Effect of Filler and Heat Treatment on the Physical and Mechanical Properties of the Brazed Joint between Carbide Tip and Steel

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Abstract. In this study, the effect of filler and heat treatment on the physical and mechanical properties of the brazed joint carbide tip and steel was investigated. Tip carbide YG6 and low carbon steel (SS400) is joining by torch brazing with two filler metals, silver, and copper filler. Heat treatment was performed in induction furnace. Microstructure and shear strength of the brazed joint have been investigated. Many silver filler layer are formed on the surface of the base metal rather then using copper filler. The highest shear strength is achieved using a silver filler metal at temperatur 725^{o}C. The highest shear load is 18.62 kN.

1. Introduction

Cemented carbide are widely used in manufacturing industries, mining, oil and gas drilling. It consists of tungsten carbide (WC) is known for its strength and hardness, and the Co as the binder [1]. This material is commonly used as cutting tools, abrasive wheels, metal forming equipment, drill tools and others [2,3]. To obtain the high quality of tools at low production cost, cemented carbide is usually joined with steel. Consequently, the joining cemented carbide with steel gets a real attention in recent years [4,5,6,7,8,9]. Nevertheless, the joining two these materials are not easily achieved. This difficulty caused by differences in chemical composition, properties, and physical characteristics. Moreover, as the ceramic particles, grain of WC is difficult to wetted. Research shows that by welding will produce residual stresses in the joint area. This is caused by the difference in coefficient thermal expansion [10,11,12].

Joining cemented carbide with steel required a special process, including mechanical assembly, diffusion bonding, brazing, and soldering [13]. From this process, the brazing is potential technique and able to join dissimilar metal [14,15]. To get a good brazed, some elements required, such as the selection of filler metal, base metal characteristics, heat input/ brazing procedure, and treatment after brazing. The selection of filler metal was the foundational step for brazing. Filler metals must be compatible with the base metal, and brazing procedure to be used. Especially for the characteristics of filler metal, a good filler metal has a low melting point, and the ability to form a bond with the base metal [16]. In other words, to make a joint to the base metal, filler metal should be able to wet the base metal and produces a low contact angle. As the base metal capillary action good penetration will occur if the base metal has a high capillary action, so that a good bond will be obtained.

Silver and copper filler metal has been widely applied for joining cemented carbide to other materials with brazing. This filler metal has a low melting point. Some research the use of this filler has been carried. As carried by Criss and Meyers [17], this study has successfully joining the cobalt using silver-copper filler metal. The results of the observation showed that the weld cracks can be minimized, and do not exceed the limit thickness. Delamination basic filler does not cause a failure in the area 4-point bending. Jing et al [18] investigated vacuum brazing on the cermet and steel using CuAgTi filler metal. The result of the investigation suggested that layer of CuNiTi solid solution is difficult formed between cermet and filler metal at 870^{o}C. Sun et al [19] researching about the effect of holding time on the microstructure and mechanical properties of ZrO2/TiAl joints brazed using Ag–Cu filler metal. Kaiwa et al [20] investigating effects additions of Ni and Co to filler metals on brazed Joints of cemented carbide and martensitic stainless steel using induction brazing. the result of the investigation suggested that the joint strength increased by adding the 2 mass% Ni and 0,5 mass % C into brazing alloy.

However, from the author's knowledge, there are no experimental data of the joining between cemented carbide and steel using torch brazing. In this study, Cemented carbides have been brazed with low carbon steel by torch brazing using two filler metal, silver, and copper filler. To improve the characteristics of joint, this study proposes the heat treatment. The effect of each element on the microstructure and mechanical properties of the brazed layer was observed and analyzed.

2. Experimental

Silver (Ag) and copper (Cu) filler metals are used in this study. The chemical composition of filler metals are shown in Table 1. Tip carbide YG6 with a dimension of 25x15x8,5 mm and low carbon steel (SS400) with a dimension of 40x15x10 mm were used as test specimens. The chemical compositions of test specimens are shown in Table 2. Before brazing, the contact surfaces of specimens were polished using silicon carbide abrasive paper (number 200 to 400). Figure 1 (a) shows the schematic representation of the apparatus and types of joints used for brazing. The joint clearance was kept at 0.1 mm using a thickness gauge of 0.1 mm in thickness. To keep the specimen remains constant, use tools such as jig (fixture), as shown in Figure 1(b).

