Characterization Of Galvanized And Copper Sheets Joined By Resistance Spot Welding

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Abstract

Due to the metal's propensity to develop oxides during welding, joining conductivity metals like copper and galvanized iron (G.I) using conventional welding processes is a time-consuming and costly endeavor. Welding these metals may be expensive, however resistance spot welding (RSW) and other technologies have shown to be a cost-effective option in a number of situations. Resistance spot welding is a common technique in the fabrication of sheet metal for the aerospace and automotive industries.Copper and Galvanized Iron sheets were welded at an angle, and the welding pressure was adjusted during the RSW process to create a strong yet visually distinct connection between the two metals. In contrast, duration and current for welding were held constant in the experiment. To do this, you'll need copper 1.5 mm thick & G.I0.8 mm thick. When the welding is done, XRD and SEM will be used to examine the welded area's microstructure in order to learn more about its characteristics. The results of this experiment demonstrated that the RSW method was effective for welding Copper and Galvanized Iron covered with magnesium sheets, among others.

Key words: Copper, Galvanized iron, Microstructure, Resistance spot welding, Welding.

I. INTRODUCTION

To the layperson who wonders, "What is welding?" Most of us have yet to learn how much effort and innovation went into making welding what it is today [1]. Welding artifacts from thousands of years ago have been discovered. Forge welding entailed heating two metal surfaces and hammering them together under force or pressure and was a standard method of joining metals in ancient times. Welding as a process became what it was today in the 19th century [2]. Few people who wonder, "What is welding?" realize that forge welding, which predates electricity, is what's being referred to. The industrial revolution led to the development of new, more efficient welding techniques that were previously only possible with a great deal of manual labour [3].

A. Importance of welding

When asked, "What is the importance of welding?" It is only sometimes brought to our attention that a significant number of buildings would be demolished if this metalworking method was no longer used. A metal that a skilled welder has joined cannot be disassembled without being shattered [4]. The automotive, construction, and aviation industries, among others, have relied on welding for decades and will continue to do so in the future [5]. Even oil rigs in the middle of the ocean use it, as it can be welded into various configurations that are resistant to the extreme, corrosive conditions in the ocean [6].

This study focuses on applying resistance spot welding to evaluate the thickness of magnesium interlayer coatings on incompatible metals (i,e Copper and Galvanised Iron).

B. Resistance spot welding

In resistance spot attachment (RSW), metal surfaces that come into contact with one another are joined using the heat generated by their resistance to electric phenomena.

Controlled stress applied by electrodes is used to shape workpieces into squares. The technique uses two shaped copper alloy electrodes to pay attention to attaching cutting-edge into a tiny "spot" and clamp the sheets alongside. Typically, the sheets' dimensions are five by three meters (zero by zero eighteen inches). The steel can be weakened and the weld corrected by driving a modern of excessive size through the trouble spot [7].

The magic of spot attachment is that it can take place even while not excessively heating the rest of the sheet because many powers are often added to the spot in a brief time (approximately 10-100 milliseconds).

According to the sheet's material properties, thickness, and the type of electrodes, the amount of heat (energy) brought to the spot is determined by the resistance between the electrodes. This type of electricity is chosen to suit the significance and duration of this. Not applying enough force can make the metal not melt and, at worst, create a negative weld [8]. When welding, using too much electricity can cause the metal to overheat, eject liquid material, and create a hole instead of a weld. Spot attachment serves another purpose: the power brought to the spot is usually controlled to provide dependable welds [9].

As an alternative to spot attachment, projection attachment uses raised sections, or projections, on one or both of the painting pieces to be joined to focus the weld in a specific area. Directing the heat at the protrusions makes it possible to join thicker sections or place the welds closer together. As an additional feature, the projections may indicate a strategy for setting up the components [10]. Welding studs, nuts, and other components of opportunity screw devices to metal plates are commonly used for projection attachment.

It is also frequently seen in the form of crossed wires and bars. More than one projection weld is often prepared with the help of careful planning and jigging, as is the case with any other excessive manufacturing method [11]. Figure. 1 shows the working principle of RSW.

