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Friction spot joining of dissimilar materials
마찰교반점용접을 이용한 이종재료의 접합

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ABSTRACT The Friction spot dissimilar welding of galvanized steel/Al6061-T6 was performed to investigate the mechanical characteristics of the joints. The presence of thin film of aluminum oxide on the surface and melting of zinc in the coating, made substandard joint characteristics for dissimilar Friction spot joining (FSJ) performed with out removing the coating. Where as, for dissimilar FSJ of galvanized steel/Al6061-T6 after removing the coating, superior agitation and welding quality has been obtained for a configuration of galvanized steel as the upper plate and Al6061-T6 as lower plate. The results from tensile tests and microscopic examination for various combinations of the welding parameters have been presented.

1. INTRODUCTION

Friction stir spot welding (FSSW) is a new process that recently has received considerable attention from the automotive and other industries. An exploratory study was conducted to investigate the feasibility of dissimilar friction stir spot welding of galvanized steel/Al6061-T6.

Galvanized steels are used in many applications that require spot welding during fabrication. Galvanized steel have zinc coating with is soft and conductive compared to uncoated steel and therefore requires higher welding currents, welding times and electrode forces for conventional resistance spot welding which make it non-economical process.

The dissimilar friction stir spot welding of galvanized steel/Al6061-T6 could be used in the production of aluminum doors, engine hoods, and deck-lids in the automotive industry. It has the benefits of operation and investment cost savings, weight reduction, high repeatability and consistence, low maintenance, better work environment and recycle-ability vs. other spot joining methods such as resistance spot welding (RSW) and riveting

In this present study the authors has explored the dissimilar friction stir spot welding of galvanized steel/Al6061-T6.

2. EXPERIMENTS

The aluminum alloy, Al6061-T6 and galvanized steel have been lap jointed with tool, made of high strength tool steel with tungsten carbide coating. The plates are 1mm thick 30mm wide and 100 mm long. The shoulder diameter, pin upper and lower diameter and pin length are 13mm, 2.5mm, 1.5mm and 1.2 mm respectively.

FSJ has been carried out, removing and without removing the coating on galvanized steel and also changing the upper plate material. The resulting friction spot joints were subjected to tensile test, micro-structural observation and SEM. The tensile shear tests were conducted at a crosshead speed of 2.5mm/min. The highest tensile shear strength was determined by systematically varying tool rotation speed, dwell time, and upper plate material property, keeping the Plunge depth constant.

The samples for metallographic examination were prepared based on the standard metallographic technique. The welded plates were sectioned, mounted and polished up to 1 micron diamond paste and etched. The Chemical composition and mechanical properties of Al 6061-T6 and galvanized steel are as given in table1 and table 2 respectively.

Table 1 Chemical composition and mechanical properties of Al 6061-T6

Chemical compositions (wt %)			
Al	Fe	Si	Cr
98	0.7	0.4-0.8	0.04-0.35
Mg	Cu	Mn	Zn
0.8-1.2	0.15-0.4	0.15	0.25
Mechanical properties			
Yield strength	Elongation (%)		Tensile strength
276(MPa)	17		310(MPa)
Density (g/cc)	Thermal conductivity (W-m/K)		Elastic modulus
2.7	153		72(GPa)

Table 2 Chemical composition and mechanical properties of Galvanized steel

Chemical compositions (wt %)			
Fe	C	Si	Mn
bal	0.11	0.10	0.9
P	S	Al	Zn coating
0.15	0.05	0.34	46g/m^2
Mechanical properties			
Yield strength	Elongation (%)		Tensile strength
163(MPa)	49		291(MPa)
Density (g/cc)	Thermal conductivity (W-m/K)		Elastic modulus
7.8	65		65(GPa)

3. RESULT AND DISCUSSION

It is generally thought that a hot-dip Zn coated steel sheet shows similar behavior to an aluminum part during welding. But during the Friction spot joining, a surface part to be welded is heated at a high temperature above 660°C. The high temperature heating causes formations of a molten Zn, to which Fe and Al are diffused to form Al-Fe-Zn ternary alloy layer at an interface between the plates. Consequently at the weld nugget brittle ternary and binary alloys layers are formed, resulting in the obstruction of bonding between the plates. So in the present study the coating of galvanized steel has been removed before friction stir joining.

