iJRASET
International Journal For Research in
Applied Science and Engineering Technology

INTERNATIONAL JOURNAL FOR RESEARCH

IN APPLIED SCIENCE & ENGINEERING TECHNOLOGY

Volume: 7 **Issue:** XI **Month of publication:** November 2019

DOI: http://doi.org/10.22214/ijraset.2019.11045

International Journal for Research in Applied Science & Engineering Technology (IJRASET)
ISSN: 2321-9653; IC Value: 45.98; SJ Impact Factor: 7.177
Volume 7 Issue XI, Nov 2019- Available at www.ijraset.com

Effect of Electrode Materials type on Resistance Spot Welding of AISI 304 Austenitic Stainless Steel (ASS) Sheets

Ali Güray Ertem[1], Yahya Altunpak[2]
[1, 2]Abant Izzet Baysal University, Faculty of Engineering, Mechanical Engineering, 14280, Bolu, Turkey

***Abstract:** In this study, AISI 304 austenitic stainless steel sheets (ASS) with 0.6 mm thickness was joined by resistance spot welding using two different electrode materials. The effects of CuCo2Be and CuCrZr electrode materials and two different welding parameters (time and current) on the mechanical properties of welded samples are defined in terms of peak load. The hardness and tensile shear load bearing capacity of weldment was determined and the microstructure and macrosutructure of welded samples was also evaluated. The most suitable welding parameters for each electrode material were determined. In the welding study, weld parameters giving maximum tensile strength were determined in different electrode and cooling conditions.*
***Keywords:** Resistance spot welding; CuCrZr electrode; CuCo2Be electrode, austenitic stainless steel*

I. INTRODUCTION

The most commonly used welding method in the industries is resistance spot welding (RSW). Especially, automobile and white goods structural assemblies contain a few thousands of spot welds. For example, 0.6 mm austenitic stainless steel sheet is heavily used in the white goods industry. Austenitic stainless steels (ASS) are widely used in industrial applications due to their durability, corrosion resistance, mechanical machinability, excellent electrical conductivity and thermal properties [1]. It is more advantageous in terms of strength, ductility and hardness than other types of stainless steel [2]. The researchers investigated the effect of different welding parameters on spot welding of AISI 304 stainless steel. For this purpose, macro and microstructure of welded parts were evaluated and their hardness and tensile strengths were examined. [3, 4]. In another study, the effect of different welding atmospheres on the welding quality of 304L stainless steel resistance spot welding was investigated and it was tried to obtain optimum welding quality [5]. In a welding study with AISI 316L austenitic stainless steel, an increase in the tensile strength of the weld was observed with increasing welding current. In the weld region, the columnar structure was formed parallel to the electrode compression direction of the grains, and in the HAZ region the particle size increased compared to the base metal [6]. 304 stainless steel spot welding investigated the effect of the cooling rate and stated that the cooling rate affects both the weld zone hardness and weld strength [7].

CuZr, CuCrZr, CuCo2Be, CuCoNiBe, CuNiSi, CuNiSiCr, CuW and others. etc. materials are used for tip production in the resistance spot welding of hard sheet materials such as stainless steels. For example, high-conductivity alloys consist of Be from 0.2 % to 0.7 % and higher content of Ni and Co.When welding stainless steels, much higher electrode forces are required but lower welding current [8]. When the literature is examined, there are many studies on the welding ability of different steels and stainless steels. However, there is limited research on the effect of different electrode material types on resistance spot welding parameters. The suitability of the welding parameters used in the resistance spot welding of stainless steels has a direct impact on the welding ability and quality. Therefore, in this study, it is aimed to investigate the effect of different welding parameters, especially electrode material type and cooling system on the resistance point weld strength of 0.6 mm austenitic stainless steels.

II. EXPERIMENTAL PROCEDURE

In this study, AISI 304 quality austenitic stainless steel sheets (ASS) used in the white goods industry with a thickness of 0,6 mm were combined with resistance spot welding using two different electrode materials and three different welding parameters (time and current). The mechanical properties and the chemical composition of the sheet are given in Table 1. The hardness and tensile shear load carrying capacity of welded joints were determined and microstructure of welded samples were also evaluated. In the welding studies, a timer and current controlled resistance spot welding (RSW) machine with a capacity of 20 kVA and controlled by a programmable logic controller (PLC) was used. Welds are made of CuCo2Be and CuCrZr electrodes with 6 mm diameter and 45º cut cone tips. The chemical composition and mechanical properties of the electrode materials used in this study are given in Table 2.

