Microstructure and mechanical property of resistance spot welded joint between pure titanium and stainless steel with interlayer of Nb

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Abstract. Commercially pure titanium and type 304 stainless steel sheet was welded by using the resistance spot welding with a niobium insert as well as welding the specimen by different welding current. The tensile shear strength and the factors of affecting mechanical properties of the joints was investigated during observing the interfacial microstructure of the joint. The joint diameter and the joint shear strength increased with the increase of welding current. It is observed that the reaction layer generated on the nugget center near the side of the titanium which the component is α-TiFe . The formation of the reaction layer have been observed in the nugget center near the side of Ti. The organization of the reaction layer is α -TiFe, the lower the nugget center and nugget center near the stainless steel side are Fe and Fe_2Nb eutectic structure. The tensile test results show that the joint fracture also called the interface fracture occurred in the side of SUS304/NB. The test results show that the intermediate layer prevents direct contact of titanium and stainless steel, directly inhibits the adverse reaction of the interface and improves the performance of the joint.

Introduction

With the development of industry, there has been a growing interest in using lightweight materials for fabrication of auto-body structures which will contribute to improved fuel efficiency and reduced environmental impacts[1]. Aluminum and magnesium have been paid extensive attentions due to their advantages such as low density, high specific strength and high specific stiffness. Therefore, it is necessary to joining aluminum and magnesium because it not only can reduce the structure weigh but also can save materials.

In this regard, there has been a large number of studies focus on the joining of dissimilar aluminum and magnesium. However, it is easily create hot crack and void issues when aluminum and magnesium were welded by using traditional fusion welding methods. Resistance spot welding is a solid state joining technique applied for almost all known metals, and one of the oldest electric welding processes in use today. The weld is made by the combination of heat, pressure, and time[2-4]. So this method can avoid above issues to a certain extent. Unfortunately, direct joints between aluminum and magnesium, suffer from poor strength and ductility. Such poor mechanical properties are a result of development of brittle inter-metallic phase, i.e, Mg17Al12 and Al3Mg2 during welding, as already investigated in literature[5-8]. Thus, in order to achieve a strong joint during welding, direct contact between aluminum and magnesium should be avoided. This can be achieved by inserting an inter-layer element at the contact area of the two base materials.

In this paper zinc and tin was used as inter-layer for dissimilar joining of A6061 to AZ31 by resistance spot welding. Attempts have been made to improve the mechanical properties via optimizing the welding parameters. The micro-structural characteristics and fracture mechanism of the joints are discussed.

Experimental procedures

The base materials used in this study were 1.0 mm thick plates of commercially pure titanium (Ti) sheet and stainless steel (SUS304). The chemical compositions are listed in Table 1. Nb foil of 30mm×30mm×0.09mm mm was used as the interlayer.

Table 1 Chemical composition of SUS304 and Ti (mass %)

Materials	Elements (mass%)					
SUS304	Fe	Cr	Ni	Mn	Si	C
	Bal.	18.0	8.0	1.25	0.85	0.06
Ti	Ti	Fe	O	H	N	
	Bal.	0.20	0.15	0.013	0.05	

Resistance spot welding was carried out by a DC spot welding machine. The welding current was changed every 2kA between 8 and 14kA at the fixed electrode force of 2807N and welding time of 10cycles. Fig.1 shows the shape and size of joints. The microstructure of joint was observed using a scanning electron microscope (SEM, JSM-5600, acceleration voltage: 20kV).

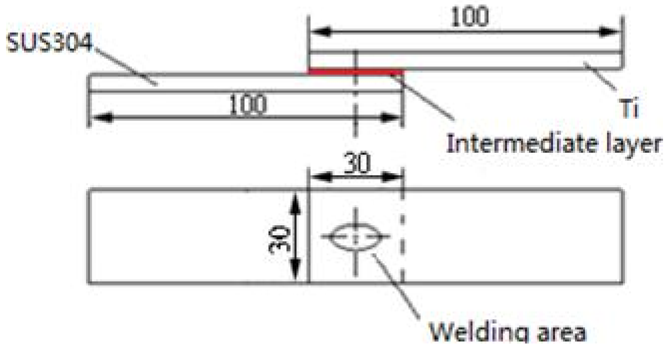

Fig.1 Shape and size of specimen for welding

In order to examine the mechanical properties of the joints, the tensile-shear testing was performed at the speed of 1.0 mm/min at room temperature. Listed in this paper, the results were the average value of the five joints for the welding under the same condition

Results and discussions

Fig.2 shows the electronic scanning of the nugget center interface area, when the current is 5kA, the time is 10cycles, and the electrode pressure is 2807N From the figure we can see the interface of parent material Ti and Nb appears a step which is a new reaction layer at the joint. And it is observed that the thickness of the reaction layer is 5μm and "dendritic" organization appears at the side of stainless steel.

