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Resistance Spot Weld Ability of Mild Steel Coated with Zn, Galfan and ZA12

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Abstract: In this study, the weldability of mild steel coated with different Zn-based materials to prevent corrosion with resistance spot welding process was investigated. For this purpose, the surfaces of mid steel were coated with pure Zn, Galfan (Zn5Al) and ZA12 (Zn11Al1Cu) alloys. Hot dipping technique was used for coating. Mild steels with dimension of 1.5X15X40 mm were immersed in the melted Zn and alloys, and the surfaces were coated by waiting for 2 minutes. Steel and coated steel pairs were joined by resistance spot welding process. The welding interface microstructures were examined under light optical microscopy (LOM). Weld interface strengths were measured by axial shear tests. The tests were performed at the room temperature and with a tensile speed of 5mmmin-1. Microstructure investigations showed a good bonding occurred between the coating and the steel and between the welded materials. Mechanical tests have shown that coating the steel reduces the weld strength and the decrease in strength continues with the increase of alloying elements in the coating.

Keywords: Mild steel, Coting, Welding, Strength

Introduction

Mild steels are widely used in various construction manufacturing in all areas of industry. Joining these materials, which can be in different forms, by welding techniques is a frequently used method, especially in the automotive sector. The temperature of the welding interface must be above or very close to the melting temperature for successful bonding. Although there are many different welding methods, we can collect them into two main groups as melting and solid-state welding methods. Resistance spot welding technique, which is a solid-state welding method, is used to join sheet-shaped materials.

Electric resistance spot welding is a method of welding with heat that occurs due to the resistance of the workpieces against the electric current passing through the workpieces held together under pressure between the electrodes. The contact surface of the parts to be welded is heated with low voltage and high current applied for a short time and transformed into a molten welding core. When the electric current is cut off, the molten metal quickly cools and solidifies. Meanwhile, the electrodes continue to hold the welded parts tightly and then retract and release the part. Welding process is usually completed in less than one second. (Yener, 1999; Baytemir, 2011).

The main resource variables affecting the welding quality are listed as follows; effect of the welding current, effect of the welding time, effect of electrode force, effect of electrode composition and shape on heating,

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material of workpiece, effect of surfaces of parts to be welded, effect of distance between welded points, contact conditions of electrode and workpiece (Hayat, 2005). Resistance spot welding is an easily controllable process, inexpensive equipment and a serially repeatable method. The welding process widely used in joining metal sheets such as iron, steel, aluminum alloys, magnesium alloys, titanium alloys, super alloys, and joining of different metals (Kahraman, 2007; Qiu, et al.200; Han et al., 2010; Shirmohammadi et al., 2017; Bemani et al., 2020; Babua et al., 2012).

Corrosion and rust are an important problem that limits the use of metals and alloys. Corrosion and rust can result in large issues for safety equipment because of the potential weakening of the structure. In many cases, metals become unusable earlier than expected due to corrosion. Therefore, besides the mechanical and physical properties of metallic materials, their resistance to corrosion is of great importance. Many metals and alloys are affected by the environment in which they work. Different methods are used to increase the corrosion resistance of metallic materials. One of these is coating the surface of the metal with another corrosion-resistant metal or alloy.

Galvanizing is one of the most popular methods of coating and protecting the metal. Galvanization is done by applying a protective zinc coating to steel or iron. This coating is mainly done to prevent rust and corrosion, which provides a longer useful life and increased safety.

In this study, the joint ability of steel coated with different zinc alloys by spot resistance welding was investigated. The effects of the coating composition on the weld interface microstructure and strength were revealed.

Method

1.5mm thick mild steel is used for joining with resistance spot welding. The surfaces of the 1.5x15x40mm steels were ground before coating. Steel surfaces are coated with Zn, Galfan(Zn5Al), and ZA12 (Zn11Al1Cu) alloys by the hot-dipping method. The steels immersed in the melted metal or alloy were kept in the melt for 2 minutes. The samples removed from the melt were cooled in the open atmosphere.

The welding process was carried out in a 60KW resistance spot welding machine. The copper electrode diameter of the machine was 6 mm. Welding parameters applied to all samples during welding operations are determined as follows: Welding clamping force 500kgf, welding current 35A, welding time 40 periods, and cooling time 4sec.

After the welding process, a cross-section was taken from the middle of the welding interface. These cross-sections were prepared metallographically and the welding interface microstructures were examined under an optical light microscope.