Welds were made under uncooled and cooled conditions. For joining 4 Bar electrode force, 5, 10 and 15 cycles (1 cycle=0.02 s) welding time and 3.4, 4.4 and 5.4 kA welding current were applied. Optical examination of welded samples was examined under microscope. Vickers microhardness tests were performed under 100 g load in 10 seconds. Tensile-shear test samples were prepared according to ASTM: E8M and maximum tensile loads were measured on a universal tester.

Table 1. Chemical composition and mechanical properties of AISI 304 austenitic stainless steel used in experiments

Chemical composition (% by weight)								Mechanical properties	
C	Mn	Si	Cr	Ni	P	S	Fe	YS (MPa)	UTS (MPa)
0,08	1,79	0,491	18,08	8,28	0,019	<0,001	70,39	290	675

YS (Yield strength); UTS (Maximum tensile strength)

TABLE 2. SPECTRAL ANALYSIS OF ELECTRODE MATERIALS

Alloy Nearest Int. standard	Chemical Composition (%)	Hardness (HB)	Electrical conductivity (IACS %)	Thermal Conductivity (20 °C) (W/mK)
CuCo2Be CB4) DIN 2.1293 C17500	Co 2,4-2,7 Be 0,4-0,7 balace Cu	270	43	200
CuCrZr DIN 2.1293 C18150	Cr 0,8 Zr 0,08 balance Cu	150	88	320

Samples for metallographic examination were prepared using standard metallography procedure and the specimens were etched in a solution (10 ml nitric acid (HNO3), 15 ml hydrochloric acid (HCL), 10 ml acetic acid, 2 drops of glycerin) Optical examination of the welded samples was carried out using a Leica microscope. The load of 100 g was applied for 10s in Vickers microhardness test. Tensile-shear test samples were prepared according to ASTM: E8M and tested using a universal testing machine. The crosshead speed was kept constant 1 mm min-1.

