Interfacial phenomena at NbC-M2 Cemented Carbide/AISI 4140 Steel Using Brazing Technique

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ABSTRACT

Cermets, which are a subset of ceramic materials, are widely used in the cutting industry because of their excellent hardness, strength and wear resistant properties. Various cermets have been used in this industry for a long time, but due to a number of disadvantages such as instability at high temperatures and toxicity of their elements, they must be replaced with more suitable materials.

Among these, niobium carbide (NbC)-based cemented carbides attracted a lot of attention in recent years and can be chosen as suitable and novel alternative because of unique properties. However due to the inherent fragility and inability to produce these materials in complex forms, they need to be joined to the holder with high toughness such as steel. Brazing is one of the most common methods for joining these two components due to the simplicity of the process and also creating a connection with suitable strength. The main problem in brazing of cermets is the wettability of these components by metals or filler alloys. This parameter has a main role individually in sound brazed joints. Also other parameters such as brazing temperature, holding time, surface roughness have great effect on brazed strength.

The aim of this study was to investigate brazing of NbC-M2 based cermet to steel substrate by a nickel based (AWS BNi-2) filler metal. First, wetting behavior of the cermet substrate by the molten filler was investigated at different times, temperatures and surface roughness using a sessile drop technique. The lowest wetting angle was measured to be about 10°, which was achieved at a temperature of 1100 °C, a time of 15 minutes and a surface roughness of treating with sandpaper No. 1200 micrometers. In the next step, brazing of NbC-M2/AISI 4140 was performed at different brazing times and temperatures. Microstructural examination and phase analysis within the joint area were done using a X-ray diffraction (XRD) apparatus and a scanning electron microscope (SEM) equipped with an energy dispersive x-ray spectrometer (EDS). The strength of the joints was measured using a shear testing method. The highest shear strength was achieved for the joints which were brazed at 1100 °C for 10 minutes.

Materials and Methods

Nickel-based solder alloy (AWS BNi-2) filler metal (Ni,7Cr, 4.5Si, 3.1B, 3Fe) was used to perform wettability tests and join the NbC-M2 cermet to the AISI 4140 steel holder in a tube furnace under argon atmosphere and heating rate of 15 ˚C/min.

Wettability tests were done according to Table 1 in different conditions to investigate and evaluate the effect of these variables on the wetting angle. In second step, the cermet samples were placed on steel holders, among which was a BNi-2 solder alloy in order to perform the brazing tests according to table 2.

Table 1. Conditions of wettability test specimens (optimal surface roughness(OR))

Sample code	S_1	S_2	S_3	T_1	T_2	t_1	t_2
Grit SiC No.	5000	1200	400	OR	OR	OR	OR
T (°C)	1100	1100	1100	1000	1050	1100	1100
t (min)	15	15	15	15	15	5	10

Table 2. Brazing conditions of samples

sample code	A05	A10	A15	B05	B10	B15	C05	C10	C15
T (°C)	1000	1000	1000	1050	1050	1050	1100	1100	1100
t (min)	5	10	15	5	10	15	5	10	15

Results

Wettabiliy

According to Table 3, it can be seen due to the capillary action in the surface treated with sandpaper No. 1200, the wetting angle decreases to its minimum value about 10˚ and the solder alloy is spread over a wider range. Also by increasing temperature and time parameters, the reactivity with the base surfaces and consequently the wettability increases.

Table 3. Results of wetting tests

Sample code	S_1	S_2	S_3	T_1	T_2	t_1	t_2
Wetting angle(˚)	17	10	21	21	16	16	11

Brazing

Temperature effect

According to Fig. 1, during the brazing process, the diffusion of melting point depressants (MPD) elements towards the cermet and the dilution and subsequently diffusion of the binder elements towards the joint area lead to the formation of isothermally solidified gray zones. The remaining melt forms dark phases as athermally solidified zones (according to the elemental analysis in Fig. 2). Also, due to this phenomenon, the separated NbC particles are preferentially decomposed in the areas near the interface and form the Nb_2Ni and Cr_7C_3 phases with nickel and chromium in the filler according to the X-ray diffraction pattern in Fig. 3 as the reaction layer. Temperature has a great influence on formation of sound joints. The phenomenon of element diffusion is encouraged by increasing this parameter.

