Study Experimental Joining Dissimilar Metal of Cemented Carbide and Carbon Steel under TIG Brazing

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Received: July 7, 2021. Revised: November 28, 2021. Accepted: December 28, 2021. Published: December 29, 2021.

Abstract—In the manufacturing industry, cutting tools are the main component. To produce the best performance of the cutting tool is required high cost. The cemented carbide and steels are joined using brazing. The aim of the work is to investigate the joining of dissimilar metals between cemented carbide and carbon steel using arc brazing. The TIG brazing method has been prepared for the joining of carbide insert and carbon steel. Phenomena that occur in the joint were observed using a scanning electron microscope (SEM). The composition of the constituent elements of the brazed area was characterized by energy dispersive spectroscopy (EDS). Vickers hardness machine is used to hardness test in the brazed area. The results of the microstructure analysis and EDS test composition indicate that solid solution phase enriched Cu is detected in the brazed area. The Fe and C elements are diffusions into the brazed area. The hardness value in the brazed area is 12,16 HVN, greater than based metals especially SS400. Thus, the solid solution phase of Cu and elements of Fe and C affect the hardness value.

Keywords—Dissilmilar joint, Cemented carbide, Carbon steel, CuSi alloy

I. Introduction

CEMENTED carbide is one of the hard materials, wear-resistant, and high temperature resistant. The advantages of cemented carbides are used to make cutting tools. However, cemented carbide is more expensive, because the main composition is tungsten and cobalt. To reduce the cost production of cutting tools, cemented carbide is joined with steel. However, the joining cemented carbide to steel sis so difficult by confensional fusion welding, because the two materials are of different types. The main reason is due to the difference in thermal expansion between the two materials [1]–[5].

Technologies are developed to joint the dissimilar metals, such as diffusion bonding[6], TIG brazing [7], electron beam welding [8], etc. Brazing is one of the special techniques for joining dissimilar metals, because the base metal is not melted, and has low residual stress. The brazing process is affected by heat input, filler metal, and characteristics of base metal. In recent years, joining dissimilar metal have been studied. Winardi (2018) [9] is researching the effect of post-brazed heat treatment on the microstructure and shear strength of cemented carbide and carbon steel using Ag-based alloy. The torch brazing is used in the joining process, and the heat treatment process is done in the induction furnace. The result of the examination shows, the increasing temperature of heat treatment leads to an increase in solid solution phase enrich Cu. The maximum shear test is 214.14 MPa at 750^{o}C. Jing et al (2014) [10] also investigated the joining of Titanium alloys with steel using CuNi as filler metal. It was stated that at low temperatures, the filler metal is difficult to formed to the based metal. The higher the brazing temperature, the layer and solid solution of the filler metal increases which can increase the shear strength of the brazed joint, On the other hand, if a layer and a less solid solution are formed on the surface of the base metal, the mechanical strength decreases. Maximum strength reaches 260 MPa when brazed at 910^{o}C. Jiang et al (2016) [11] investigated the joining of WC-CO and steel using Ag-Cu filler metal. from the results of testing and observation, it was found that, solid solution of Cu is widely dispersed in the filler metal and has an important function to increase the strength of the joint because it has high hardness. The joint strength increases with the widening of the -Cu layer. With increasing brazing temperature and holding time, the total area and amount of -Cu decreased. The results of the mechanical test showed that the maximum shear strength of the joint was 366 MPa when brazed at a temperature of 770ºC for 30 minutes.

Cu-Si is one of the Cu alloys widely used to filler metal [12]-[14]. The lower melting temperature of CuSi makes it ideal for joining Cu to steel, galvanized steel, and others. This advantage is very interesting to be developed in the joining of dissimilar metals. In addition, the CuSi is also suitable to TIG process. So, the main contribution of this study is investigate the dissimilar metal joint between cemented carbide and carbon steel using CuSi alloy under TIG brazing. The phenomena occurring around the joint will be investigated and discussed.