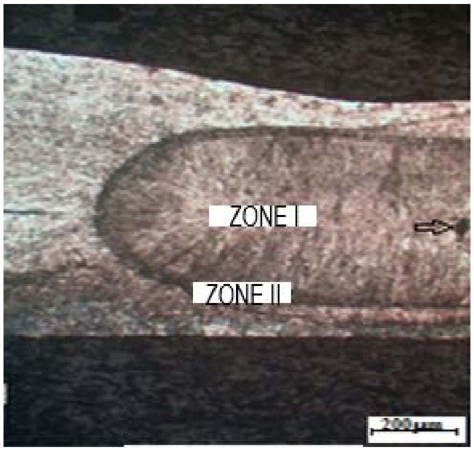
III.RESULTS AND DISCUSSION

A. Metallurgical Characterization

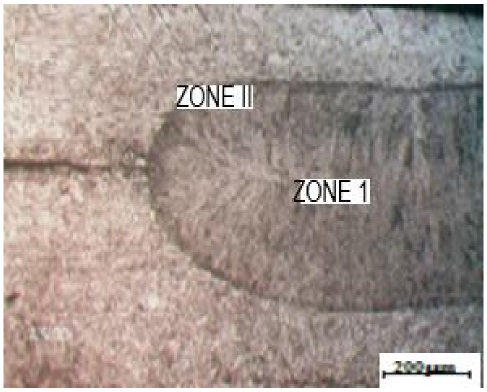
Figure 1a shows the macrostructures of AISI 304 austenitic stainless steel sheets made of resistance spot welding using both low welding current (3,4 kA) and low welding time (5 Cycles). Here it is seen that the austenite phase regions in the open portions are between the undesirable δ-ferrite phase regions (the darker part). The δ-ferrite phases are undesirable because these materials make hot forming difficult and can lead to crack formation. In the weld core, there are two distinct regions in terms of ferrite content. It is obvious that the ratio of δ-ferrite at the core edge shown in the second region is higher than the core center (first region Because there is not enough time for ferrite-austenite solid state conversion due to the higher cooling rate in the second zone. As a result, the amount of δ-ferrite which could not be converted to austenite in the second zone was higher than the first zone which cooled later. Generally, small and coaxial grain formation with rapid solidification in a very limited area in the second zone, and then dendritic solidified grain structure occurs towards the first region (core center). Furthermore, the gap in the weld core in the region indicated by the arrow clearly shows that these welding parameters (3.4 kA welding current, 5 cycle welding time) and a sufficient weld seam are not formed (Figure 1a). The tensile strength values of the samples using these parameters were also low as expected. In general, a very narrow heat-affected zone (ITAB) is observed in the welded zone (Figures 1a and 1b). This can be attributed to the fact that austenitic stainless steels have relatively lower electrical and thermal conductivity than other stainless steels. A slight decrease in hardness in the ITAB zone can also be attributed to grain growth. Figure 1b shows the welding macrostructure of AISI 304 austenitic stainless steel sheets made of resistance spot welding using both high welding current (5.4 A) and high welding time (15 cycles). Similarly, it can be observed that austenite phase zones and δ-ferrite phase zones are between them and the δ-ferrite ratio in the second zone is much higher than the first zone. However, it can be clearly seen that a better weld seam is formed here. Özçatalbaş et al. stated that the reason for this was the dendritic solidification delay due to rapid cooling [7].

International Journal for Research in Applied Science & Engineering Technology (IJRASET)
ISSN: 2321-9653; IC Value: 45.98; SJ Impact Factor: 7.177
Volume 7 Issue XI, Nov 2019- Available at www.ijraset.com

No martensite phase occurred at the grain boundaries because high temperature ferrite was suppressed due to austenite conversion and unstable cooling conditions. In general, the core center microhardness measurements of these samples were also slightly lower than the core edge (Figure 2a and b). In addition, the microhardness values of the core and its surroundings of welded samples cooled with water were higher than the samples which were welded without cooling. When the microstructure of welded samples is examined, it is seen that the particles are larger in the ITAB region than the base metal. Kianersi et al. found similar results in their study on spot welding of austenitic stainless steel sheets [6]. The ASS exhibited grain growth in HAZ producing a soft region compared to the BM which served as a preferred fracture path during PF of the welds [9].

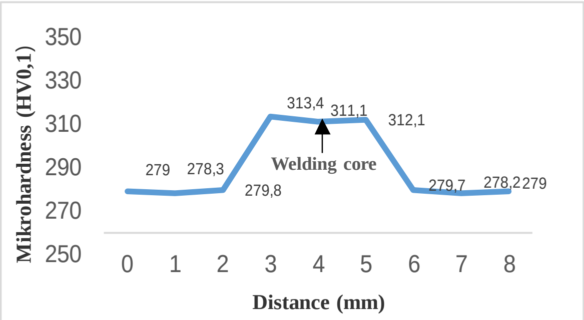


(a)

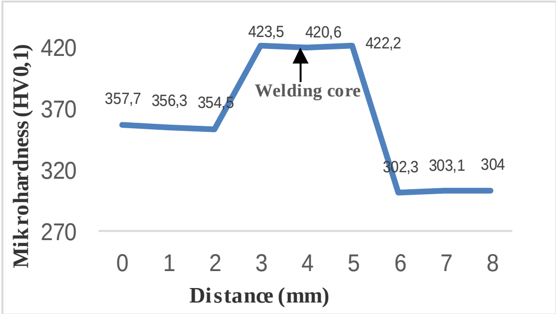


(b)

Fig. 1 Typical macrostructure of welding regions of AISI 304 austenitic stainless steel welded to spot welding using 3.4 kA welding current and 5 cycle welding time, (b) 5.4 kA welding current and 15 cycle welding time.



(a)



(b)

Fig. 2 Vickers microhardness profile of the welded sample made using a CuCo2Be electrode with 5.4 kA current, 15 cycles of welding time, a) in an uncooled environment, b) in a cooled environment

B. Mechanical Properties

Figure 3 shows the maximum tensile load values of welded samples made using cooled and uncooled CuCo2Be and CuCrZr electrodes under a welding current of 5.4 kA and 4 bar electrode compression force. As can be seen in the figure, the maximum tensile load value (6,037 kN) was achieved in the welded sample made using the uncooled CuCo2Be electrode. It can be seen that increased welding time increases weld tensile strength of welded samples made with CuCo2Be.

