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BRAZING OF TIC CERMET TO STEEL

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Abstract: *Shear strength of induction brazed TiC cermet joints was studied. Traditional and amorphous brazing filler metals were tested. Amorphous Cu-Ti and Ni-Co-Fe filler foils were found prospective for vacuum brazing of a cermet. The joints achieved the shear strength 260-300 MPa. Traditional Cu-Zn and Ag-Cu type filler metal was found prospective for air brazing and shear strength of up to 190 MPa was obtained. Interface chemical composition of brazed joints and fracture morphology of joints was analyzed.*

Key words: TiC cermet, brazing, shear strength

1. INTRODUCTION

Hardmetal and cermet use in tools and wear resistant parts enable the service life to be prolonged. In many cases, in tools for finish machining (especially turning of special alloys) usually a TiC - based cermet with Ni and Ni (Mo) alloys or a steel binder is used. In spite of Ni and Ni alloys being the most widely used binder materials for TiC cermets, iron alloys Fe-Ni are attractive. Cermets based on TIC have found their application because of such properties as low density, relatively high mechanical strength, high oxidation resistance and low (close to steel) thermal expansion coefficient. Titanium carbide cermets with a steel binder are used as materials withstanding high-cycle fatique-stamping and as blanking or die materials [1-3].

TiC-Ni cermets produced by self–propagating high temperature synthesis can be used for valves, tappets in engines, seals or bearings, which are exposed to severely erosive fluids in mining, geothermal drilling and coal liquidification [4-6]. The most favourable properties of such composites are their low friction coefficient, high adhesive wear resistance and fair resistance to corrosion.

To save expensive cermets and simplify the design of complicated tools and wear parts, bimetallic or dual compounds of "cermet-steel" can be used. Fair durability of these bimetals depends on the quality of a joint between the cermet and steel. Diffusion welding was successfully used for joining TiCNiFe cermets. Using Ni and permalloy inserts and heating in vacuum, a shear strength up to 260-300 MPA was achieved [2-3].

In the production of bimetallic hardmetal WC-Co cutting tools commonly used brazing as bonding technique. To ensure high quality high vacuum during brazing is to be applied. Cu or Ag based filler metals named as traditional filler metals (TFM) are used.

The brazing of different materials is apt to present numerous difficulties arising out of their chemical, physical and mechanical properties. One common technological difficulty is insufficient wetting of carbides by the brazing filler metal. This may be due to ineffective shielding by the protective atmosphere or low vacuum in furnace or a non-uniform process temperature in the case of induction heating.

However, conventional vacuum furnace brazing of the TiC cermet was reported in [4-6] using a silver-based filler metals.

TiC cermets with a 40% Ni binder content were successfully brazed in a vacuum furnace (vacuum $6.6*10^{-3}$MPa) using Ag-54Cu-33Zn traditional filler metal [4-5]. The shear strength of joints up to 95.7 MPa was achieved. Conventional furnace brazing with slow heating and cooling rates was used. The maximum strength was obtained when optimal brazing parameters were used: 850-900 °C and for 15 min heating. The fracture of joints occurred in the central zone of the interlayer. When the brazing temperature was higher or the brazing time was longer than 15 min, the shear strength of the brazed joint decreased and the fracture occurred in the interface of the cermet-filler metal or filler metal-steel.

On the basis of structural and chemical composition and fracture examinations of the joints, an interface evolution model and fracture model for the TiC cermet-steel joint was developed in [5-6].

In [6] the results of vacuum brazed TiC cermet with the Ag-31Cu-23Zn filler metal were reported. The maximum shear strength of 120.7 MPa for joints brazed at 850 °C for 15 min was achieved. The interface structure can be divided from three up to five zones, depending on the temperature and brazing time.

New amorphous filler metals (AFM) reported in [7-8] produced by a rapidly solidifying technology are successfully used for vacuum brazing of WC-Co based hardmetals. Ni-Pd and Ni-Co type AFM have been used. These AFM are prospective due to their chemical composition as well as compatibility with hardmetals and cermets.

AFM were used when high vacuum (10^{-3} – 10^{-7} Pa) furnace brazing was applied.

Special silver containing brazing filler alloys with the trade name Argobraze enable rock drills to be produced with satisfactory mechanical properties of joints [9]. These alloys have lower melting temperature and are usually preferred to economize of heat energy and reduce internal stresses. Silver based filler alloys are expensive. Silver–free copper based filler metals (trade marks B,C,D,F Bronze) are cheaper and can also be utilized to produce rock drills [9].

However, information concerning the prospects of brazing technology for joining TiC based cermets to steel is comparatively restricted.

In many applications induction heating is a faster and more efficient technique than the traditional vacuum furnace heating. No reports on the influence of a lower vacuum or air atmosphere and shorter time in the brazing process on the mechanical strength of TiC-based cermet joints have appeared.