Mechanical strengths were determined by applying axial shear to the welding interface. Shear tests were carried out on a universal testing device in the geometry shown in Figure 1. The tests were carried out at room temperature and a tensile speed of 5mmmin^{-1}.

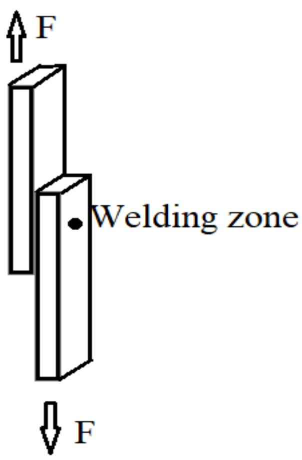


Figure 1. The shear test geometry

Results and Discussion

Optical microstructure photographs of the steel and surface coatings used in the welding process are given in Figure 2. From the microstructures, it is seen that the mild steel has a ferritic structure and the coatings on the surface adhere well to the steel. The surface of the steel could be coated with Zn, Galfan, and ZA12 without a gap or oxide layer between the steel and the coating. In addition, it can be seen from the microstructure pictures that all coatings are approximately the same thickness. The coating thickness is a reflection of the residence time in the melt.

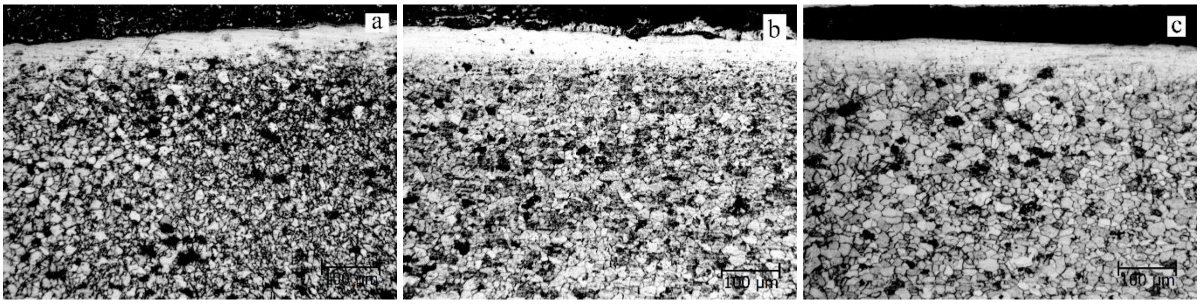
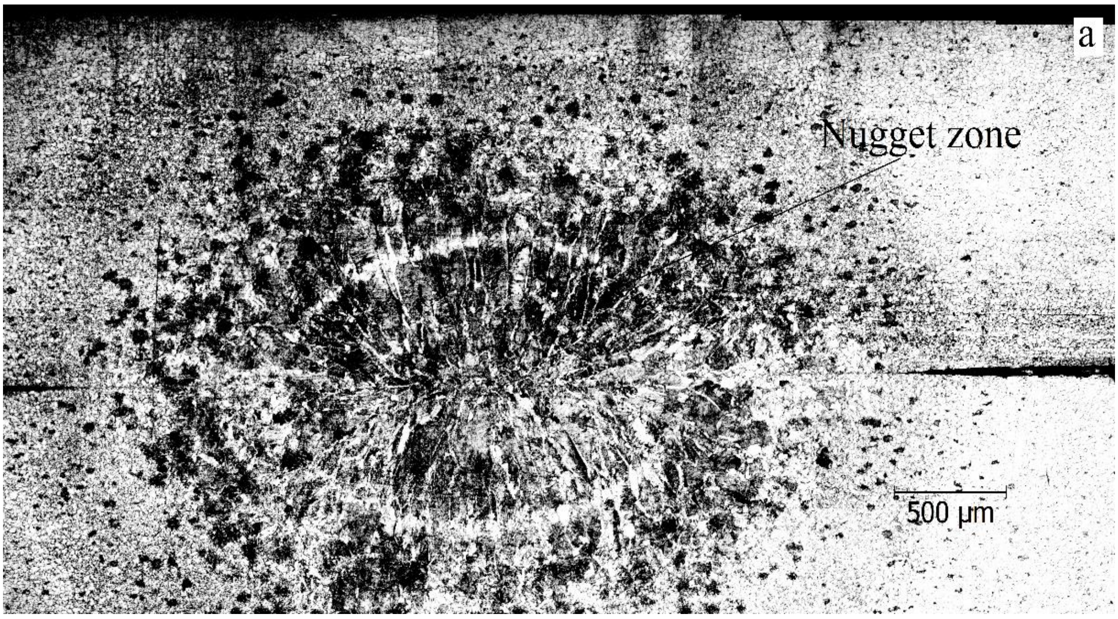


