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Evaluation the Microstructure and Mechanical Properties of the Dissimilar Joint between Pure Copper and Stainless Steel 316

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1. Introduction

Joining of dissimilar alloys is widely used in different industries. The stainless steels and pure copper have different thermomechanical properties that makes those difficult to weld. However, dissimilar joints of stainless steels and pure copper have a wide range of application in cooling systems and heat exchangers. The joining of copper to stainless steels causes an inhomogeneous structure and may have some problems, including the formation of gaseous pores in copper and formation of sigma phase in stainless steels.

In this paper, the microstructure and mechanical properties of dissimilar GTAW of stainless steel 316 to copper is investigated and the formation of sigma phase after post-weld heat treatment is studied.

2. Experimental procedures

The dissimilar joints of stainless steel 316 and commercially pure copper with 5 mm-thick were prepared using GTAW method with two different filler metals (ERNiCu-7 and ERCu). The autogenous welding of stainless steel 316 plates is also performed with 316L filler metal to compare with the dissimilar joints. To investigate the effect of post-weld heat treatment on the joints, the autogenous and dissimilar welds were heat treated at 850˚c for 14 hr followed by cooling in the furnace.

3. Results and discussions

3.1. Microstructure. The microstructure of autogenous weld of steel 316 showed austenite and small amounts of delta ferrite in the fusion zone. The HAZ of stainless steels represented a slightly grown austenite grains, as well. The formation of delta ferrite at the HAZ near the weld pool prevented the austenite grains growth.

Using ERNiCu-7 and ERCu as filler metals to join cooper to stainless steel 316 resulted in a similar microstructure of HAZs (Fig.1). The copper grains extremely grew from 25 μm in base metal to 170 μm in HAZ. The Copper and iron have a low solubility in each other; therefore, the dissimilar welds consist of two different phases. The welded zones with ERNiCu-7 and ERCu fillers contained the Ni/Cu-rich and Cu-rich phases among the Fe-rich dendrites, respectively. There were some gas pores and inclusions which usually existed in the dissimilar copper to stainless steel joints.

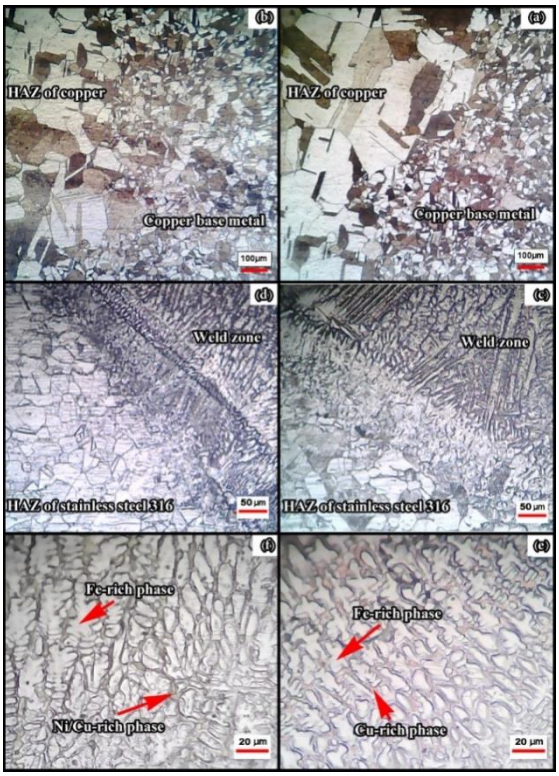

Fig. 1 – The microstructure of the dissimilar joints. HAZ and base metal of copper in the weld with (a) ERCu and (b) ERNiCu-7 filler; the interface of 316 stainless steel HAZ and the weld zone with (c) ERCu and (d) ERNiCu-7 filler; the middle part of fusion zone with (e) ERCu, and (f) ERNiCu-7 filler.

3.2. Mechanical properties. The fracture of transversal tensile specimens occurred in copper HAZ which was the result of sever grain growth. The impact test indicated that the higher toughness was related to the autogenous 316 steel. The dissimilar weld by ERNiCu-7 filler had a higher

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toughness compared to the dissimilar weld by ERCu filler, which was due to the existence of much more Ni in the composition.

3.3. The sigma phase formation. The sigma phase is a detrimental compound in stainless steels which may form during manufacturing processes or service life. In the weld zone of the autogenous weld, after post-weld heat treatment, there were some precipitates. Based on the low amount of Ni and high amount of Cr, these precipitates could be the sigma phase (Fig. 2). The results of JMatPro calculations also predicts the formation of sigma phase in the weld zone after heat treatment. The dissimilar weld zones did not contain sigma phase even after heat treatment. It is because of the existence of Cu or Ni/Cu in the composition. The Cu and Ni are austenite stabilizer elements which inhibit the sigma formation. The JMatPro calculations show that adding a little amount of Cu or adding much more Ni to the 316L steel move the sigma phase TTT curves to the lower temperatures and also increase the time needed for sigma phase formation.

4. Conclusions

- The autogenous 316 steel weld consists of austenite dendrites. The dissimilar weld fabricated by ERNiCu-7 and ERCu filler metals had a microstructure consisted of Ni/Cu-rich and Cu-rich phases among the stainless-steel dendrites.
- The dissimilar joints had a higher strength comparing with the Cu base metal. The fracture toughness of the weld with ERNiCu-7 filler was highest due to the existence of much more Ni.
- Some sigma phase particles can be found in the autogenous 316 steel weld after heat treatment but the existence of Cu or Ni (austenite stabilizers) in dissimilar copper to 316 steel joints prevents the formation of sigma phase.

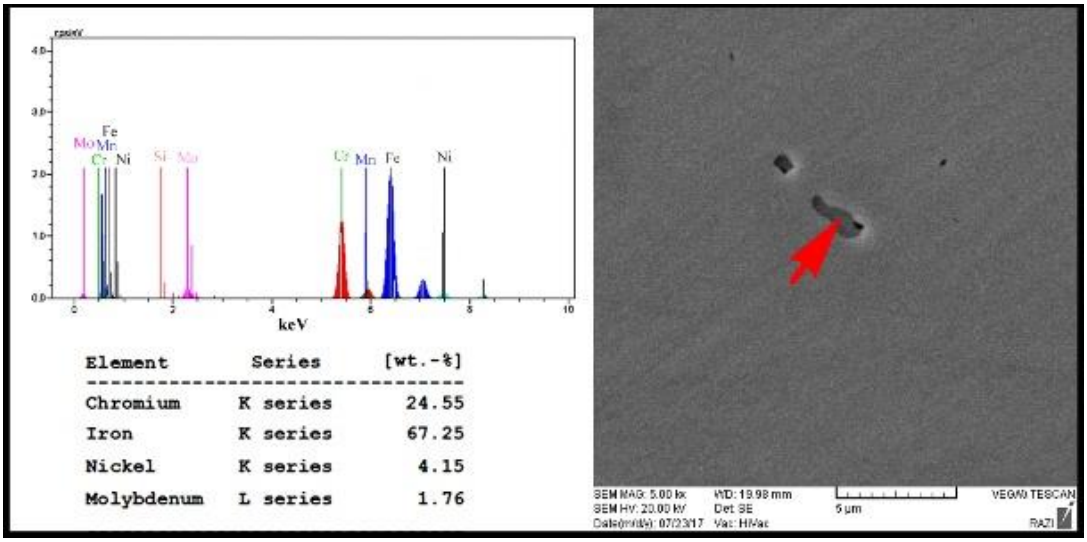

Fig. 2 – Sigma phase in autogenous 316 steel weld and the EDS results revealed by oxalic acid.