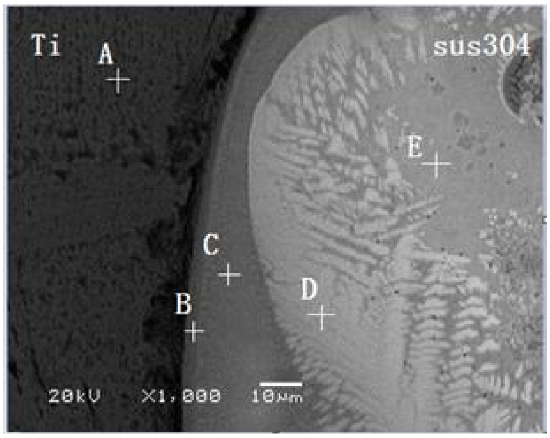

Fig.2 SEM images the of the interfacial region SUS304/Nugget

Under the same process conditions, the energy spectrum of spot welded joints is analyzed and the results of line scanning are shown in Fig.3. It can be seen from the figure that the composition of the two elements of Ti and Fe in the reaction layer is a platform with relatively homogeneous content, indicating that the reaction layer contains compounds of Ti and Fe elements.

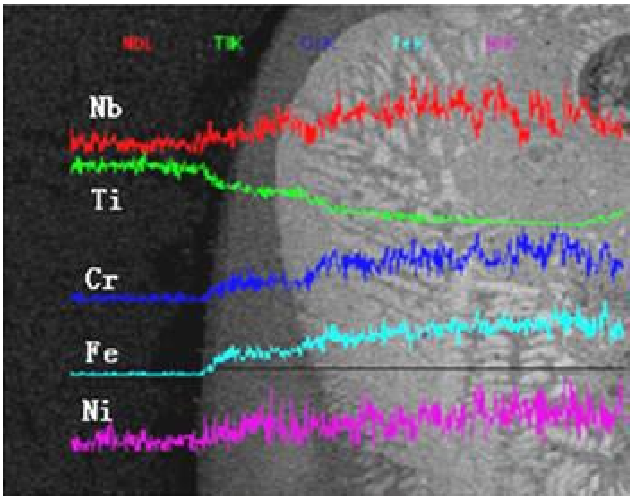

Fig.3 SEM images the of the interfacial region SUS304/Nugget

Fig.4 shows the relationship between the welding current and the nugget diameter. Spot welding test generally requires the nugget diameter D ⩾ 4t0.5, where t is the thickness of the plate. In this experiment, t is 1mm, so the range of nugget diameter should be greater than or equal to 4mm. The test results show that the minimum nugget diameter is 4.3mm greater than the minimum allowed of nugget diameter which is 4mm, so the welding area meet the requirements. meet the requirements of the weld region.

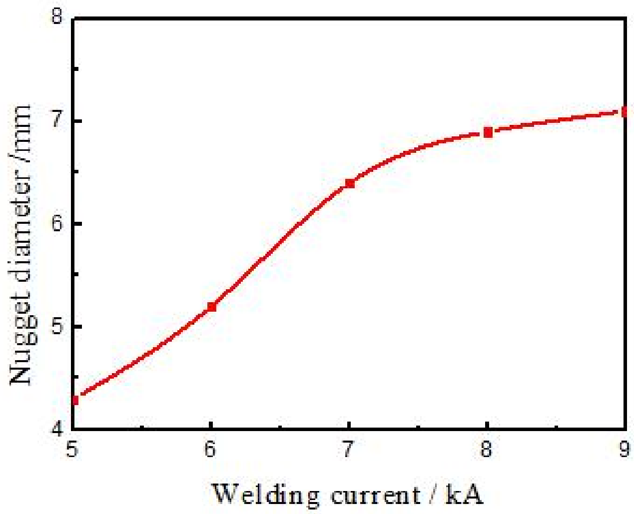

Fig.4 Effect of welding current on nugget diameter

Fig.5 shows the relationship between the welding current and the shear load. It can be seen from the figure that the shear load of the joint increases continuously with the increase of the welding current. We can get the following relationship. With the increase of the nugget diameter, the shear load of welding joint is increasing. However, with the increasing of current, the amount of melting of intermediate transition layer should be more and more. Then the thickness of the IMC compound layer will increase, while the shear resistance of the joint will be reduced. Therefore, the shear resistance of welded joints should reach a maximum point, and this maximum point should appear after the current is 9ka. Then there will be a downward trend

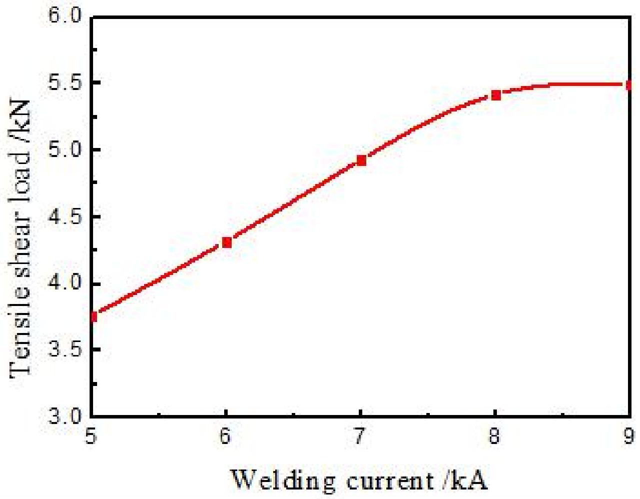

Fig.5 Effect of welding current on nugget diameter

Conclusions

This work has been concerned with the dissimilar resistance spot welding of Ti to SUS304 with Nb interlayer. The following conclusions have been drawn:

1. The nugget diameter of pure titanium and SUS304 stainless steel welds increases with the increase of welding current in the small current (5-9kA) range.
2. The intermediate transition layer (Nb) prevents the direct contact between Ti and stainless steel, and inhibits the direct adverse reaction of the interface and improves the joint performance.

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