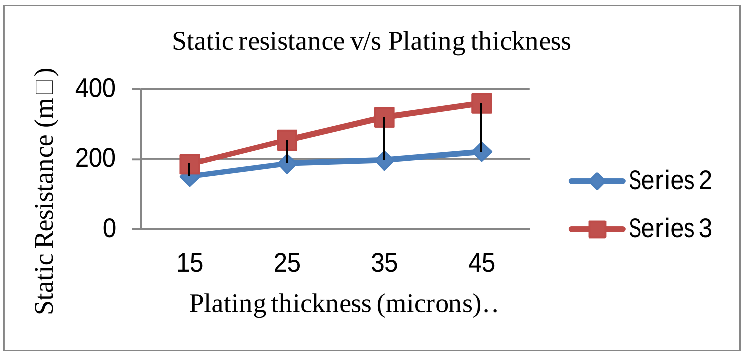

Fig 5.1: Effect of platting thickness on static resistance of the weld system.

It can be seen that the static resistance of Chromium plated electrode caps is more than that of nickel coated electrode caps as well as non plated electrode caps. Nickel coated electrode caps also show higher resistance than non plated electrodes.

VII. TENSILE SHEAR TEST

The tensile shear load of joints increased with the increasing of the welding current and time. It is owed to the increasing of the nugget diameter, which is a major influence factor for joint strength in shear fracture. With increase in current for the various electrode platting there are variations in the maximum load carrying capacity of the welds i.e., the ultimate load or maximum load for welds is varying. The variations in Ultimate load are shown below with the help of graphs. The tables below show the peak or maximum or ultimate load that a weld can sustain before it fails, along with the nugget diameters and ultimate shear stresses.

The ultimate shear stress is calculated as follows:

Ultimate shear stress = Ultimate Load / Area on which the load acts.

Ultimate load is in kN

Area is in mm^2

Ultimate shear stress = peak load / $[(\Pi / 4) * d^2]$

$= 9.16 * 1000 / [(\Pi / 4) * (4.6)^2]$

$= 556 \text{ N} / mm^2$

Table 5.1: Non plated electrode

Current (A)	60	70	80	90	100
Peak load (kN)	4.04	7.20	9.16	9.40	9.0
Nugget diameter (mm)	3.5	4.3	4.6	4.8	5
Shear stress (N/mm^2)	420	495	556	505	458

Table 5.2: 15 microns thickness chromium plated electrode.

Current (A)	60	70	80	90	100
Peak load (kN)	4.04	7.36	8.64	8.80	8.0
Nugget diameter (mm)	3.6	4.3	4.5	4.7	4.9
Shear stress (N/mm^2)	397	507	543	507	424

Table 5.3: 15 microns thickness nickel plated electrode.

Current (A)	60	70	80	90	100
Peak load (kN)	4.20	7.36	7.72	9.32	9.56
Nugget diameter (mm)	3.6	4.2	4.7	4.9	5
Shear stress (N/mm^2)	413	531	444	494	486

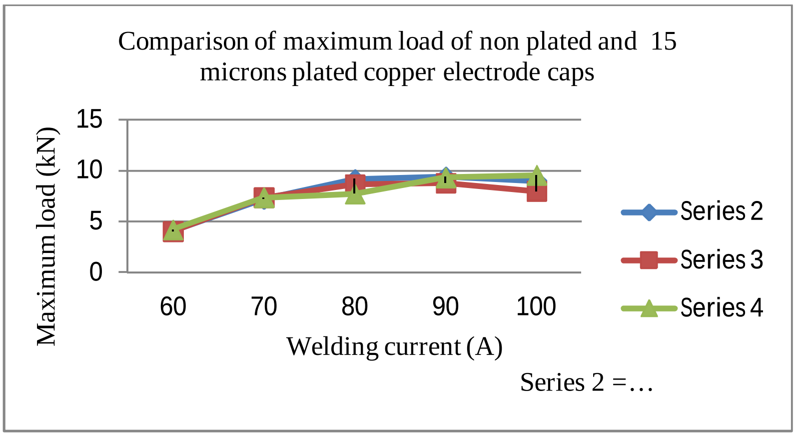

Fig 5.2: Effect of welding current and 15 microns plating on maximum load carrying capacity.