The present paper describes the influence of the brazing filler composition and brazing atmosphere (vacuum, air) on the strength of a joints TiC cermet to steel.

2. EXPERIMENTAL PROCEDURE

The study focuses on the joints based on the titanium carbide (70 wt%) base cermet with the Fe-Ni steel (Fe Ni14) binder phase. The mean grain size of the carbides was 2.2 – 2.5 μm. Specimens with the diameter of 17.0 – 18.6 mm and the height of 10 mm were used.

Carbon structural steel (grade 45, 0.45%C) was used as a counterpart. The diameter of the counterparts was 20 mm, the height 50 mm. The hardmetal and steel counterparts that were to be bonded were ground to the surface finish $R_a \leq 1$ μm.

Experimental amorphous filler metal (AFM) foils with the thickness of 50 μm and the designation S 1311, S1201, S1204 and commercially available Ni-Co type AFM grade MBF20 were tested.
Traditional brazing filler alloys were selected from the production list of commercially available alloys.
Copper based traditional filler metals (grade F- Bronze) as well as Ag-based filler metal (grade Argobraze 49H) were used as traditional metals (TFM) for brazing carried out in the air (Table 1). Fluxes with the trade name Tenacity 125 and 300 were used.

Table 1. Chemical composition of amorphous filler metals (AFM) and traditional filler metals (TFM)

Grade	Type	Composition	Brazing T, °C
S1201	AFM	52Ti-24Cu-12Zr-12Ni	920
S1204	AFM	72Cu-28Ti	1020
S1311	AFM	70Ni-16Co-5Fe-4Si-4B-0.4Cr	1030
MBF20	AFM	82Ni-7Cr-4Si-3B-3Fe	1070
F-Bronze	TFM	58Cu-38Zn-2Mn-2Co	910
Argo-braze 49H	TFM	40Ag-16Cu-23Zn-7.5Mn-4.5Ni	690

The brazing processes were conducted in the special diffusion welding equipment UDS-4 in vacuum (0.1 – 0.2 Pa). Joints were heated by the induction heating (440 kHz) generator.
The foils of AFM were placed between cermet and steel parts under low pressure (5 kgf) induction heated for 1 min. The brazing process in the air was carried out without applied pressure.
To estimate the strength of joints the shear strength of the respective bimetallic specimen was determined by a special device (Fig. 1).

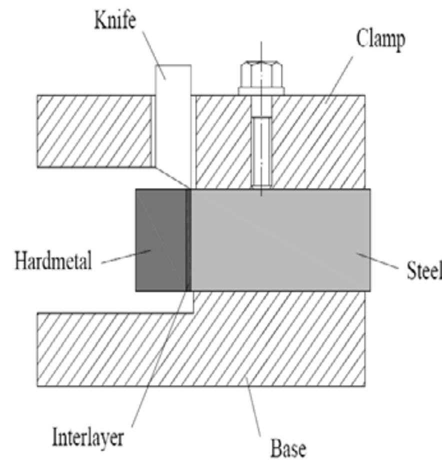


Fig. 1 Shear strength test device

The value of mechanical strength is the mean result of 3-5 identical samples.
The distribution of chemical elements in the bonding zone was examined by an electron probe microanalysis (EPMA) and the fracture surfaces of brazed joints were examined by a scanning electron microscope (SEM).

3. RESULTS AND DISCUSSION

The mechanical properties of the brazed joints depend on the type of filler metal and brazing conditions (Table 2).
Table 2. Shear strength of brazed joints

Bonding atmosphere	Filler metal	Shear strength, MPa
vacuum	AFM S1311	260
vacuum	AFM S1204	300
vacuum	AFM MBF20	200
air	AFM S1311	220
air	Argobraze 49H	190
air	F – bronze	200

Vacuum brazing of TiC cermet to steel using amorphous filler metals demonstrate an obvious superiority over air brazing. Lower strength of specimen joined with amorphous filler metal MBF20 may be explained with low vacuum in furnace and fast induction heating. The most prospective AFM for joining TiC-based cermets are the Cu-Ti type (grade S1204) and the Ni-Co-Fe type (grade S1311) alloys. The chemical composition of AFM (grade S1204) is more compatible with the basic structure of a cermet and the AFM of grade S1311 – with the binder composition.

A decrease in the shear strength of brazements was observed when the protective atmosphere – vacuum was not applied and the joining process was carried out in the air. The shear strength of joints "TiC-cermet-steel" was practically the same when traditional Cu-based TFM (grade F-Bronze) and Ag-Cu based TFM were used.