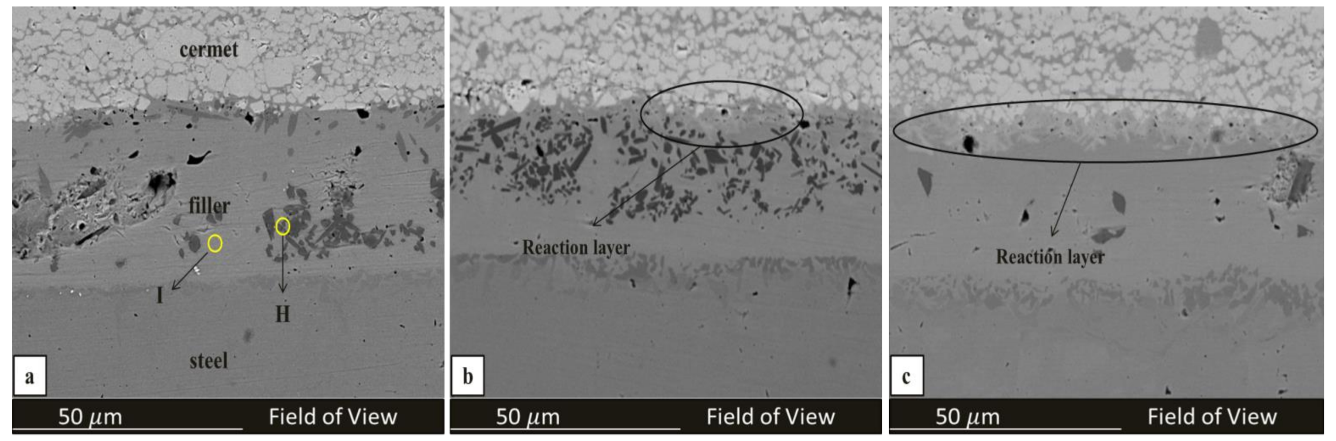

Fig. 1. SEM images of NbC-M2/AISI 4140 brazed joints for a) A10, b) B10 and c) C10.

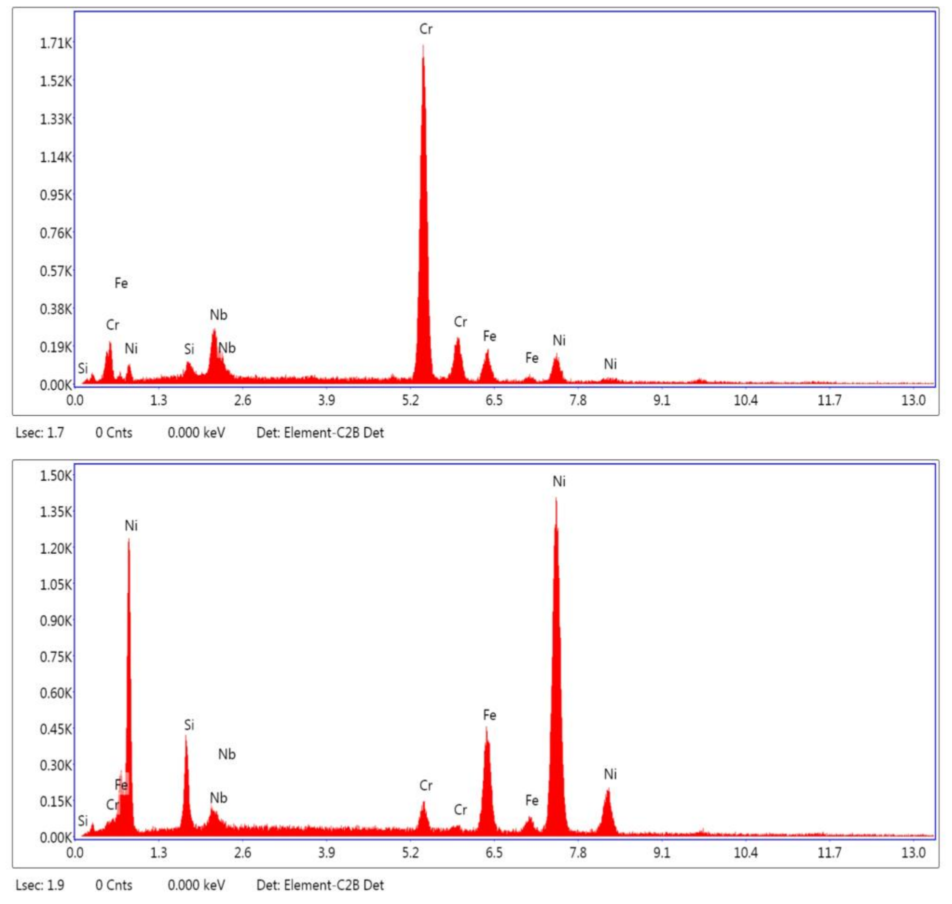

Fig. 2. The EDS analysis of a) dark phase (H) and b) gray phase (I)

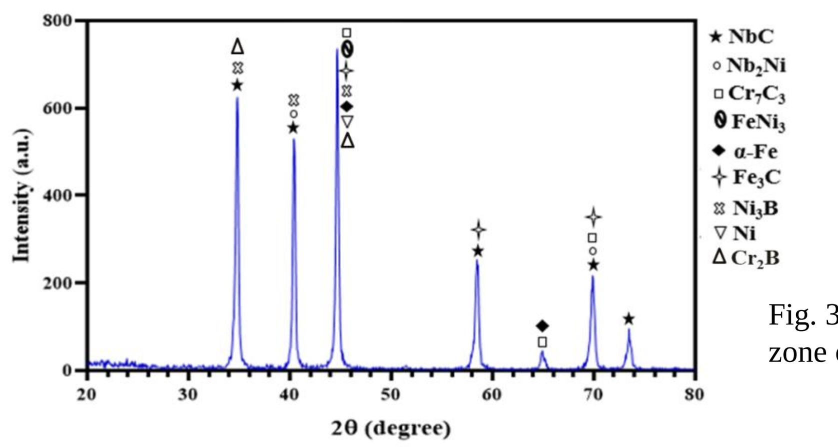

Fig. 3. XRD analysis result of the bonding zone of the brazed joint (C10)

Time effect

As shown in Fig. 4, in addition to the temperature parameter, the time parameter is also required to achieve a homogeneous structure. So that in 15 minutes, the dark and brittle phases are completely eliminated. However, in addition to excessive diffusion of the elements, dilution of components and formation of cavities due to binder depletion zones, molten flow and leakage from the joint area intensified in long times.