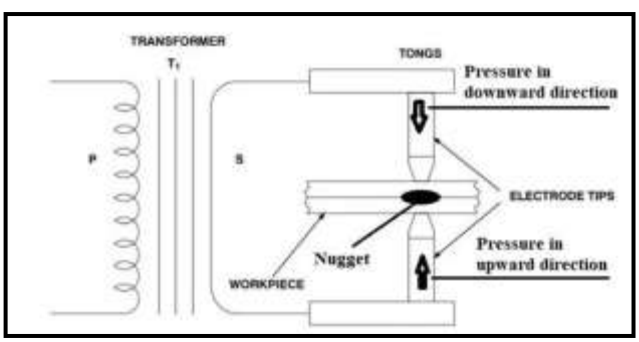

Fig.1. Working Principle

Because carbon metallic electrodes have a higher electrical resistance and lower thermal conductivity than copper electrodes, spot welding is commonly used when joining these materials. In the auto industry, spot welding is commonly used to join the various pieces of sheet steel that go into making a vehicle [12]. Most industrial robots on assembly lines are spot welders, and these machines can be operated fully automatically [13]. The repair industry makes extensive use of spot welding.

The automotive, railroad, and aviation industries, as well as specific non-structural components of the aerospace industry, rely heavily on resistance spot welding (RSW) to join panels and bodies [14]. Aircraft tanks are typically made using RSW of dissimilar metals of varying thickness ratios [15]. The structure and strength of the component and its specific function must be taken into account during the design of the welding process, which requires multiple spot welds next to each other in the same region of the manufactured component. Shunting occurs when an existing spot weld deflects electric current from a subsequent weld [16]. Due to this shunting phenomenon, the shunted weld might not generate enough heat to form a sufficiently large nugget. Numerous studies on the shunting effect in the RSW of steel have found that weld spacing is the most critical factor influencing shunting. The shunting effect during the RSW process in steel can be effectively avoided by increasing the weld spacing (between 15 and 25 mm). Shunting is a problem in the aluminum RSW process, but this method could be more effective because aluminum has a much lower bulk resistance. As a result, it is essential to learn what causes shunting in RSW processes involving aluminum and how to counteract or eliminate it effectively [17].

From the above studies, it is clear that spot welding of dissimilar metals, such as copper and galvanized iron, is a complex process, with many variables influencing the quality of the weld[18]. More research is needed to develop new techniques for spot welding of dissimilar metals because the optimal welding conditions for copper-galvanized iron joints may vary depending on the application and because the current studies on Al-Cu FSSW (tool features, macroscopic characteristics of welded joints, microstructures, defects in welds, and mechanical properties of joints were reviewed) may also vary [19]. In order to improve the binding strength and joint quality of Al-Cu FSSW, scientists have exerted a great deal of effort[20]. The publication of some promising findings is certainly cause for optimism, but much more research is required before Al-Cu FSSW technology can be used widely in industry[21]. In The rotation of the tool is the driving force behind the Al-Cu FSSW process's material flow, combination of incompatible components, and creation of microstructurally sound junctions.

II. LITERATURE REVIEW

Literature Survey is carried out on the various papers published by academic publishers to enhance resistance spot welding knowledge and to identify the research gap.

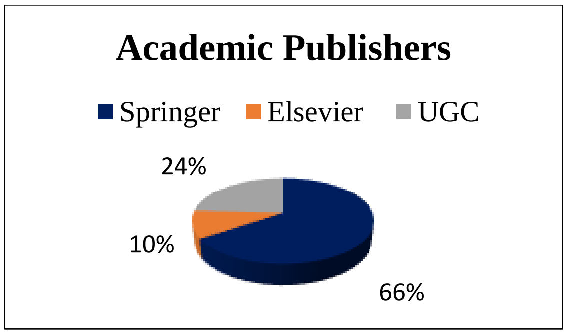

Fig. 2. Classification of literature review according to academic publishers

According to academic publisher referred as shown in Figure. It shows that 66% of literature review consists of Springer academic publisher, while Elsevier contributes 10% of total literature review, University grant commission contributes 24%.

III. MATERIALS AND METHODOLOGY

A. Galvanized iron sheets (G.I)

Putting a stop to corrosion and extending the life of this steel sheet, the coating is zinc. You may find trustworthy internet retailers selling both galvanized plain sheets and galvanized profile sheets[22]. It is possible to choose between A hot-dip galvanized sheets & electro-galvanized steel sheets due to differences in the galvanizing processes. Its low price and high corrosion resistance make it an attractive construction and manufacturing material[23-26]. If you want to find out more, keep reading.