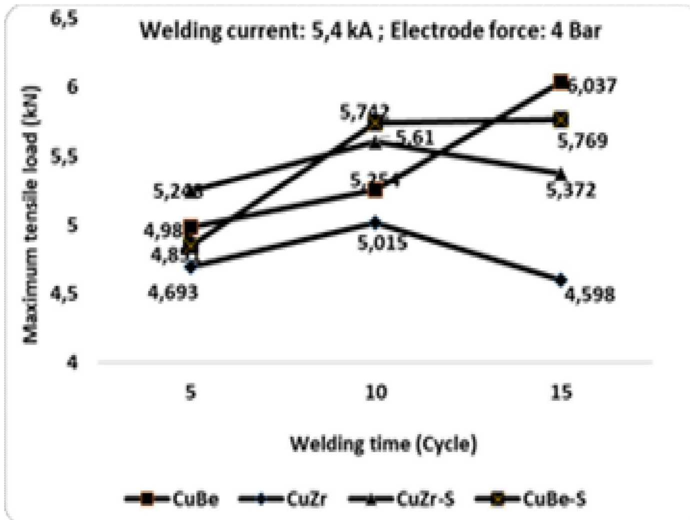
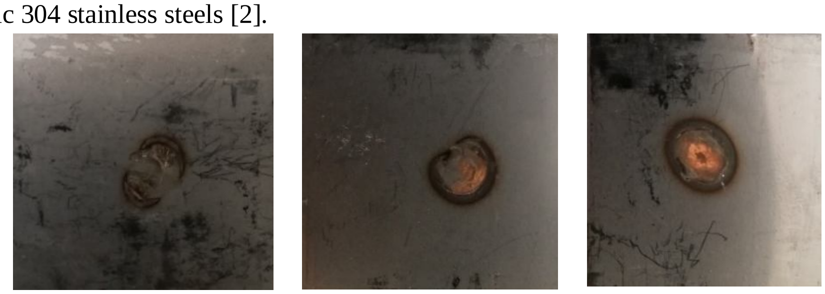


Fig. 3 The effect of increased welding time on maximum tensile load in welded samples made with and without cooled CuCo2Be and CuCrZr electrodes under 4 bar electrode force and 5.4 kA welding current

The weld core photographs of the welded samples made with the uncooled CuCo2Be electrode are shown (Figure 4). As can be seen in the figure, welding core sizes increased due to increasing welding time. Jamaludin and Hisyam found similar results in their work on spot welding of austenitic 304 stainless steels [2].



(a) (b) (c)

Fig. 4 The appearance of welding cores of samples welded using an uncooled CuCo2Be electrode and a) 5 Cycle, a) 10 Cycle, a) 15 Cycle welding time under 4 Bar electrode force and 5.4 kA welding current

(a) (b) (c)

Fig. 5 The appearance of welding cores of samples welded using an uncooled CuCrZr electrode and a) 5 Cycle, a) 10 Cycle, a) 15 Cycle welding time under 4 Bar electrode force and 5.4 kA welding current.

In the welding studies using both uncooled and cooled CuCrZr electrode, high welding current (5.5 kA) and high welding time (15 cycles) caused deterioration in welding seams. As a result, tensile strength values have also decreased. Figure 5c shows the welding cores of welded samples made without cooling with CuCrZr electrode. As shown in the figure, when 15 cycle welding time is used, it is seen that there is a significant deterioration of the welding core. This can be attributed to the electrical conductivity of the electrodes. Because the electrical conductivity of Cu-Cr-Zr electrodes is about twice that of the Cu-Co-Be electrode. (See Table 2). This means that less welding time is required when working with CuCrZr electrodes. In some spot welding studies using austenitic 304 stainless steel, it has been reported that weld core diameter and weld tensile strength increase up to a certain optimum value due to increased welding current and time [2], [10], [11]. In addition, welding resistance in different cooling and protective atmospheres has been reported to increase the resistance of the chain [3], [5].