Figure 2. The cross-sections of coatings. a) coated with Zn, b) coated with Galgan, and c) coated with ZA12

Cross-sections of welding interfaces are seen in figure 3. These microstructure images were taken using the photo-merging method since the all-welding interface did not fit into the objective lens. From the figures, it can be seen that a nugget zone is formed at the welding interface. It was observed that the coatings were lost in the welding zone in all samples except the Zn coated sample. No significant nugget zone was formed in the Zn-coated sample. In the nugget zone at the heat-affected zone, columnar grains were formed, extending from the outside to the center. Grain coarsening of the steel was also observed at the boundary of the nugget zone. In general, no gap formation was found at the weld interface. Only in the sample coated with ZA 12, a large void was observed.

The shear test results at room temperature with a tensile speed of 5mmmin-1 are summarized in Figure 4. It was observed that the welding interface strength of the welded samples is decreased when the coating was applied. During the tests, it was determined that the fracture occurred in the form of tearing at the weld boundary in the uncoated mild steel, on the other hand, it was determined that the fracture occurred directly from the joint area in the coated samples. Tearing in uncoated samples is due to grain coarsening at the boundary of the nugget zone. Since the strength of the coarser grains is lower, the deformation took place in this region. In the coated samples, as the strength of the joint area is lower than that of mild steel, the fracture occurred in this area.