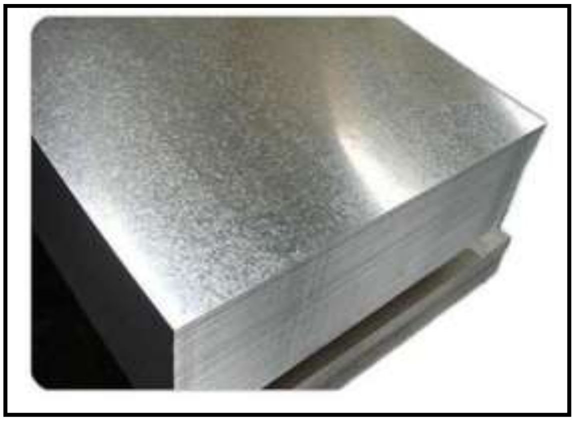

Fig.3. Galvanized iron sheets

Table.1 GI Sheet's chemical make-up [27].

Chemical Properties	Metric	English
Atomic Mass	55.845	55.845
Atomic Number	26	26
Thermal Neutron Cross Section	2.53 bams/atom	2.53 bams/atom
X-ray Absorption Edge	1.743A	1.743A
	14.601A	14.601A
	17.169A	17.169A
	17.4838A	17.4838A
Electrode Potential	-0.0400 V	-0.0400 V
Electro negativity	1.83	1.83
Ionic Radius	0.640A	0.640A
	0.740A	0.740A
Electro chemical Equivalent	0.695g/A/h	0.695g/A/h
	1.042g/A/h	1.042g/A/h

B. Copper

The chemical symbol for copper is Cu and its atomic number is 29 [28-31]. Cuprum is the Latin word for copper. In addition to being very malleable, ductile, and soft, it also has excellent thermal & electrical conductivity.

Pure copper's newly exposed surface is an eye-popping reddish hue. Sterling silver for jewelry, copra nickel fornautical equipment and money, constant as for strain gauges, and thermocouples for temperature monitoring all include copper as an important component[32]. The metallic form of copper is one of the few that may be found in nature (native metals). This led to its widespread adoption beginning about the year 8000 B.C.E. As early as 5000 B.C., it was being extracted from supplied ores and melted down; by 4000 B.C., it was being cast in a mold; and by 3500 B.C., it was being purposefully alloyed with another metal, tin, to form bronze[33]. The Romans used Cyprus as a major copper mining hub, and the Latin term for copper, fromaescyprium (metal of Cyprus), got corrupted to cuprum over the centuries (Latin). In this context, the word copper first appeared; it wasn't until the 1530s that the contemporary spelling was adopted[34].

Fig.4. Copper Material

Table.2 The Elements That Make Up Copper[25].

Chemical Properties	Metric	English
Atomic Mass	65.546	65.546
Atomic Number	29	29
Thermal Neutron Cross Section	3.8 bams/atom	3.8 bams/atom
X-ray Absorption Edge	1.38A	1.38A
	11.269A	11.269A
	12.994A	12.994A
	13.2578A	13.2578A
Electrode Potential	-0.520 V	-0.520 V
	-0.340V	-0.340V
Electro negativity	1.9	1.9
Ionic Radius	0.720A	0.720A
	0.960A	0.960A
Electro chemical Equivalent	1.185g/A/h	1.185g/A/h
	2.38g/A/h	2.38g/A/h

Table.3 Elemental and atomic composition of magnesium[30].

Chemical Properties	Metric	English
Atomic Mass	24.3050	24.3050
Atomic Number	12	12
Thermal Neutron Cross Section	0.060 bams/atom	0.060 bams/atom
X-ray Absorption Edge	9.5117A	19.5117A
	197.39A	197.39A
	247.92A	247.92A
	247.92A	247.92A
Electrode Potential	-2.37 V	-2.37V
Electro negativity	1.31	1.31
Ionic Radius	0.660A	0.660A
	0.820A	0.820A
Electro chemical Equivalent	0.454g/A/h	0.454g/A/h

IV. EXPERIMENTAL SETUP

A. Resistance spot welding (RSW)

Resistance Spot welding requires a transformer, two copper electrodes, and a pair of tongs to hold the welded pieces while they are being heated. When the voltage is too high or too low, the transformer will adjust it automatically.

