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Short Communication

Mechanical Properties Study of Copper/Stainless Steel Dissimilar Weld Joints

Yogesh Singla[1]* and Rakesh Joshi[2]

[1]*Materials Science and Engineering Department, Case Western Reserve University, USA*

[2]*Research Scientist, Design and Product Development Department, India*

***Corresponding author:** Yogesh Singla, Research Associate, Materials Science and Engineering Department, Case Western Reserve University, USA

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Abstract

The objective of the present investigation was to measure the mechanical properties of dissimilar weld joints of copper to stainless steel 304, fabricated using Tungsten inert gas (TIG) welding process. As-welded specimens were heat treated to a temperature of 650 °C for 1h, 2h and 3h. Tensile strength and microhardness measurements were made to analyze the effect of post weld heat treatment on the mechanical properties of dissimilar weld joints of copper and stainless steel. Specimens heat treated at 3h showed increase tensile strength and hardness, when compared to the specimen's heat treated at 1h and 2h.

Keywords: TIG welding; Heat treatment; Hardness; Tensile strength; Mechanical properties

Abbreviations: GMAW: Gas Metal Arc Welding; GTAW: Gas Tungsten Arc Welding; SAW: Submerged Arc Welding; TIG: Tungsten Inert Gas

Introduction

In the rapid development and improvement of welding techniques, rivets and fasteners have now been replaced with welding for joining of machine component. Welding has many advantages over other joining processes; however, it also has harmful metallurgical effects on the welded region of the joint. Most of the structural joins are developed using stainless steel. This is because of its good weldability property. Copper has also been recognized as a suitable candidate to due to the combined properties, such as strength, conductivity, corrosion resistance and ductility. Copper and its alloy have high thermal conductivity in comparison to stainless steel. Therefore, the use of this material is helpful to reduce the heat dissipation to the environment. The reduced heat dissipation can significantly decrease the formation probability of deleterious phases, such as sigma phase after prolong heating [1-8]. Many researchers have published the effect of various joining processes on the weld properties of copper to stainless steel joints. Mai et al. [1] and Yao et al. [4] used laser welding process for joining of copper to stainless steel. Magnabosco et al. [2] have studied the properties of copper/stainless steel using electron beam welding. Similarly, Durgutlu et al. [5] and Akbari et al. [7-8] have talked about the influence of joining of copper/stainless steel by explosive welding on the mechanical and microstructural properties.

Conventional welding processes, such as gas metal arc welding (GMAW), gas tungsten arc welding (GTAW) and submerged arc welding (SAW) are mostly used for joining, since, higher operational costs limits the use of laser and electron beam welding [3]. In the present study, bimetallic joint formed between copper and stainless steel 304 with the help of tungsten inert gas (TIG) welding. Mechanical properties of the weld joints were measured via tensile strength and microhardness evaluation of the interfacial region between copper and stainless steel 304.

Experimental Details

Two plates, stainless steel 304 and copper having dimensions 80×20×4 mm^3 were used as a substrate material. The nominal chemical composition is given in Table 1. Both the plates were welded together with Tungsten Inert Gas (TIG) welding with a filler wire made of stainless steel 316. It is well known that due to the higher thermal conductivity of copper, heat losses are more, therefore, to minimize the effect of heat losses, single bevel joint was made on copper side at an angle of 45°. Schematic of welding of the two plates is shown in (Figure 1). Prior to welding, both the plates were cleaned with acetone. TIG welding parameters throughout experimentation are presented in Table 2. Post weld heat treatment process was carried out in a muffle furnace at a temperature of 650 °C. A total of three samples were prepared from the weld zones, each of which was heated for 1,2 and 3hrs. After heat treating at a set temperature and time, the samples were allowed to cool at room temperature. The tensile strength of both as welded and heat-treated samples having dimensions 140×10×4 mm^3 was evaluated at a room temperature using universal tensile testing machine. In order to perform the hardness tests of as welded and heat-treated samples, three regions, namely, base of stainless steel, welded region and base of copper was selected. Microhardness tests were done at constant load of 200g with 20s of dwell time and an average of 5 readings has been reported

Table 1: Nominal chemical composition stainless steel, copper and filler wire.