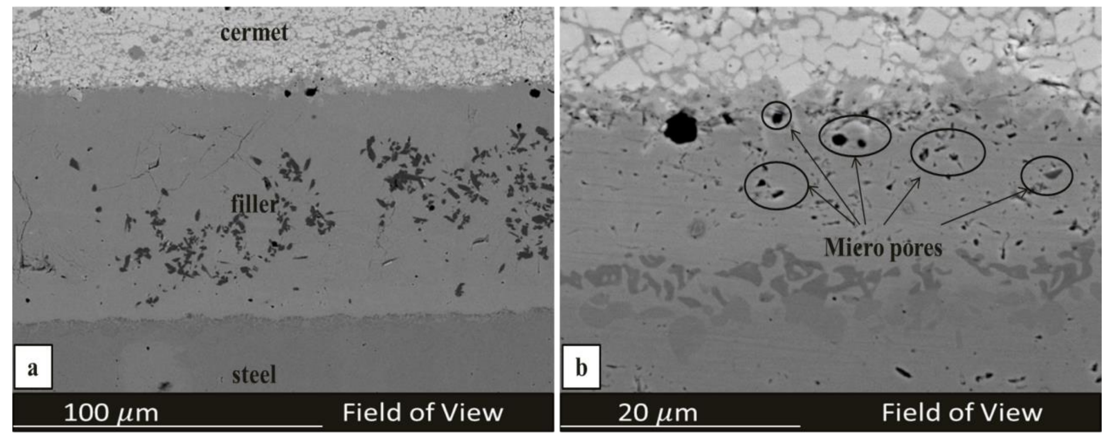

Fig. 4. SEM images of NbC-M2/AISI 4140 brazed joints for a) C05 and b) C15.

Joint shear strength

Fig. 5 shows the shear strength of NbC-M2 brazed joints to AISI 4140 steel. According to the Fig. 4c, with increasing the temperature up to 1100 ˚C and the time up to 10 minutes and finally reaching a uniform structure, the shear strength of the brazed joint reaches to the maximum value of about 105 MPa.

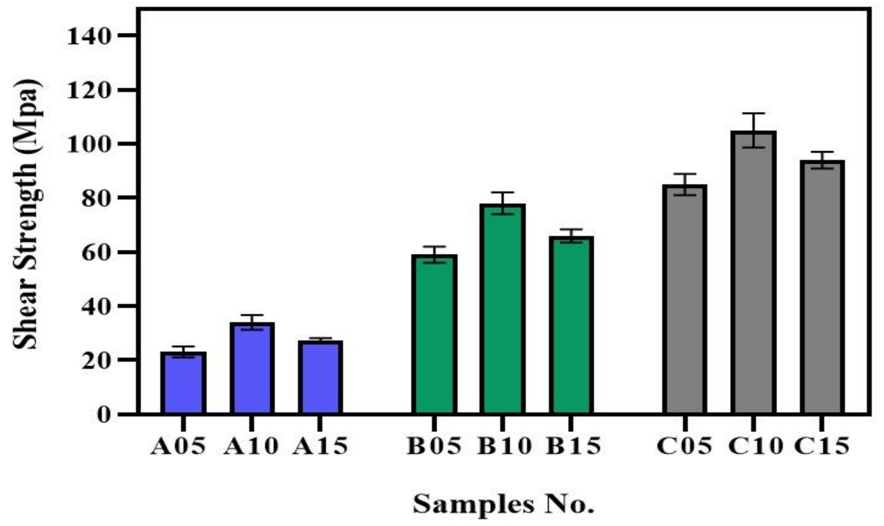

Fig. 4. Shear strength of the brazed joints in different times and temperatures.

CONCLUSIONS

- The BNi-2 filler alloy was able to wet the surface of the cermet. The minimum wetting angle was estimated about 10 ˚ at the roughness obtained by treating with P1200 grit SiC papers and temperature of 1100 ˚C for a time of 15 minutes.
- In microstructural studies, it was found that with increasing temperature up to 1100 °C and time up to 15 minutes, the diffusion phenomenon is encouraged and the dark and brittle phases within the structure are reduced. This issue resulted in the formation of a continuous reaction layer consisting of Nb_2Ni and Cr_7C_3 phases at the interface of the filler alloy and the cermet.
- With increasing time up to 15 minutes, due to excessive diffusion of the elements, corrosion cavities are created in the joint area.
- The brazed sample at 1100 °C and an average time of 10 minutes, had a maximum shear strength of about 105 MPa due to its uniform structure.

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