To establish a circuit between the power source and the electrodes, tongs are needed. Electrodes for resistance welding typically consist of metals like copper (Cu), tungsten (W), copper-tungsten alloy (Cu-W), etc. With enough pressure on the tongs, the current flow may form hot spots or nuggets in the space between the two pieces of work. Combining works is now a viable option.

B. Welding Equipment

In this test, a state-of-the-art, mid-frequency resistance spot welder was used as the RSW device of choice (custom release worked by method for Centerline Ltd. For University of Waterloo). The weld coupons and RSW tools are shown in this image in a simplified form. The MFDC RSW system is outfitted with a state-of-the-art record keeping system that can keep track of three different variables at once: stack and edge voltage.

Fig.5. Spot welding equipment.

The following are the parameters used in the study's welding. The FF25 type of cathode tops was used and their dimensions were 50.80 mm in diameter and 16 mm across the face. The welding current, which should be between 16 and 24 kA for Ni-based materials, is one of the most crucial welding parameters for this timepiece

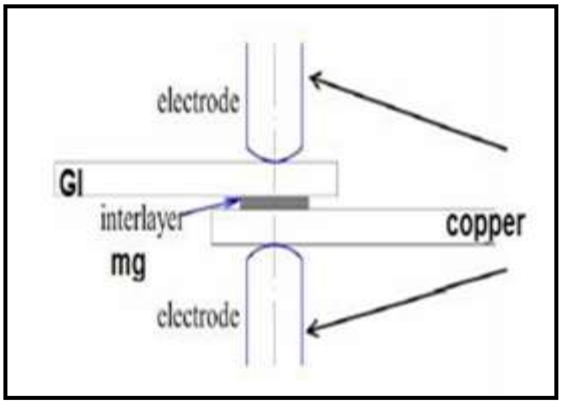

Fig.6. Both a resistance spot welder and a voucher system for welding

. Steel covered with a Zn layer will be between 16 and 32 kA. Because of the little size of the Au-secured Ni sheets, however, welding currents larger than 24 kA have never been measured for Ni-fundamentally based entomb layers. On the digital face of this watch is a graphical depiction of the conventional welding schedule.

Table.4 WeldingSpecifications[35].

Specime nseries no	Electro deforce (N)	Wel d time (cycles)	Weld curre nt (kA)	Specime nseries no	Electro deforce (N)	Wel d tim e (cycles)	Weld curre nt (kA)
1	3237	2	23.50	8	3237	5	28.50
2	3237	2	26.40	9	4709	2	26.40
3	3237	2	26.90	10	3826	2	26.40
4	3237	2	27.20	11	2649	2	26.40
5	3237	1	27.80	12	2354	2	26.40
6	3237	3	28.00	13	3237	2	26.40
7	3237	4	28.40				

C. Experiments Performed

Using AISI304, AISI1020, and AA2024 as the foundation material, the ERS Welding process was used to successfully weld both identical and dissimilar connections. It took the same amount of time to complete the welds at a constant pressure of 3.3 to 3.9 kgf. Once the welds have been visually inspected, they undergo radiological testing. Welded joint samples were tested for TSFL and micro hardness, and then compared to ASTM standards. Several metallographic tests, including micro, macro, SEM, and EDAX analysis, were run on welded samples to investigate the structural changes produced the weld's nugget zone.

The mechanical, metallurgical, fact graphic, and corrosion properties of dissimilar joints welded with a range of RSW weld parameters were evaluated. These parameters included current (50A-30kA), voltage (50-70W), and pressure (3.4-3.9kgf). In order to get the best possible outcomes, we used the RSM model to fine-tune the RSW welding procedure. With the aim of decreasing process-wide pressure, cycle time, and energy consumption, the RSM model was created employing central composite rotatable design (CCRD). The welds on the sample were first put through a radiography test to rule out any potential flaws. Metallographic testing (SEM, EDAX, micro, and macro), and fact graphic testing (TSFL, micro hardness), were performed on welded and fractured samples, respectively, in line with applicable ASTM standards. Corrosion testing was performed on weld samples made with optimal process parameters and compared to those made with non-optimized process parameters.