II. Experimental

The base materials with different properties are made as to the specimen, namely, YG6 cemented carbide & SS400 carbon steel. In the experimental, filler metal using CuSi alloy. The chemical compositions of the base material and filler metals are listed in Table 1. Before brazing, the surface of carbon steel is clean with Sic paper. The arrangement of the joint is shown in Figure 1. The surface gap of the specimen is measured using a thickness gauge (0.1mm). The jointing operation is done using the TIG process at 80 A. Ar at a 5L/m flow rate is used as the shielding gas. After the brazing process, the specimen is cut into 10x10x5 mm. The surface of the brazed area is polished using SiC paper grid 400 to 2500 and then polished using metal polish paste. The microstructure specimen is analyzed using a Scanning electron microscope (SEM). The element of the microstructure is known by energy dispersive spectroscopy (EDS). The hardness value is tested using a Vickers hardness machine.

Table 1. Chemical compositions of base materials and filler alloy.

Element	W	C	CO	Fe	Cu	Si	Ti	Mn	P	S
YG6	83.30	10.29	2.43	1,45	-	-	2.54	-	-	-
SS400	-	0.11	-	main	-	0.22	-	0.59	0.017	0.02
Filler Alloy	-	-	-	-	97	3	-	-	-	-

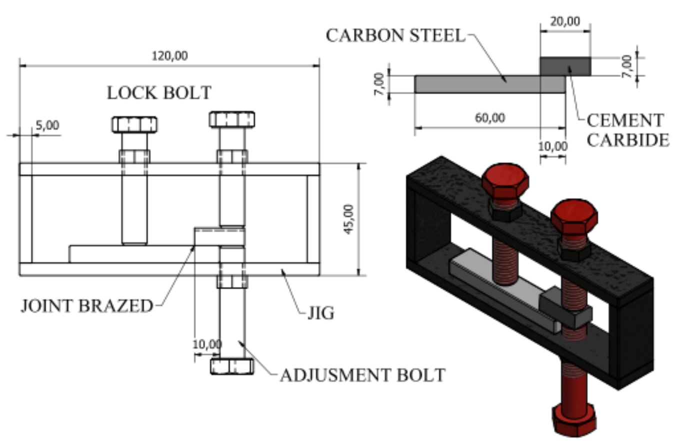

Fig. 1 The arrangement of the brazed joint

III. Result and Disscusions

After being brazed using CuSi alloy, the specimen surface was cut and smoothed using sandpaper. The cross-section of the brazed joint dissimilar metal between cemented carbide and carbon steel is shown in Figure 2. During the brazing process, Cu deposition has been successfully achieved. There are no visible defects in the cross-section. During the brazing process, the penetration that occurs into the surface of the base metal (SS400) is very deep due to the influence of the brazing current. The arc generated by the brazing current causes little damage to the base metal. The location of the damage is shown in the red mark in Figure 2. The high heat input causes the steel surface to melt and mix with the filler metal. The phenomenon is the same as that experienced by Lee (2019)[15]. Two types of damaged parts can be seen (Figure 3) : the upper and lower sides of the base metal, which are affected directly and indirectly by the arc. Usually, penetration occurs on the underside of the lap joint due to the presence of the HAZ with the arc pool.

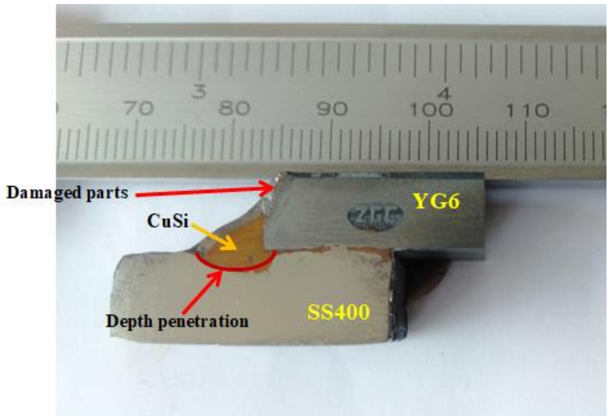

Fig. 2 Cross section of brazed joints using CuCi

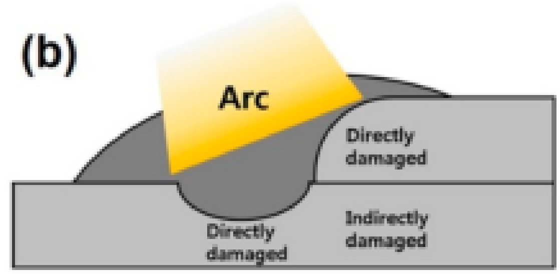

Fig. 3 locations of damaged parts (Lee et al 2019)