Two cases of FSJ have been carried out in this study. Case1: Galvanized steel as bottom plate and Al6061-T6 as upper plate and case 2: Galvanized steel as upper plate and Al6061-T6 as bottom plate

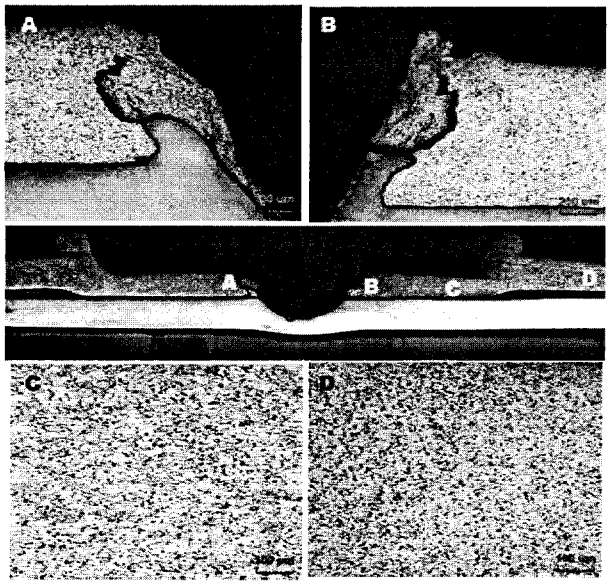

Fig.1 Macro and microstructure of dissimilar FSJ upper plate: Al6061-T6, bottom plate: galvanized steel,

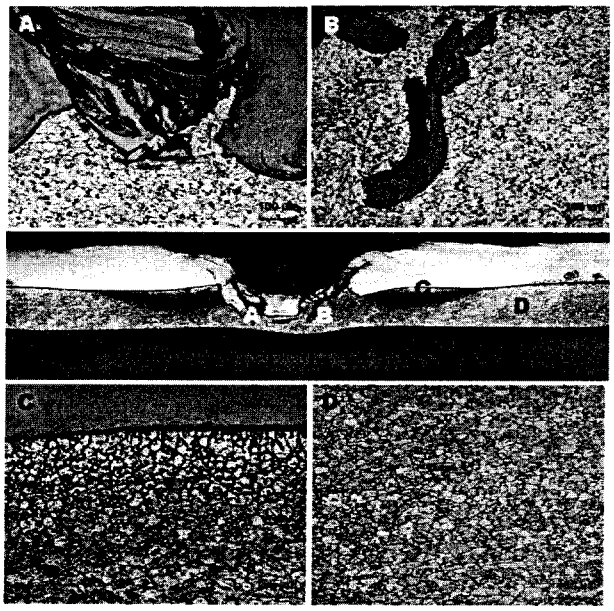

Fig.2 Macro and microstructure of dissimilar FSJ upper plate: galvanized steel, bottom plate: Al6061-T6,

The macro and micro structure of the Case1 has been shown in figure 1. The agitation was observed inferior in this case and kissing bond has been developed which reduced the tensile shear strength as shown in figure 3 and 4.

The macro and micro structure of the Case2 has been shown in figure 2. The agitation was observed superior in this case and there by wider dynamic recrystallized zone which increase the tensile shear strength.

In case 2 the temperature has increased above the melting point of aluminum and Al6061-t6 beside the tool pin has melted and recrystallized forming a better bond with the steel plate at higher rotation speed as shown in figure 3.

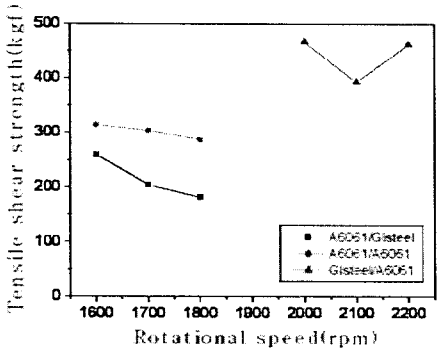

Fig.3 Tensile shear fractured load in dissimilar Friction spot joining (plunge depth:1.2, dwell time: 2.0sec)

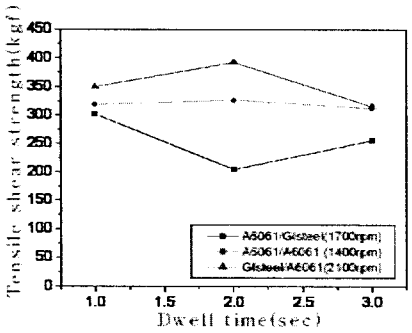

Fig.4 Tensile shear fractured load in dissimilar Friction spot joining (plunge depth:1.2)

4. CONCLUSION

This study investigated the feasibility of friction stir spot dissimilar welding of galvanized steel/Al6061-T6. It was found that:

1. The high strength tool steel with tungsten carbide coating was capable of dissimilar welding of galvanized steel/Al6061-T6 with out notable wearing.
2. As is the case with other coated steel sheets, FSJ welding may remove the coating from Galvanized sheet exposing the base steel. These areas are comparatively small compared to other conventional welding and should be covered with metal-sprayed zinc, aluminum-zinc, zinc-rich paint or organic coatings.
3. The maximum tensile shear fracture load has been obtained for a configuration of galvanized steel as the upper plate and Al6061-T6 as lower plate.
4. The tensile shear fractured load value of dissimilar galvanized/Al6061-t6 (case2) is higher that the similar welding of Al6061-t6.
5. The agitation was observed superior when galvanized steel as the upper plate of the lap joint, there by wider dynamic recrystallized zone.

It is expected that substantial improvement in joint strength of this dissimilar welding can be achieved if the bonding ligament width can be increased through further process development and modifications to the tool geometry and parameter optimization.

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