V. RESULTS

Cut, mounted, cleaned, and checked weld samples were then prepared for optical and checking electron microscopy (SEM). We conducted this study using an Oxford Instruments INCA-350 energy dispersive spectrometer attached to a JEOL JSM-6460 scanning electron microscope (SEM) (EDS). At least three samples were utilized for each condition to calculate an average length for the combination chunks by determining the length of the Al and Mg cross-segments on the transverse weld segments. Whereas a 2% hydrofluoric corrosive solution was needed to scratch the surface of the Mg composite, an acidic Picric drawing arrangement was required for the Al combination (acidic corrosive - 20 mL; picric corrosive - 3 g; ethanol - 50 mL; water - 20 mL). The fracture surfaces were studied by scanning electron microscopy (SEM) and X-ray diffraction (XRD) using a Rigaku Ultimate IV and a Co K-alpha, respectively.

A. SEM of spot-welded Cu and GI without coating

Micrographs taken by scanning electron microscope of spot-welded Cu and GI without an overcoat is shown in Figure 7.
Zooming in and out of the SEM pictures helped identify the grain size, shape, and surface features such as morphology. The agglomeration-like structure showed in SEM images of spot-welded Cu and GI without coatings shows that the particles were heated to a high enough temperature to cause the agglomeration.

B. SEM of spot-welded Cu and GI with coating

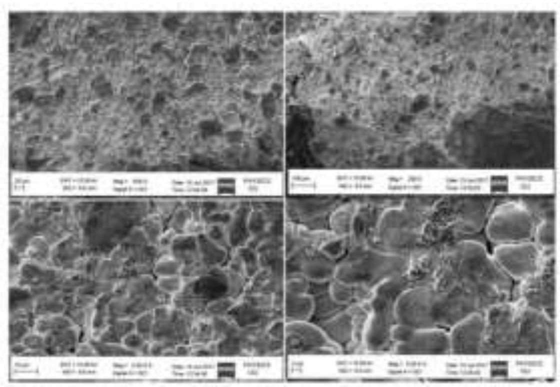

Fig.7. Spot-welded coated Cu and GI, seen at several magnifications from a scanning electron microscope

Zooming in and out of the SEM pictures helped identify the grain size, shape, and surface features such as morphology. Spot-welded Cu and GI with coatings have a tiny grain-like structure, as shown in SEM pictures, thanks to the right amount of heat input, and EDX clearly depicts the composition of components present at the weld nugget or weld spot.
C. EDX Analysis

Analysis via energy dispersive x-ray microscopy of Cu and GI that has been spot-welded but not coated (HITACHI S3400NS). Energy dispersive X-ray spectroscopy was used to find the necessary phase. Copper (Cu), galvanized iron, and even carbon might all be part of the

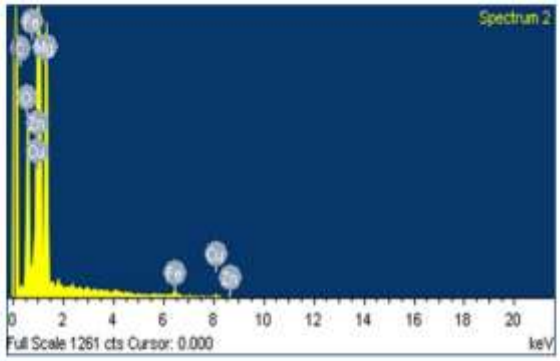

Fig.8. Copper and GI spot-welded onto uncoated EDX

Table.5. Distribution of Component Weights in Percentage

S.NO	Elements	Weight%
1	Cu	38.30
2	Fe	4.72
3	Zn	21.96
4	Mg	17.60
5	C	2.77
6	O	14.64

Coated copper and GI welds were analyzed using energy dispersive x-ray spectroscopy.

EDX scans of coated, spot-welded Cu and GI (HITACHI S3400NS). The required phase was found using energy dispersive X-ray spectroscopy. In this sample, we find Copper (Cu), Galvanized Iron (Fe), and Magnesium (Mg).

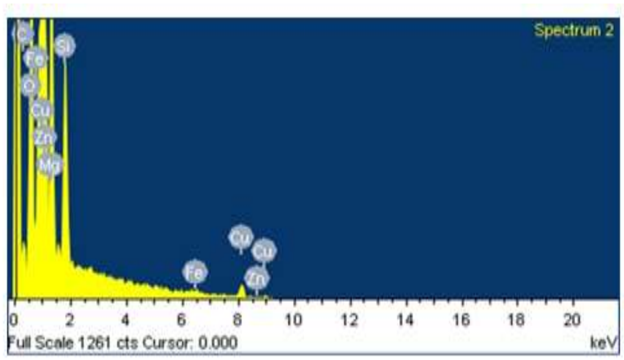

Fig.9. Electron Dispersive X-ray Photographs of Coated, Spot-Welded Copper and Glass-Fiber-Reinforced Plastic (GI)