IV. CONCLUSIONS

The experimental results obtained in the study are as follows;

There are two distinct regions in the weld core in terms of ferrite content. No martensite phase occurred at the grain boundaries. The ratio of δ-ferrite in the second region (core edge) is higher than the first region (core center). In general, it is observed that in the second region, small and coaxial grain formation occurs with a rapid solidification in a very limited area, and then dendritic solidified grain structure occurs towards the first region (core center). Core central microhardness measurements were slightly lower than in the second region.

In resistance spot welding of AISI 304 austenitic stainless steels, the best welding parameters to give maximum strength are different for each electrode material. Welding parameters giving maximum tensile strength (5.61kN) in studies with CuCrZr electrode; without cooling, the welding current is 5.4 kA and the welding cycle is 10 cycles. In the studies performed with CuCo2Be electrode, welding parameters giving maximum tensile strength (6.037kN); 5,4 kA welding current and 15 cycle welding time. In the experiments with CuCrZr electrodes, when the 5.4 kA current and 15 cycle welding time were used, deterioration and melt sputtering occurred in the weld core region and consequently the weld strength decreased.

V. ACKNOWLEDGMENT

It was produced from the master thesis titled "Improving Resistance Point Welding Quality of Metals Used in White Goods Industry" completed by A. G. Ertem in Mechanical Engineering Department of Institute of Science and Technology in Abant İzzet Baysal University in 2019 [12]

REFERENCES

[1] K Shelly and D.S. Sahota "A Review Paper on Resistance Spot Welding of Austenitic Stainless Steel 316", International Journal of Engineering Trends and Technology (IJETT), vol. 47(7), pp. 424-429, 2017.

[2] S.B. Jamaludin and M. Hisyam “Study of spot welding of austenitic stainless steel type 304”, Journal of Applied Sciences Research” vol. 3(11), pp. 1494-1499. 2007.

[3] F. Karcı, R. Kaçar and S. Gündüz “The Effect of Process Parameter on the Properties of Spot Welded Cold Deformed AISI304 Grade Austenitic Stainless Steel”, Journal of Materials Processing Technology, pp. 4011-4019, 2009.

[4] L Habib, RS Ahmed, B Habib "Experimental Study of Spot Weld Parameters in Resistance Spot Welding", Journals of Mechanics and Mechanical Engineering, 22: pp.179-186, 2017.

[5] D. Özyürek "An Effect of Weld Current and Weld Atmosphere on the Resistance Spot Weldability of 304L Austenitic Stainles Steel", Materials and Design, vol. 29, pp. 597-603, 2008.

[6] D. Kianersi, A. Mostafaei and A.A Amadeh “Resistance Spot Welding Joints of AISI 316L Austenitic Stainless Steel Sheets: Phase Transformations, Mechanical Properties and Microstructure Characterizations”, Materials and Design, pp. 251-263, 2014.

[7] Y. Özçatalbaş, G. Kuştutan and U. Arabacı” Effect of Coolıng Rate On Mechanıcal Propertıes in Resıstant Weldıng Joınt of AISI 304 Staınless Steel”, Gazi University, Fen Bilimleri Dergisi Part C, Tasarım ve Teknoloji, vol. 6(2) pp. 294-307, 2018.