To investigate the properties of the brazing layer, we analyzed the microstructure of the brazed joint. Figure 2 shows the microstructure of the dissimilatr metal between cemented carbide and carbon steel brazed using a CuSi alloy. Microstructure clearly visible that the interface is free from defects, such as pores, cracks, incomplete solidification, inclusions, and others. This indicates that the filler metal has good wettability on the base metal

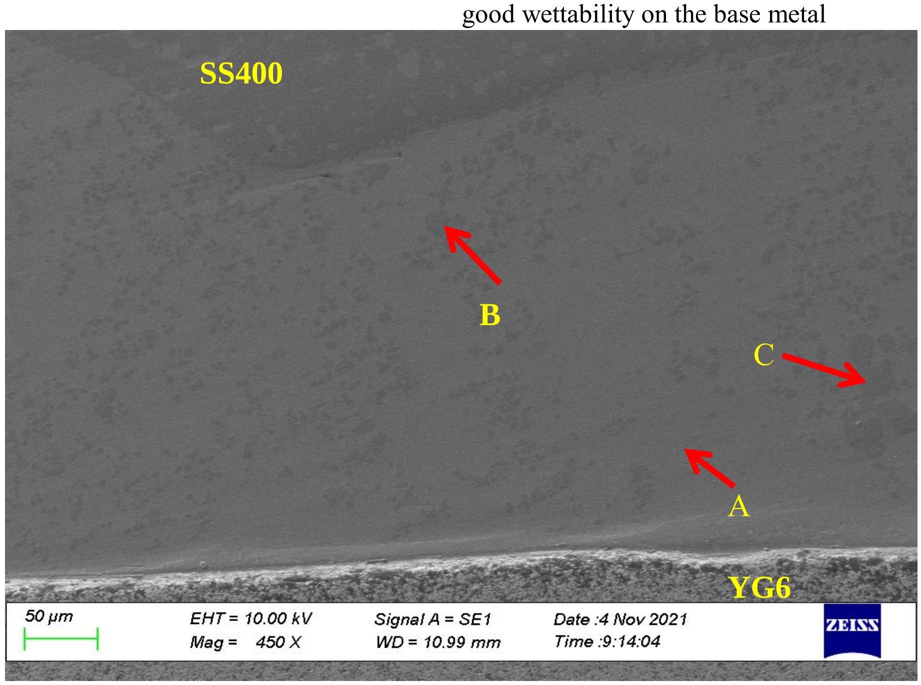

Fig. 3 Microstructure of TIG brazed joints with CuSi

In the image the microstructure is divided into 3 points, namely light colors as shown in point A, and dark colors with small textures are shown at point B, and dark colors with large textures are shown at point C. Any components contained in each point were detected using EDS, and the percentage results are listed in Table 2.

Based on the results of the EDS test, point A is a solid solution of filler metal consisting of Cu (94.92%), element C (4.32), and a small part of Si (0.76), and confirmed as a solid solution of -Cu. At point B is a solid solution enriched with

Fe, Cu, and Si, where Fe elements reach 62.95%, Cu elements reach 33.86%, and a small portion of Si 3.19%. While at point C, the highest content is Cu reaching 51.23%, Fe at 44.41%, C reaching 2.90%, and the smallest being Si at 1.46%, respectively.

Table 2. EDS results at each point in Figure 2 (wt%)

	W	CO	C	Fe	Cu	Si
A	-	-	4.32	-	94.92	0.76
B	-	-		62.95	33.86	3.19
C	-	-	2.90	44.41	51.23	1.46

Based on the EDS results in Table 2, it can be seen that the Fe element is able to diffuse into the filler metal area. In addition to Fe elements, there are also C elements released from the base metal (SS400). Due to the high brazing current, the heat input to the base metal is also greater. This causes some of the base metal surface to melt and mix with filler metal deposits. In addition to the influence of heat input, the degradation of the base metal is also caused by the low brazing speed The brazing speed varies inversely with the heat input. Heat input is very large at lower brazing speeds, and excess heat causes deep penetration [16]-[18]. The thermal diffusivity of the base metal is the most important for the penetration sensitivity due to the cooling rate. Lee (2019) [12] stated that proper arc current and velocity are required even if the brazing temperature is more than the melting temperature of the base metal. The smelting of the base metal and filler creates a fusion zone, having a depth and width of penetration.