Table 1. Filler metal composition

Metal	Ag	Cu	Ni	Ti	P	Other	Melting range (^{o}C)
Ag	Main	40	0,1	0,3	-	-	800-879
Cu	Main	-	-	-	7,5	0,15	704-815

Table 2. The chemical composition of specimen

Metal	C	Si	Mn	P	S	Ni	Cr	Fe	WC	Co
SS400	0,22	0,59	0,59	0,017	0,02	-	-	Main	-	-
YG6	-	-	-	-	-	-	-	-	94	6

After brazed, the specimens were then heated at temperature 700°C, 725^{o}C, and 750^{o}C by induction furnace for 30 minutes. Then cooled to room temperature with a cooling rate of 5°C/s. All of the test specimens was cleaned and ground ± 1mm using a diamond blade grinder. After grinded, the test specimens are polished with metal polish. Microstructures of the brazed layer were observed using microscope micro. Shear tests were performed on a mechanical testing machine (Model 4106 SHT) with a travel speed of 0.5 mm/min at room temperature, as illustrated in Figure 2. The results of the test specimen fractures were also analyzed.

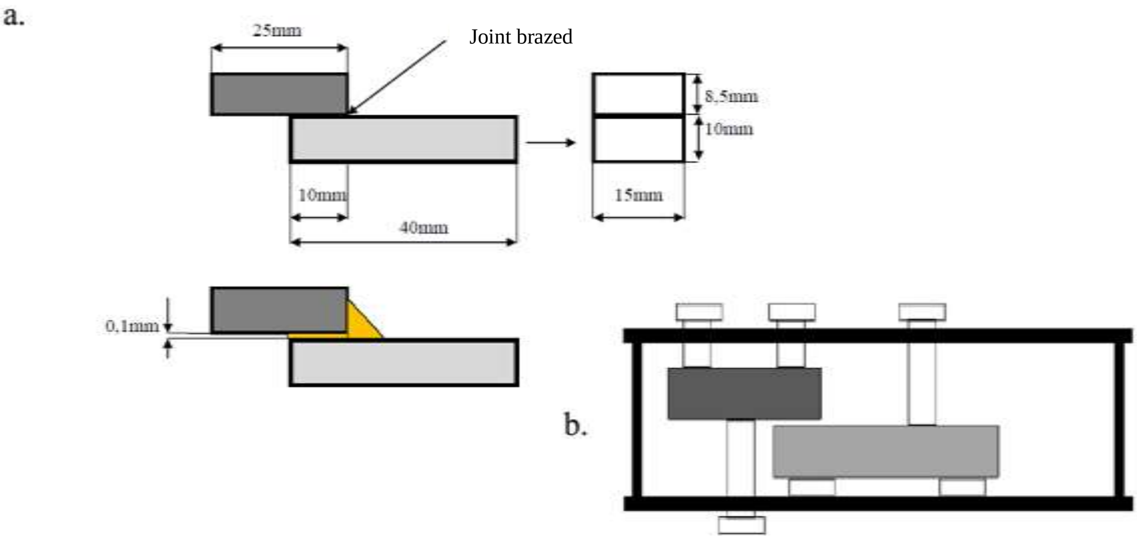

Figure 1. (a) Schematic and types of joints, and (b) Jig (fixture)

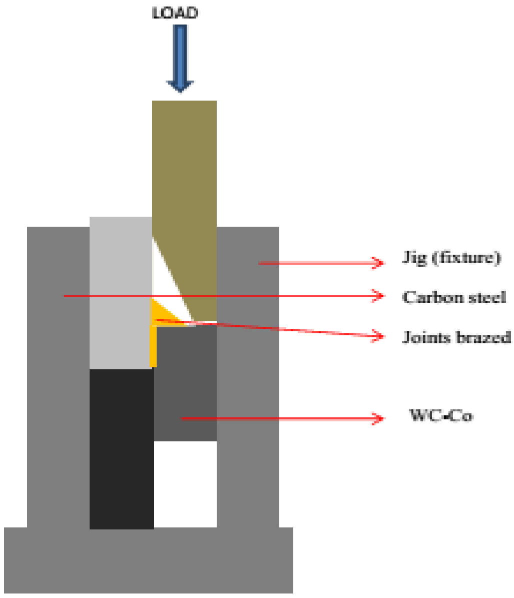

Figure 2. Schematic shear testing

3. Results and Discussion

Figure 3 shows the average shear strength of joints brazed with silver and copper filler. Which are at different temperature for 30 minutes. The test results indicate that the shear strength of joints brazed with silver filler is better than copper filler. Treatment temperature has a significant effect. The shear strength increased when the treatment temperature is increased from 700°C to 725^{o}C, but decreases when the temperature up to 750^{o}C. The maximum shear load of 18.62 kN at a temperature of 725^{o}C using silver filler metal. This result is higher than the copper filler metal. While the joint with copper filler (Cu) and heated at 700 °C has the lowest shear load of 4.94 kN. Increasing the temperature can improve the fluidity of filler metals and promote the diffusion of elements to achieve a homogenous microstructure. Excessively high temperatures would induce the growth of filler metal grains and thus deteriorate the property. Moreover, at high temperature will allow the occurred of defects or void in the filler metal. Void caused by inability filler metal to remove air or gas during cooling process of

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joint. This void causes failure in the joint. However, the cooling process has a function against the brazed layers. The area of diffusion also gives the influence of the shear strength. Uzkut et al [21] stated to obtain high diffusion area, can be achieved with the slow cooling process after heating.

