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THE IMPACT OF BRAZING PARAMETERS ON THE STRENGTH OF A WC/Co-FILLER METAL-STEEL JOINT

Key words

Metal-ceramics material, brazing, machining tools.

Abstract

Manufacturing and geotechnical engineering utilise a number of machining tools. In their construction, a significant role is played by brazed joints, thanks to which the machining element can be made of WC/Co materials. The metal-ceramics material is joined with steel or cast steel elements with the use of filler metal, based on copper alloys. The components of filler metals are different depending on technological requirements. These may be the alloys of copper, silver, zinc, nickel, cobalt, and manganese. The article presents various techniques of brazing 40HM steel and WC/Co material with filler metal not containing zinc Cu87Mn10Co3. The experimental joints were made with the use of distance rods, steel mesh, and nickel mesh. The impact of the material that provides repeatability of the geometry of the brazing process was tested on the strength of a joint that is subjected to shear stress. The impact of distance elements is mostly positively assessed; however, in some data from publications,

the impact of steel mesh is assessed negatively. In order to assess the correctness of joints, x-ray computer tomography was conducted.

Introduction

During the production of tools designated for applications in geotechnical engineering, the working machining element, mostly manufactured as a WC/Co profile, is joined with a steel mandrel of the tool most often by brazing. Other techniques like gluing, pressure welding, or welding, including laser welding, are also used [1–3]. The durability and reliability of tools depend on the quality of the joint. In brazed joints, the selection of filler metal is key, because it directly impacts the strength of the resulting joint. Filler metals based on copper alloys are the most common. Alloying additions aim at both increasing strength parameters and improving the conditions for producing the joint. Take the example of cobalt, whose presence in filler metal facilitates the process of wetting WC/Co material. A few percent content of manganese in filler metal allows wetting cemented carbides in which there exist phases which are difficult to wet (TiC or elemental carbon) [4]. Commercial filler metals that contain silver are characteristic of low melting temperature (600–800°C) [5] and are used for joining materials in tools in which exceeding the temperature of phase transformation is unwelcome.

The process of brazing determines the quality of the joint, during which special attention is paid to achieving proper gap. The filler metal joins both elements and compensates stresses that occur during the cooling of a brazed joint, resulting from different expandability coefficients of cemented carbide and steel [6]. In turn, it is significant for the joint to correctly carry the stress, which occurs during the work of the tool. Due to this fact, the thickness of the gap cannot be too small and the maximum strength parameters of the joint are usually achieved for a certain width of the gap. Introducing additional filling elements (reinforcing) between the carbide and steel, for example fibres or meshes, facilitates the control over the thickness of the gap and generally improves the strength parameters of the joint [7]. It is important for the reinforcing elements to be characteristic of higher melting temperatures than the filler metal itself.

1. The aim and research methodology

The conducted research was aimed at defining the impact of brazing parameters (temperature and the applied distance element) on the quality of achieved brazed joints. The quality of the joint was verified by conducting a shear stress test.

2. Materials

Experimental brazed joints were manufactured according to the following scheme: steel base–filler metal sample–distance element–WC/Co profile ("sandwich"). The samples were brazed with the use of the following three different distance elements:

1) A pair of parallel steel wires 0.2 mm in thickness 4 mm apart,
2) Stainless steel mesh 0.3 mm in thickness in a shape of a circle 10 mm in diameter, and
3) Nickel mesh 0.2 mm in thickness in a shape of a circle 10 mm in diameter.

The base in all cases constituted discs 17.4 mm in diameter and 4.5 mm in height made of 40HM steel. In the discs, holes were made 1 mm in diameter and 4 mm in depth, which allow placing a measuring thermo-element. Cuboidal WC/Co profiles with dimensions 7 × 7 × 5 mm made of B30 grade were brazed to the base. The joints were made with Cu87Mn10Co3 filler metal in a form of cylinders 3 mm in diameter and height selected for the applied distance elements. The height of the filler metal cylinders was selected experimentally, providing complete filling of the gap. Examples of sets before brazing are presented in Figure 1.

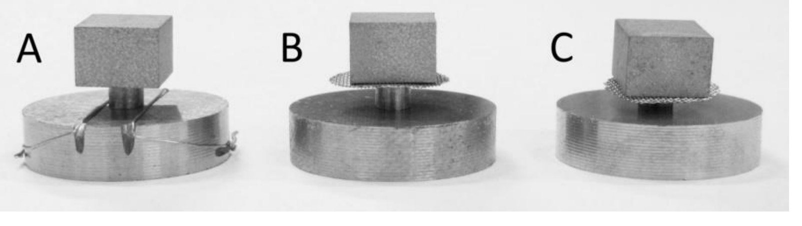

Fig. 1. The set before brazing: A – with steel wires, B – with steel mesh, C – with nickel mesh

3. Producing experimental brazed joints

Samples of experimental joints were manufactured in a working coil of an induction generator, placing the set on the upper surface of a porous ceramic cylinder with a centrally placed measuring thermos-element. The samples were heated inductively in the coil 35 mm in diameter using approx. 25% of 10 kW generator power. Three series of measurements were conducted, heating the sets to three selected values of temperature: 1040°C, 1080°C and 1120°C. The selection of temperature value was made based on the double equilibrium diagram of copper and nickel. At 1080°C, the process of nickel dissolving is initiated in pure copper. Producing joints at this temperature was complemented by joints at temperatures higher by 40°C and lower by 40°C. Overheating the filler metal by 40°C in a short time above 1080°C should not cause dissolving of nickel mesh in liquid filler metal.