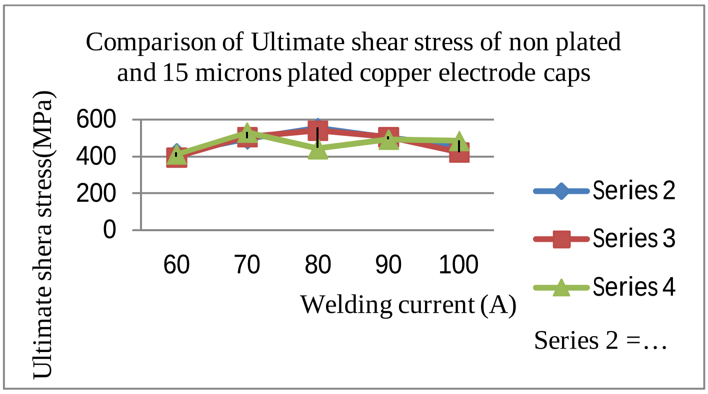

Fig 5.3: Effect of welding current and15 microns plating on ultimate shear strength.

From the graph shown above it can be seen that for platting thickness of 15 microns and varying current maximum load carrying capacity of non plated electrode is compared with that of Ni and Cr coated electrodes. It can be seen that 15 microns has no significant effect on maximum load carrying capacity as well as the ultimate shear stress when compared to that of non plated electrode.

Table 5.4: 25 microns thickness chromium plated electrode.

Current (A)	60	70	80	90	100
Peak load (kN)	5.44	8.52	8.96	7.92	8.76
Nugget diameter (mm)	3.6	4.3	4.5	4.8	5
Shear stress (N/mm^2)	534	586	563	438	446

Table 5.5: 25 microns thickness nickel plated electrode.

Current (A)	60	70	80	90	100
Peak load (kN)	4.08	6.24	9.0	9.20	9.36
Nugget diameter (mm)	3.7	4.1	4.7	4.8	5
Shear stress (N/mm^2)	380	472	525	508	477

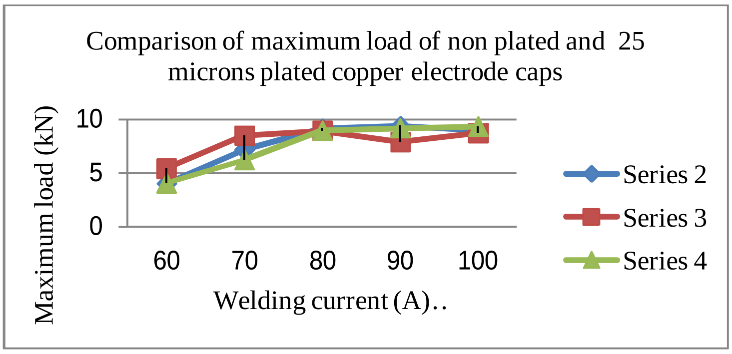

Fig 5.4: Effect of welding current and 25 microns plating on maximum load carrying capacity.

For 25 microns thickness it is seen that as compared to non plated electrode, the Cr plated electrode shows greater load carrying capacity at relatively less welding current. For non plated electrode maximum load is observed at 80A and 90A. Whereas for 25 microns Cr plated electrode higher maximum load carrying capacity is observed at 70A and 80A, which is due to the increased resistance of the weld system.

As the resistance is increased the current consumption is reduced to attain that range of maximum load which non plated electrode welded welds could attain at 80A - 90A. Beyond this the load is observed to be reduced. For Ni plated electrode there is no significant change as compared to non plated electrode.

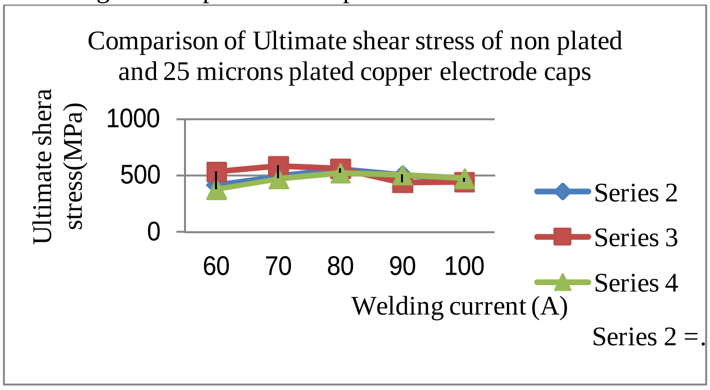

Fig 5.5: Effect of welding current and 25 microns plating on ultimate shear strength.

Table 5.6: 35 microns thickness chromium plated electrode.