Table.6. Proportional Weight Distribution of Its Components

S.NO	Elements	Weight%
1	Cu	56.69
2	Mg	24.72
3	Fe	10.96
4	Zn	4.60
5	C	2.77
6	O	1.03

D. XRD pattern of spot-welded Cu and GI without coating

$$D = \frac{0.9\lambda}{\beta cos\theta} nm$$

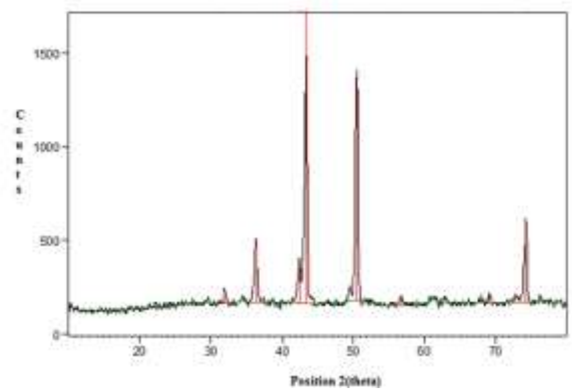

Fig.10.XRD pattern of spot-welded Cu and GI without coating

Spot-welded, uncoated copper and germanium X-ray diffraction (XRD) pattern (GI) Peaks at (36), (35), (43), and (55, 741) with values of (1, 0, 1), (2, 0, 0), and (1, 1, 0) can be A seen in the XRD pattern of uncoated, spot-welded Cu and GI (2 2 0). All of these findings agree with the JCPDS card 89-2838, which demonstrates that Cu and GI may form cubic-shaped particles. Crystal size distributions are calculated using the Debye-Scherer formula.

A key part of the Debye-Scherer equation is the

$$D = \frac{0.9\lambda}{\beta cos\theta} nm$$

statement that

Where D – Average size of the particle [nm]

λ --Wavelength of the radiation [A°]

Diffraction angle (in degrees)

Full width at half maximum (FWHM): It is expressed as a letter "B" in terms of radians. With this formula, an average crystal size of 48 nm is calculated. Indicated by a

$= b = 3.61505\ A°.$

E. XRD pattern of spot-welded Cu and GI with coating

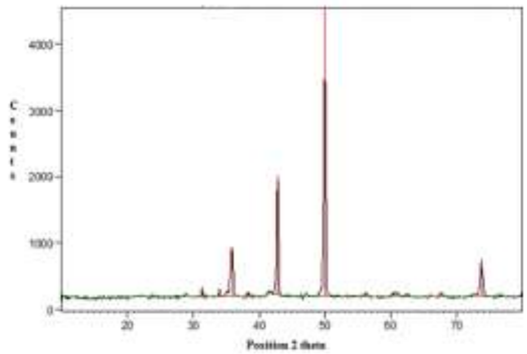

Fig.11.XRD pattern of spot-welded Cu and GI with coating

X-ray diffraction (XRD) pattern for copper and germanium (GI) with a coating used for spot welding There are XRD peaks at (35.090), (42.898), (50.575), and (73.703) for coated GI and spot-welded Cu, with (1.01), (1.0), (2.0), and (2.2) values, respectively. These findings corroborate the cubic atomic structure of Cu, as predicted by JCPDS card number 89-2838 for peak 50.575. The Debye-Scherer formula is used to determine a typical crystal size.Angle [of] diffraction Its FWHM in radians is denoted by the letter "B." According to the aforementioned equation, the typical size of a crystal is 38 nm. When a = b = 3.61505 A°, the lattice parameter is determined.

VI. CONCLUSION

The results of this experiment demonstrated that the RSW method was effective for welding Copper and Galvanized Iron covered with magnesium sheets, among others. Copper and Galvanized Iron sheets were welded at an angle, and the welding pressure was adjusted during the RSW process to create a strong yet visually distinct connection between the two metals. In contrast, duration and current for welding were held constant in the experiment. The agglomeration-like structure showed in SEM images of spot-welded Cu and GI without coatings shows that the particles were heated to a high enough temperature to cause the agglomeration. Spot-welded Cu and GI with coatings have a tiny grain-like structure and EDX clearly depicts the composition of components present at the weld nugget or weld spot.

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