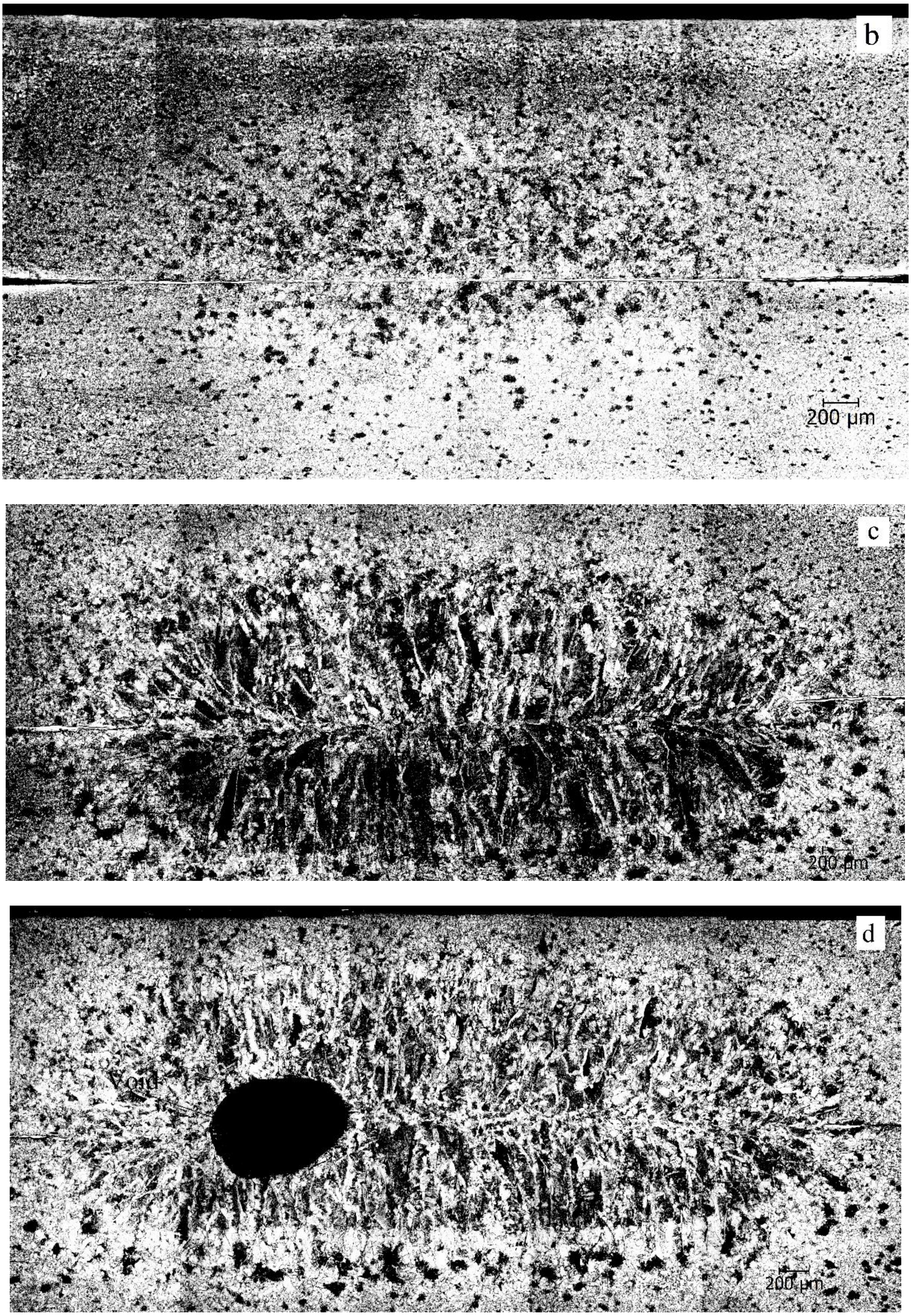


Figure 3. The cross-sections of welding interfaces. a) mild steel, b) Zn coating, c) Galfan coating, and d) ZA12 coating.

In addition, since none of the coatings were ductile, there was no plastic deformation during fracture. There was a slight decrease in the welding interface strength with only Zn coating, whereas there was a serious decrease in the welding interface strength of the Galfan and ZA12 coated samples. The Al content of the coating is considered to be effective in this result. It is known that Al is undesirable because it forms brittle intermetallic phases (Fe3Al, FeAl, etc.) in steels. These phases may be the cause of the decrease in strength.

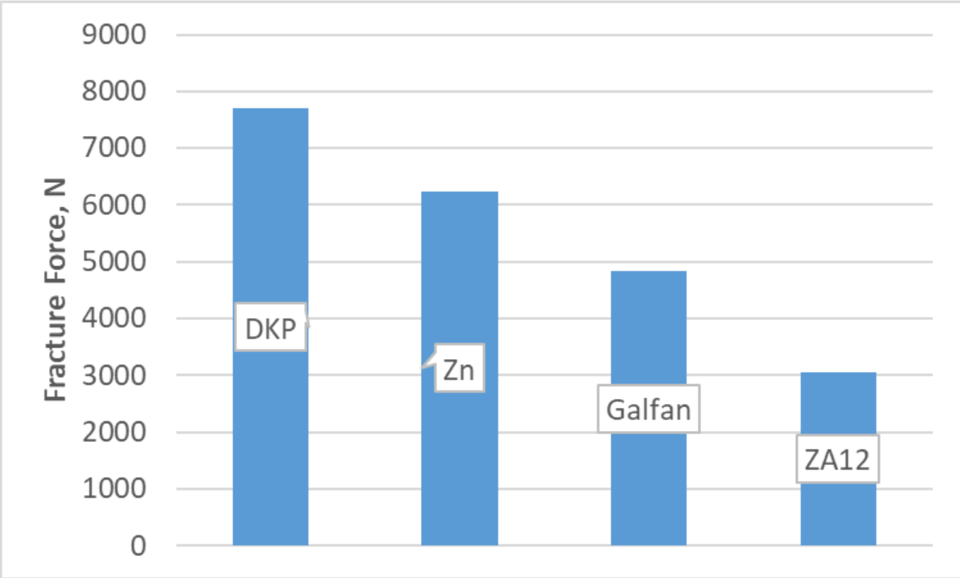


Figure 4. The strength of the welding interfaces.

Conclusion

At the end of this study, it has been proven that ZA12 alloy, which has higher corrosion resistance and does not change color over time, can be coated in addition to the traditionally hot-dipping galvanized (Zn coating) and partially widespread Galfan (Zn5Al) coating to increase the resistance of steels against rust and corrosion.

Since resistance spot welding is widely used for joining sheet-shaped materials, it is also important that steels coated with different materials can be joined in this way. In this study, it has been seen that steels coated with Zn-based materials can also be joined by resistance spot welding.

They do not form solid solutions with Fe both Zn and Al, which are the elements that make up the coating, on the contrary, they form intermetallic phases. Since the formed intermetallic phases are generally brittle, they determine the welding interface strength. Although the increase in Al content in the coating increases the corrosion resistance, the welding interface strength systematically decreased due to an increase in the amount of brittle intermetallic phases during the welding process.

Recommendations

1. The effects of coating thickness on the strength at the end of resistance spot welding should be investigated.
2. Since the welding parameters will affect the interface microstructure, the effects of welding parameters on the strength of the weld interface should be investigated by using different welding parameters.

Scientific Ethics Declaration

The authors declare that the scientific ethical and legal responsibility of this article published in EPSTEM journal belongs to the authors.

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