The mechanism for the formation of the microstructure above cannot be separated from the action and interaction of heat synthesized by the arc and the interaction between Cu, Fe, and Si. During the TIG brazing process, the brazing arc current causes high heat to be transferred continuously and hits the steel surface, causing the steel surface to melt. Then some of the Fe element is extruded out and settles around the location of the area affected by the arc current, as shown in Figure 3. On the other hand, some of the Fe elements mix with the liquid metal Cu-Si to form a solid solution of CuFeSi. In this case, the element Fe detected is very small.

To clarify the results of the analysis, element mapping using EDS is shown in Figure 4. The green color is the result of mapping the Cu element, the red color is the map of the Fe element, the purple color is the image of the distribution of the Si element, and the light blue color is the capture of the W element. Based on Figure 4, the braze area is dominated by Cu, Fe, and a small part of Si.

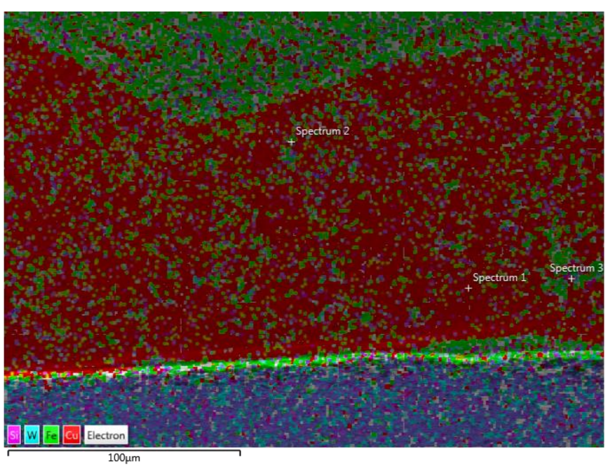

Fig. 4 EDS mapping element

The results of the EDS mapping show that there are 2 phases in the braze area, namely the Cu matrix and the Fe solid solution. It can be seen that the Fe element is able to diffuse and spread widely into the filler metal area. Fe elements are evenly distributed throughout the layer.

It can be concluded that these particles result from the action of the anode arc welding. Because the welding machine is operated in DCSP mode, a high-density electric current flow from the cathode to the anode. During the arc brazing process, many high bright spots are observed on the surface of the base material, and these points are the anode points. The 'anode point' action causes the micro-iron particles to melt and migrate, and are distributed throughout the filler metal zone [19]. To determine the phase formation, the Fe-Si binary phase diagram is studied, there are several possibilities for the formation of compounds such as FeSi, FeSi2, Fe5Si3, Fe2Si, and others [20]. The Fe-Si compounds will not be produced and grow at the same time. It is important to determine the Gibbs free energy and the diffusion coefficient of each compound using thermodynamic calculations [21]-[22]. However, in the mapping in Figure 4 no compounds were detected because the particles do not have enough energy to form compounds

IV. HARDNESS

The distribution of hardness values at the joints was detected using Vickers Hardness measured from one end to the other with a load of 30 gf for 30 seconds. The hardness value in the connection area is 12.16 HV. In base metals, especially carbon steels close to the brazed area, the hardness value is smaller than the brazed area, which is 10.15 HV, and in cemented carbide 70.21 HV. The diffusion of Fe and C elements in the brazed area has a significant impact on the brazed area. The hardness value of the brazed area is higher than that of the base metal, especially carbon steel.

V. CONCLUSION

This study was carried out to investigate the microstructure and mechanical properties dissimilar metal cemented carbide and carbon steel using CuSi alloy under TIG brazing. The result obtained are summarized as follow:

1. The brazed layer consist matrix of Cu, and solid solutions enriched Fe and Cu. The Fe and C element dissolution from based metal especially carbon steel (SS400).
2. The diffusions of Fe and C element in the brazed area are contributed to hardness. The hardness value in the barazed area is greater than based metal.

For future work, the study is focused to investigate the intermetallic compounds in the brazing area.

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Sources of Funding for Research Presented in a Scientific Article or Scientific Article Itself

This work was supported by a PTUPT 2021 research grant from the Ministry of Education, Culture, Research, and Technology of the Republic of Indonesia [contract # 13/E4.1/AK.04.PT/2021;18/AMD-SP2H/LT-MULTI-TERAPAN/LL7/2021; 140/VI.4/PN/2021]