Samples were heated to the selected temperature, after reaching this temperature, the induction coil was manually turned off. The joints were made in a protective atmosphere. Nine series of samples were made – three distance elements, three different temperature values, and three samples in each of the series.

4. Testing the quality of manufactured joints

Samples underwent shear stress tests. The achieved maximum value of shearing force was calculated into the value of average shear stress according to the following formula (1):

$$\tau = \frac{F}{A} \quad (1)$$

where:

τ – average shear stress,
F – shearing force destroying the joint,
A – surface area of the joint (A = 49 mm^2).

The achieved results of measurements are presented in Figure 2.

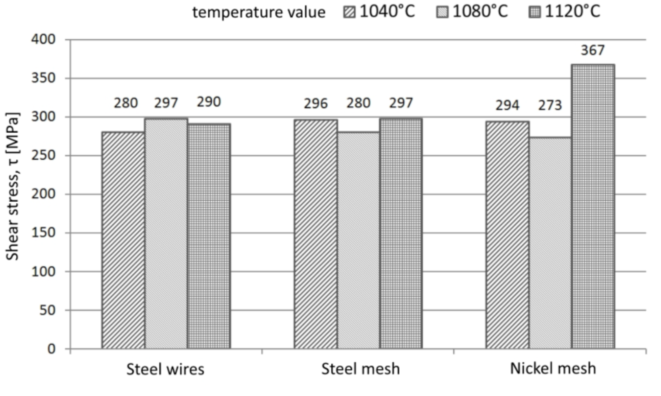

Fig. 2. The results of measuring shear stress in relation to the value of temperature at which the joint was made and the applied distance element

In order to define the quality of joints at an angle of the presence of brazing effects, non-destructive tests were conducted with the use of a V|tome|x L-450 computer tomography machine. The obtained series of photographs allow the assessment of a tested sample at an angle of porosity presence both in the produced joint and in the material of WC/Co profile. Figure 3A presents a tomography photograph taken in the plane of a brazed joint. Mesh and slight porosity in the joint are clearly visible. Figure 3B presents the view of a destructed joint. The shear of the joint took place between mesh and a WC/Co profile, visible is the structure of mesh and sections of a destructed joint at the level of the surface profile-filler metal.

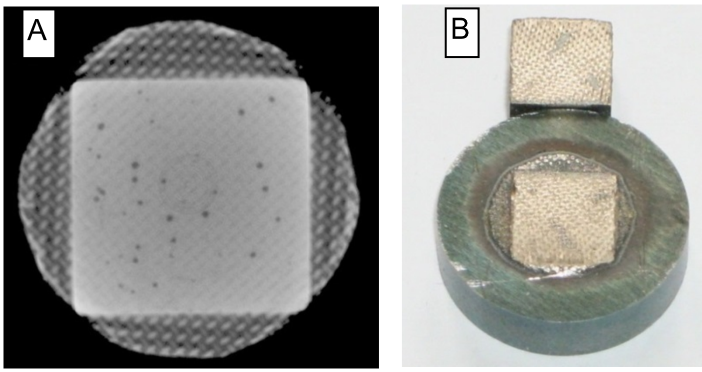

Fig. 3. A – A photograph taken in the plane of the joint with the use of a computer tomography machine, B – A photograph of a destructed joint after conducting shear stress test

Summary

All manufactured samples were characteristic of slight porosity, which lowered the strength of tested joints. The achieved results, after measuring the shear stresses of samples, indicate practically equal strength. The expected differences of the joint strength in relation to the type of applied distance material were not observed. Joints made with the use of nickel mesh at 1120°C were characteristic of the highest strength. The increase in strength is related to the change of filler metal composition caused by partial dissolving of mesh into the filler metal. The samples in which steel wires were used as a distance element do not have visible porosity in the joint.

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Wpływ parametrów lutowania na wytrzymałość połączenia WC/Co–lutowie–stal

Słowa kluczowe

Materiały metalowo-ceramiczne, lutowanie, narzędzia skrawające.

Streszczenie

Przemysł przetwórczy oraz geotechnika wykorzystują w swojej działalności olbrzymie ilości narzędzi skrawających. W ich konstrukcji znaczącą rolę odgrywa połączenie lutowane, dzięki któremu element skrawający może być wykonywany z materiałów typu WC/Co. Materiał metalowo-ceramiczny łączony jest z elementami stalowymi lub staliwnymi przy wykorzystaniu lutowi wysokotemperaturowych, bazujących na stopach miedzi. Składniki lutowi są różne i, w zależności od wymagań technologicznych, mogą to być stopy: miedzi, srebra, cynku, niklu, kobaltu oraz manganu. W artykule przedstawiono różne techniki wykonania połączenia lutowanego stali 40HM i materiału WC/Co lutowiem bezcynkowym Cu87Mn10Co3. Doświadczalne połączenia wykonywano z wykorzystaniem dystansowych drutów stalowych, siatek lutowniczych stalowych oraz niklowych. Zbadano wpływ materiału zapewniającego powtarzalność geometrii procesu lutowniczego na wytrzymałość połączenia poddanemu naprężeniu ścinającemu. Wpływ elementów dystansujących jest przeważnie oceniany pozytywnie, jednak w niektórych danych literaturowych [5] wpływ siatki stalowej oceniany jest negatywnie. Do określenia poprawności wykonanych spoin wykorzystano rentgenowski tomograf komputerowy.