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Dissimilar Joint Properties of Cu to 304 Stainless Steel by GTAW Process

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1- Introduction

Joining of dissimilar metals to each other is common in various industries to achieve different properties of these metals in a compound. Different parameters affect the weldability of dissimilar metals, such as atomic radius, crystal structure and solubility of metals in the molten and solid state. The addition of alloying elements in the molten pool usually results in the formation of different intermetallic phases. Many of these intermetallic phases have hard and brittle structures which significantly affect the mechanical properties and flexibility of the joints. Stainless steels have less electrical and thermal conductivity compared to copper and its alloys. When these steels are used at high temperatures, their low thermal conductivity leads to low heat transfer. Joining these steels to copper and its alloys enhances their thermal conductivity. In this case, the formation of harmful phases such as sigma phase at high temperature applications is avoided. However, the high thermal conductivity of copper has restricted their welding operation. In other words, high thermal conductivity of copper decreases welding heat area and delays reaching the melting point. One of the most important issues in dissimilar welding is choosing a suitable filler metal to achieve good binding properties. In this study, the microstructure and properties of a dissimilar joint of pure copper to 304 stainless steel using GTAW welding process have been reviewed and the effects of two types of filler metals on binding properties were studied.

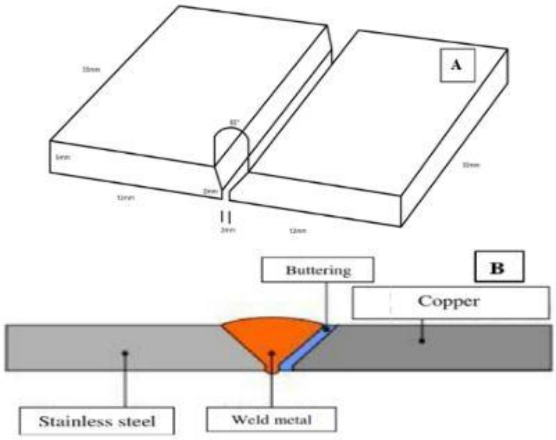
2- Experimental

In this study, 304 stainless steel and pure copper were used as base metals and two different filler metals ERNiCrMo3 and 309 stainless steel were used. Table 1 shows the chemical composition of the base and filler metals. The welded samples for both base metals were prepared as sheets with unilateral forked connection, an bevel angle of 60 °.

Table 1 Chemical composition of base and filler metals (Wt.%)

Fe	Cu	Mo	Ni	Cr	S	P	Si	Mn	C	Weight percent alloy
Bal.	0.7	0.3	8.23	19.55	0.005	0.016	0.48	1.7	0.04	AISI304
≤0.002	≥99.99	-	≤0.002	-	≤0.002	≤0.001	-	-	-	Cu
Bal.	0.5	0.75	13.5	23	0.03	0.03	0.6	2.2	0.03	ER309L
0.3	0.2	9	65	22	0.005	0.005	0.1	0.02	0.015	ErNiCrMo3

An intermediate layer was used as buttering on the surface of copper as indicated in Fig. 1 (a) and (b).



Fig, 1 Connecting plan of 304 stainless steel and commercially pure copper and placement plan of lining layer on the copper surface

Welding parameters and coding of two used filler metals are shown in Tables 2 and 3, respectively.

Table 2 GTAW welding parameters of 304 stainless steel and commercially pure copper

Parameter	Value
Welding current/(DCEN),A	200
Shielding gas	Argon
Gas flow/(L·min-1)	12
Welding pass	3
Plate thickness/mm	5
PREHEAT TEMPERAT/ °C	255
VOLTAGE/V	27
Filler diameter/mm	2.5
Tungsten electrode	W−2%TUNGESTEN
Nozzle diameter/mm	8
ELECTRODETYPE	ER309L,ERNiCrMo3,ERCu

Table 3 The codes of welded samples

Sample Code	Filler metal
ErNiCrMo3	1
Er309L	2

3- Results and Discussion

3-1- Microstructural Study

Fig. 2 shows the microstructure of sample No. 1. As shown in Fig. 2 (a), there are a number of holes in the HAZ of the copper base metal which is attributed to the high cooling rate due to high thermal conductivity of copper and also entrapment of the shielding gas in the weld metal. According to Fig. 2 (b), 304 stainless steel base metal has an austenitic matrix with some ferrite. In Fig. 2 (c) very

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fine coaxial austenitic dendrites are also observed which create an under-grain austenitic structure in the weld metal. Also, there were obvious solidification cracks due to high cooling rate in copper and thermal stresses in the welding area. Fig. 3 shows the microscopic structure of sample No. 2. As shown in Fig. 3 (a), conditions are similar to Fig. 2 (a) in terms of microstructure. In Fig. 3 (b) austenitic structure can be seen in the 304 steel base metal, but delta ferrite phase has been established in a skeletal form morphology due to the high amount of heat input. The microstructure in Fig. 3 (c) shows a fully austenitic structure with coaxial fine grains in the weld metal. No solidification cracks were observed in the weld metal.