This fact relates to the results of fracture shear tests, as shown in figure 4(a) and 4(b) the result of the observation showed, that joint brazed with copper filler many defects and void. Moreover, liquid filler metal is not able to fill the gap. Consequently, a copper layer is not formed on the surface of the base metal. Observations shows, fracture mostly occurred on the surface of the base metal. It causes a low shear strength. Observations on the joint brazed with silver filler showed, silver filler metal layer is many formed on the surface of base metals. The liquid of the silver filler can flow meets the gap of base metal. These results demonstrate the fact that the silver filler has characteristics capable of wetting and good flow. The joint fractured at the Ag zone near the cemented carbide but not at the interface, show that field of Ag near on the cemented carbide is the weakest area of brazed joints [22].

Photo macro of the joint brazing at 725^{o}C for 30 minutes after the shear test is shown in Figure 4(c) and 4(d). Wang et al expressed [23], that region of crack initiation is ductile fracture surface, which mixed with the field dimple rupture, During the cooling process, the different thermal expansion coefficients to produce the residual stress. The residual stress was dissipated by plastic deformation of Ag because it has good plasticity properties, which was good for the joint. In the shear test, Ag break along the direction of deformation, because it is not able to withstand high stress. This phenomenon is related to the formation of microstructure on the brazed layer. Figure 4 shows the microstructure of joint brazed with silver filler metals and copper in the various temperatures. When of the joint brazed with silver filler, homogeneous microstructure and there are no cracks along the line on the surface of the base metal. Silver filler metal layer is many formed on the surface of base metals, as shown in figure 4(c) and 4(d), a metallurgical bond is formed along the surface of the base metal. These results indicate that the filler metal have good wetting properties and able to fill the gap. The best condition occurred at a temperature of 725^{o}C.

The results of the observation showed that in the solid solution filler metal is many forming islands. These islands are a solid solution phase of the composition of the filler metal. This solid solution phase will give a strengthening effect on metallurgical bond. Figure 5(c) and 5(d) show the microstructure of joint brazed with copper filler metal. Along the surface of the base metal is not formed the metallurgical bond, this will reduce the joint strength.

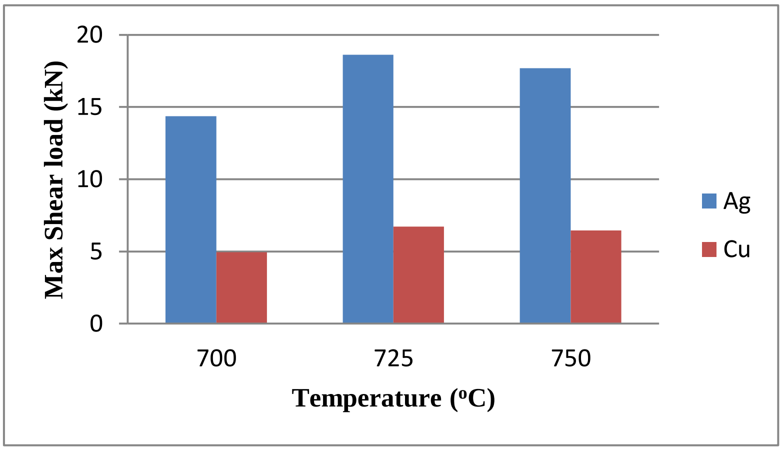

Figure 3. Shear strength of the joints brazed at different temperatures for 30 minute.