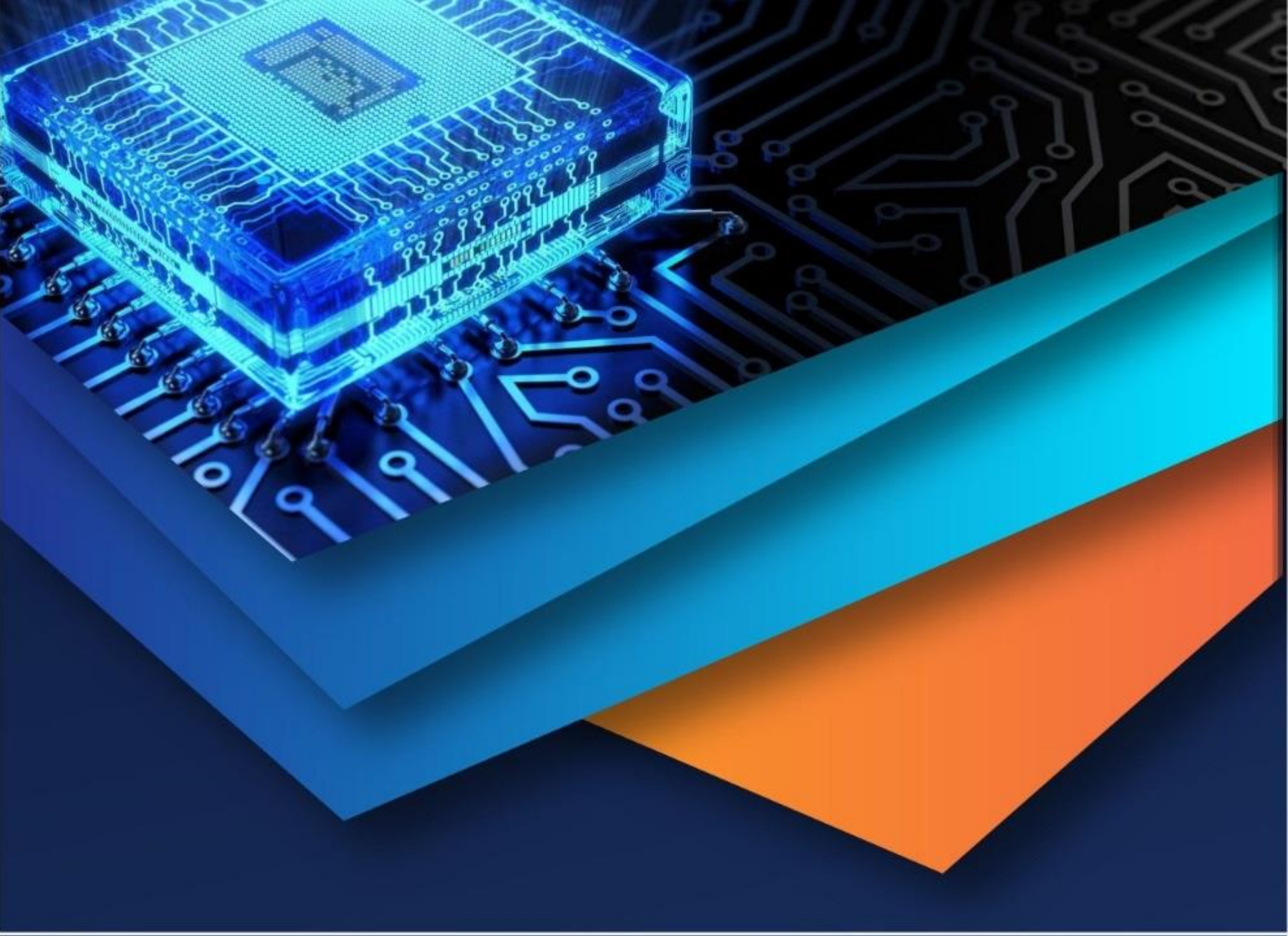
[8] M. Onsekiz and Y. Altunpak "Effect of Electrode Materials Type on Resistance Spot Welding of AISI 430 Ferritic Stainless Steel", Journal of Engineering Research in Africa, pp. 53-58, 2017.

[9] M. Alizadeh-Sh, S.P.H. Marashi “Resistance spot welding of dissimilar austenitic/duplex stainless steels: microstructural evolution and failure mode analysis, J. Manuf. Process., vol. 28 , pp. 186-196, 2017.

[10] M.H. Bina, M. Jamali, M. Shamanian and H. Sabet “Investigation on The Resistance Spot Welded Austenitic/Ferritic Stainless steel”, Int J Adv Manuf Technol vol. 75(9), pp. 1371-1379, 2014.

[11] J.B. Shamsul and M.M. Hisyam “Study of Spot Welding of Austenitic Stainless Steel Type 304”, J Appl Sci Res vol. 3(11), pp.1494–9, 2007.

[12] A.G. Ertem, “Improving Resistance Welding Quality in Stainless Steel Sheets Used in White Goods Industry”, M. Eng. thesis, Bolu Abant İzzet Baysal University, Bolu, 2019.



10.22214/IJRASET

INDEX COPERNICUS
45.98

IMPACT FACTOR:
7.129

TOGETHER WE REACH THE GOAL
IMPACT FACTOR:
7.429

INTERNATIONAL JOURNAL FOR RESEARCH

IN APPLIED SCIENCE & ENGINEERING TECHNOLOGY