In the TiC cermet brazed joint (Fig.2) intensive diffusion of Ni to the cermet is shown. In the interface of the steel-brazing filler the concentration of Ni is decreasing quickly and a fracture of joints occurred in the central area of joint. We can observe that some TiC particles floated from the TiC cermet into the brazing zone.

When the brazing process was carried out in vacuum, fracture of joints occurred in the central zone of the insert.

Fracture of joints brazed in air occurred in most cases in the interface closed to cermet (Figs. 3 and 4). Fracture at the interface of joints shows that diffusion between the contacting surfaces of cermet-filler metal was insufficient.

SEM fractographs of the fracture zone show the defects (pores, cavities, oxides), insufficient wetting of the cermet in the case of brazing in air.

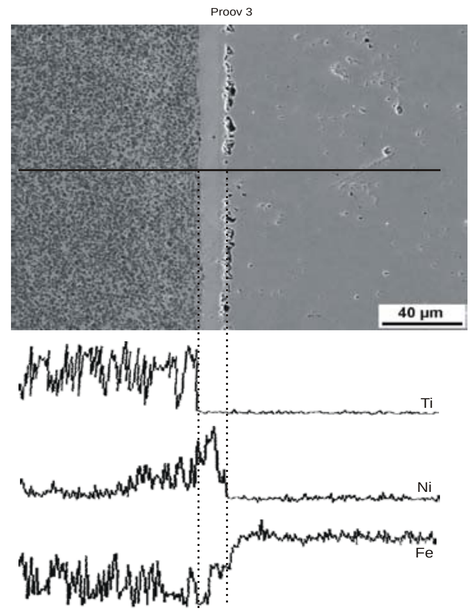
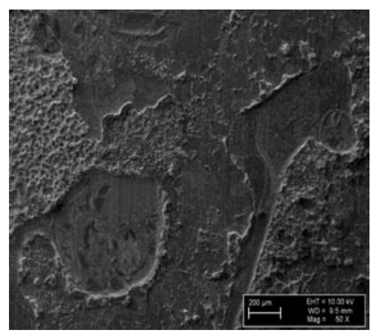


Fig.2 Chemical element distribution in the vacuum brazed joint interface using AFM S1311



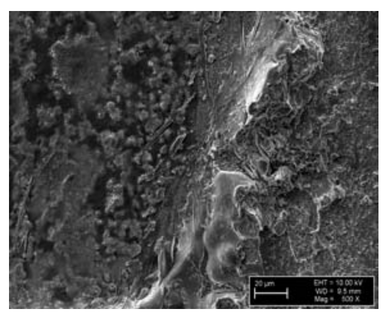
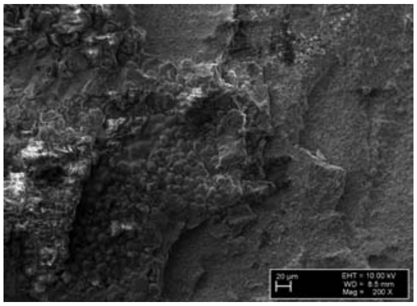


Fig. 3. SEM fractographs of the fracture zone:
TIC cermet side, air brazing with F-Bronze



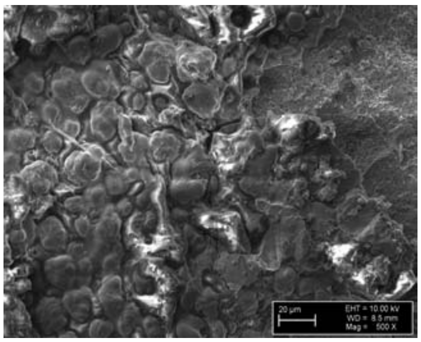


Fig.4 SEM fractographs of the fracture zone:
TiC cermet side, air brazing with AFM 1311.

4. CONCLUSION

This paper focused on study of shear strength of joints TiC cermet to steel produced by vacuum and air brazing using new amorphous and traditional filler metals. Vacuum brazing demonstrated an obvious superiority over air brazing.
The results of studies show the feasibility of bonding the TiC-steel binder cermet by means of amorphous filler alloys, employing high-frequency induction heating and relatively low vacuum atmosphere. Test results show the maximum shear strength of up to 260-300 MPa was achieved when Ni-Co or Cu-Ti type amorphous foils are used. These filler metals are prospective due their compatibility with cermet. Intensive diffusion of Ni to the insert and the interface zone close to the cermet was revealed. In most cases fractures of joints occurred through of the central zone of the insert.

The shear strength of the joints brazed in air atmosphere using amorphous and traditional filler metals was found to be in range 190-200 MPa. The joints fractured during testing in the interface close to cermet. The fracture at the interface “cermet - insert” shows that wetting of the carbide phase and diffusion between the contacting surfaces are insufficient. Different defects are observed in joining zone.

5. ACKNOWLEDGEMENTS

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