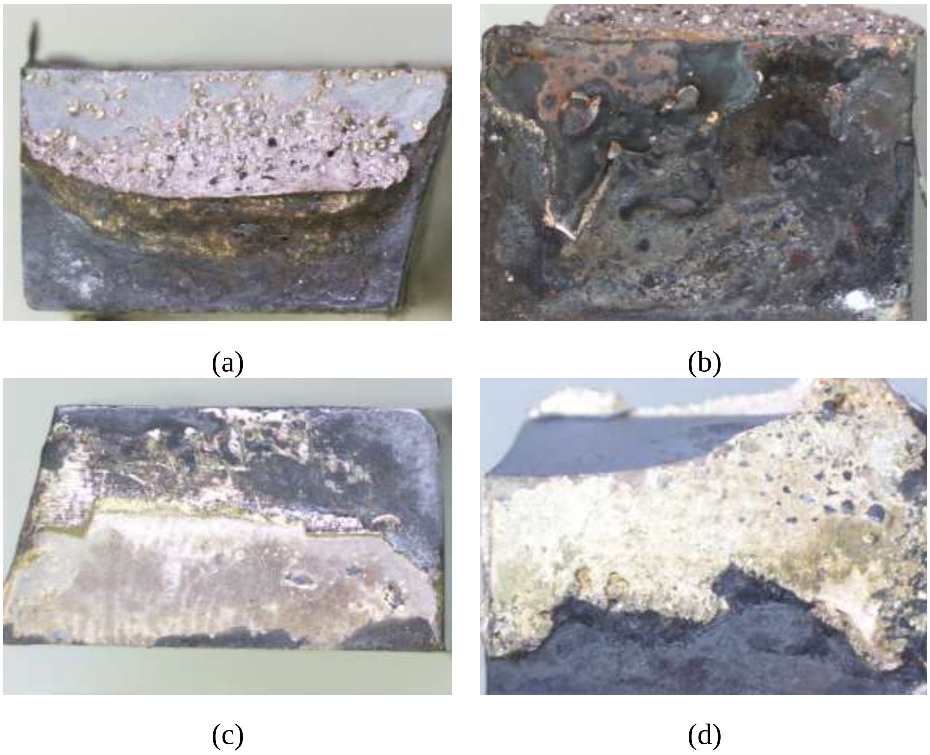

Figure 4. Fracture test specimens, (a) and (b) using copper filler metal, (c) and (d) using silver filler metal.

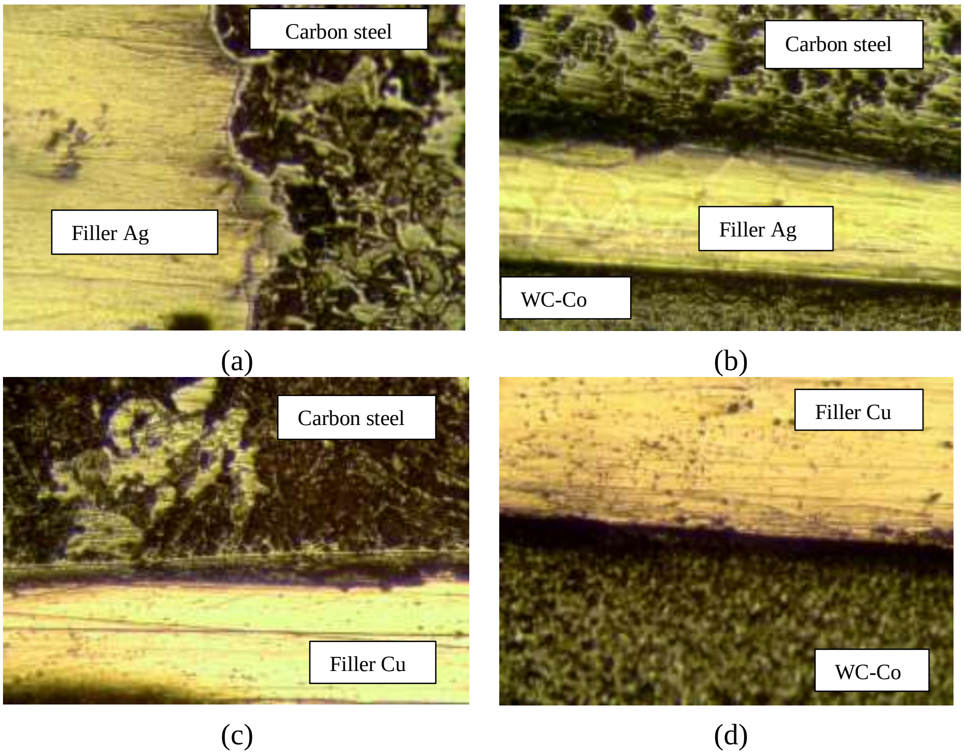

Figure 5. Microstructure of the joint brazed (a).700^{o}C, (b).725^{o}C, (c).750^{o}C, and (d).725^{o}C.

4. Conclusions

The aim of the present work is to investigate the effect of filler and heat treatment on the physical and mechanical properties of the brazed joint between carbide tip and steel under torch brazing. Many silver filler layers are formed on the surface of the base metal to reinforce the joint. In other hand, almost copper filler layers are not formed on the surface of the base metal which can reduce the strength of the joint. The shear strength increased when the treatment temperature is increased from 700°C to 725^{o}C, but decreases when the temperature up to 750^{o}C. The maximum shear load of 18.62 kN at a temperature of 725^{o}C using silver filler metal. While the joint with copper filler (Cu) and heated at 700 °C has the lowest shear load of 4.94 kN.

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