Current (A)	60	70	80	90	100
Peak load (kN)	4.60	7.48	7.60	9.0	9.20
Nugget diameter (mm)	3.6	4.2	4.6	4.8	5.1
Shear stress (N/mm^2)	452	540	458	497	450

The ultimate shear stress of 25 microns plated electrode is higher as compared to uncoated electrode. Ni plated electrode shows no significant increase.

Table 5.7: 35 microns thickness nickel plated electrode.

Current (A)	60	70	80	90	100
Peak load (kN)	4.22	7.24	9.12	9.52	7.9
Nugget diameter (mm)	3.6	4.2	4.5	4.85	5.15
Shear stress (N/mm^2)	415	523	574	516	380

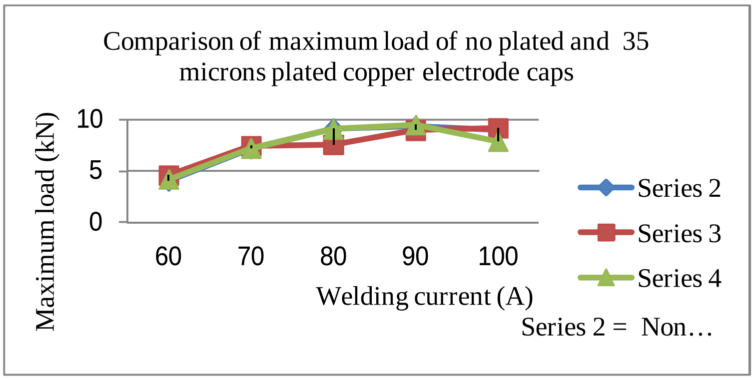

Fig 5.6: Effect of welding current and 35 microns plating on maximum load carrying capacity.

As can be seen from the graph above the maximum load carrying capacity is higher for 35 micron Ni coated electrode as compared to that of uncoated electrode. Cr plated electrode shows no reduction in as compared to the previous case of 25 microns. The expected reason for this is due to increase in resistance more heat is generated and hence welds are not relatively strong.

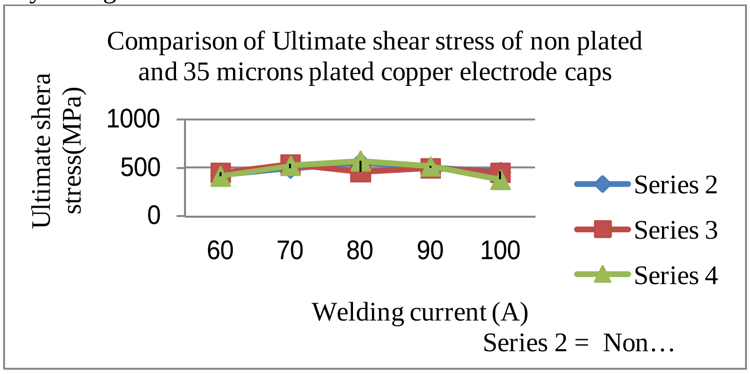

Fig 5.7: Effect of welding current and 35 microns plating on ultimate shear strength.

At 35 microns the ultimate shear stress of welds welded with Ni plated electrodes show higher values of ultimate shear stress as compared to that of uncoated electrodes. As Cr resistance is more the welds formed with 35 microns thickness generate more heat which is not suitable.

Table 5.8: 45 microns thickness chromium plated electrode.

Current (A)	60	70	80	90	100
Peak load (kN)	4.48	6.72	7.68	7.76	8.28
Nugget diameter (mm)	3.6	4.2	4.65	4.8	4.95
Shear stress (N/mm^2)	440	485	452	428	430

Table 5.9: 45 microns thickness nickel plated electrode.

Current (A)	60	70	80	90	100
Peak load (kN)	3.40	6.80	7.08	9.0	9.76
Nugget diameter (mm)	3.5	4.2	4.5	4.75	5.15
Shear stress (N/mm^2)	353	490	445	508	469

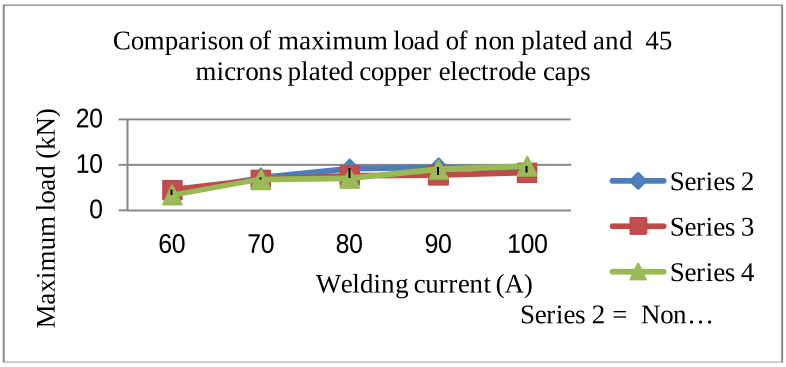

Fig 5.8: Effect of welding current and 45 microns plating on maximum load carrying capacity.