Material			
Elements (wt.%)	**Stainless Steel 304 plate**	**Copper Plate**	**Filler Wire Stainless Steel 316**
C	0.08	-----	0.05
Mn	2	-----	1.65
P	0.045	-----	0.015
S	0.03	-----	0.003
Cr	18-20	-----	18.5
Ni	12-Aug	-----	9.2
N	0.1	-----	-----
Fe	Balance	0.005	Balance
S	-----	0.005	
Mo	-----	-----	2.7
Cu+Ag	-----	99	-----
Bi	-----	0.01	-----
Sb	-----	0.002	-----
As	-----	0.002	-----
Pb	-----	0.005	-----
Si	-----	-----	0.45

Table 2: TIG welding parameters.

TIG parameters	Level
Current	100 A
Filler wire diameter	2
Shielding gas	Argon

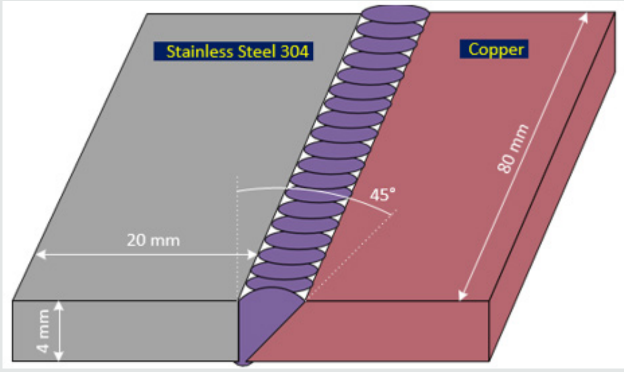

Figure 1: Schematic of joint design (units are in mm).

Results and Discussion

After welding, tensile strength of as-welded specimen and heat-treated specimens was taken and is listed in Table 3. It is seen that the tensile strength of as welded specimen is 400Mpa. Heat treatment of specimens after heat treated to 1h and 2h has no effect on the tensile strength of the specimens, when compared to the tensile strength of the as-welded specimen. The tensile strength of the specimen heat treated to 3h has increased from 400Mpa to 460Mpa in comparison to the tensile strength of the as-welded specimen. This increase in the tensile strength formation of diffusion layer at the interfacial region of steel and copper, which generally forms after post weld heat treatments. The results of tensile strength are in good agreement with the finding of Bina et al. [9], who have studied the influence of heat treatment on the bonding interface of copper and stainless-steel joint welded through explosive welding. The Results of the present study exhibited that the heat treating of specimens up to 2h is not sufficient to build the diffusion layer at the interfacial region, necessary to increase the tensile strength of the welded joints. Diffusion layer functions as a barrier against dislocations, gives rise to enhanced tensile strength. It is also well known that the formation of grains close to the diffusion layer is fine, which is helpful to restrict grain growth during recrystallization, hence increased tensile strength is obtained.

Table 3: Tensile strength of specimens.

Specimens	Tensile Strength (MPa)
As welded	400 Mpa
Heat treated to 1h	402 Mpa
Heat treated to 2h	391 Mpa
Heat treated to 3h	460 Mpa

Microhardness measurements made on stainless steel, copper fusion zone of as welded and fusion zone of heat-treated specimens at 1h, 2h and 3h are tabulated in Table 4. From Table 4, it can be observed that hardness of as-welded fusion zone is equivalent to the hardness of the fusion zone of heat-treated specimens. After

3h of post weld heat treatment, hardness was found to increase up to 176.4VHN. The increase of hardness in the fusion zone of heat-treated specimen may be because of the formation of a fine-grained diffusion layer at the interfacial region of stainless steel and copper joint. The results of hardness variation are in consistent with the findings of Bina et al. [9].

Table 4: Microhardness of specimens.

Specimens	Stainless Steel 304	Copper	Fusion Zone of As welded	Fusion Zone of Heat Treated		
				1h	2h	3h
Hardness (VHN)	280.1	19.7	150.4	153.6	158.9	176.4

Conclusion

Copper to stainless steel joints were successfully developed using TIG welding. The study reveals that heat treat of dissimilar weld joints of copper and stainless steel can significantly enhance the mechanical properties of dissimilar weld joints. The tensile strength was increased after post weld heat treatments.

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