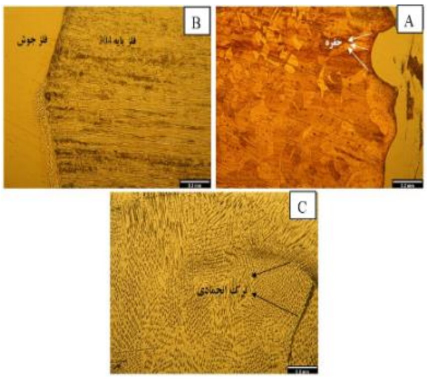

Fig. 2 (a) Microstructure of HAZ area of copper and weld metal interface, (b) microstructure of HAZ area of stainless steel and weld metal interface and (c) microstructure of weld metal of Inconel 625 filler metal

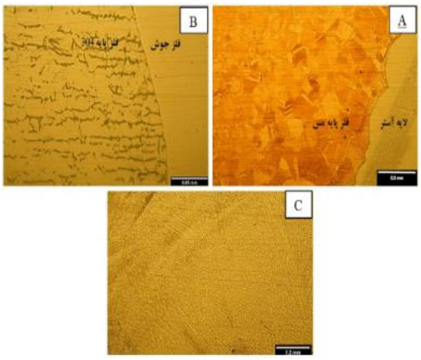

Fig. 3 (a) Microstructure of HAZ area of copper and lining layer, (b) microstructure of HAZ area of stainless steel and weld metal interface and (c) microstructure of weld metal of 309L filler metal

Table 4 The yield and tensile strengths of welded samples

Sample	Yield strength (MPa)	Ultimate strength (MPa)
1	125	229
2	144	235

3-2-Mechanical Properties

The results of tensile test of welded samples for two different filler metals of Inconel 625 and 309L stainless steel have been presented in Table 4 and Fig. 4, respectively. It can be seen that the tensile and yield strengths of 309L stainless steel weld metal is a little higher than Inconel alloy. The failure of sample 1 occurred at the copper-weld metal interface and the failure of sample 2, was seen in the HAZ of copper.

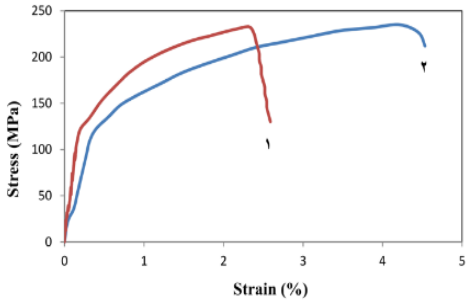

Fig. 4 True stress-strain curves for welded samples

3-3-Microhardness test

Microhardness results of welds obtained from the various filler metals, are shown in Fig. 5. The maximum amount of hardness was observed in the welded sample using Inconel filler metal.

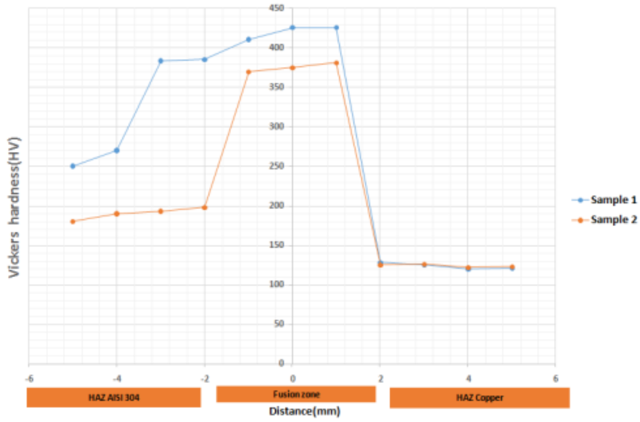

Fig. 5 Microhardness profiles of the welded samples

4- Conclusions

The most important achievements of this research are:

There is sharp interface as well as integrated coarse grain near the interface of copper and weld metal in both filler metals representing partial melting of copper during welding due to its high thermal conductivity.

The presence of solidification crack in the weld metal obtained from Inconel 625 filler metal was seen due to the high cooling rate in copper and thermal stresses in the weld zone, while there was no solidification crack in the weld metal obtained from welding with 309L filler metal.

Welded samples with Inconel 625 filler metal fractured in copper and Weld metal Interface, while the welded samples with 309L filler metal fractured in copper's HAZ area. Joining with 309L steel filler metal showed better mechanical properties compared to Inconel 625 filler metal.

The maximum amount of hardness in the weld metal for both samples observed due to the fine grain microstructures. The weld metal of Inconel 625 also showed higher hardness than 309L weld metal.