The graph shows that as the resistance of the weld system is more as compared to uncoated electrode 45 microns Ni and Cr plated electrode generate more heat due to which the welds obtained are not strong.

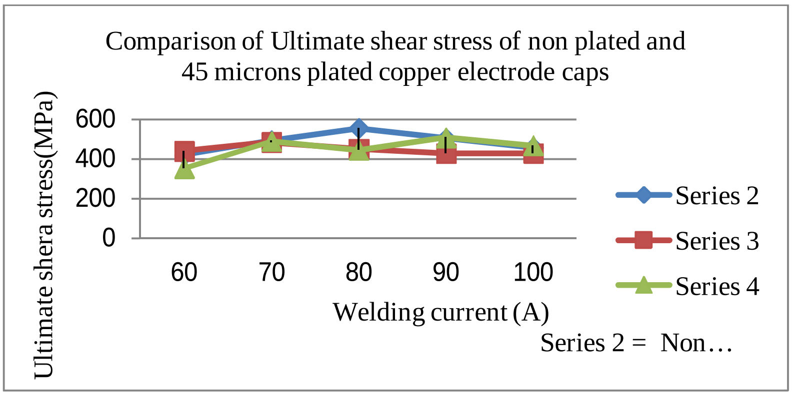

Fig 5.9: Effect of welding current and 45 microns plating on maximum load carrying capacity.

The ultimate shear stress of non plated electrode welds are having higher shear stress than that Ni and Cr plated electrode welds this is again expected to be due to more heat generation due to increase in resistance of the weld system. Increasing the thickness of the plating can result in harder electrode surface as a result of which cracks on the pated surface after a considerable increase in number of welds. By plating the electrodes as Ni and Cr have hardness high as compared to non plated electrode it is expected to wear late after giving more welds as compared to non plated electrodes.

Nugget diameter:
After the specimens were tested for ultimate load beyond which the specimens failed. The nugget diameter of the welds is measured. The nugget diameter is measured using Brinell microscope. It is observed that in all the cases i.e., for uncoated as well as coated electrodes the nugget diameter increases with increase in welding current. The nugget diameter in all the cases is found to be in the range of 3√t to 6√t, where t = thickness of the sheet in mm.

VIII. CONCLUSION

In this study it is investigated that the heat required for the resistance welding process is produced by the resistance of the work pieces to an electric current passing through the material. Because of the short electric current path and limited weld time, relatively high welding currents are required to develop the necessary welding heat. The amount of heat generated depends upon three factors: (1) the amperage, (2) the resistance, and (3) the duration of current. These three factors affect the heat generated as expressed in the formula $H = I^2Rt$, where H is the heat generated (joule), I the current (ampere), R the resistance (Ω), t is the duration of current (second).

- In this research, the nugget diameter changes as the weld current respectively as shown in the specimen. It is observed from this study that nugget diameter is insufficient with low welding current and it increases with increase in welding current.
- It is observed from the experiments that the coated electrodes have higher resistance than non coated electrode. Ni and Cr platting is least expensive and easily available.
- The effects of varying coating thickness are examined in this study which shows that with increase in plating thickness the ultimate load of welds increases up to a certain limit and then decreases. The welding current required to make acceptable welds using a non plated electrode was reduced using a plated electrode.
- Out of the two materials chosen to be platted on the electrodes the Cr plated electrodes with 25 microns thickness showed higher ultimate load with less current consumption as required with non plated electrodes.
- Ni plated electrodes with 35 microns also showed higher ultimate load than the non plated electrodes. These higher ultimate loads are achieved with comparatively less current consumption.

Ideally where 80 A - 90 A welding current where suitable current range to obtain satisfactory welds with non plated electrode. The current requirement to obtain satisfactory weld with plated electrodes was 70 A - 80 A.

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