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A Review on Thermal Stresses in High Temperature Brazing of Carbide to Steel Sandwich Brazing Alloys

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ABSTRACT

Carbides and steels are two of the most well-known types of technologically valuable materials. While steel dominates technical applications, carbides have several appealing qualities that make them desirable in some applications. Individual carbides and steels may have a broad range of properties; nevertheless, the characteristics of the majority of materials in the two groups differ dramatically. Steel-carbide joints are becoming more significant in the production of a broad range of technical products. However, attaching carbide to steel materials is often an unsolved or inadequately handled issue, as are thermal cracking, joint strength, and carbide chip off. This research focuses on easing the thermal strains that are created on carbides. It is discovered that using sandwich alloy as a filler metal reduces the thermal stress on carbides.

KEYWORDS: *carbide; steel; joining; problems; reliability*

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1. INTRODUCTION

Tungsten carbides possess extremely high hardness and wear resistance, which render them ideal for applications such as metal-cutting tools, rock-drilling tools, and industrial wear-resistant parts like dies, punches, and seals. However, tungsten carbides are brittle, and show poor resistance to impact and shock. They can therefore rarely be used unsupported, and it is common practice to attach carbide working parts to a more resilient tool holder or support, which is normally made of steel. Owing to the widely differing physical and mechanical properties of steels and hard metals, the Joining of one to the other is problematic, and the method used must be chosen with care. Brazing is the common method used to join tungsten carbide to steel. Several properties of hard metals are so different from those encountered in other engineering materials that one must have an understanding of those properties in order to design effectively. This is particularly important when dealing with assemblies in which tungsten carbides are used with steel or other structural alloys.

2. GENERAL PROBLEMS IN CARBIDE-STEELJOINT

There exist many problems between carbide and steel materials, such as the atom bond configuration, chemical and physical properties, etc. These problems make the joining of carbide to steels difficult.

General problems occurring in brazing carbide to steel are listed below:

A. THERMAL EXPANSION AND RESIDUALSTRESS

When joining carbides to steels with the brazing method, for example, metallization on the carbide surface is necessary with general inactive brazing filler metal or the use of active brazing alloys in order to get a reliable joint. The thermal expansion coefficients of carbide are generally much lower than steels. Stress will be generated in the carbide/steel joint due to the thermal expansion mismatch and will degrade the mechanical properties of the joint and can cause joint cracking immediate after the joining process. The thermal stress in the joint due to the thermal expansion mismatch should be carefully considered when joining ceramic with metal. Residual stresses are stresses that remain in the materials joining after the original cause of the stresses have been removed. Thermal residual stresses play the key role in the mechanical behavior of various joint materials. Thermal stresses may occur in a heated structure which is rigidly constrained, and also in a structure with temperature gradients. Thermal residual stresses in the ceramic/metal joints can be classified into three groups in accordance with the mechanism that produces them.

- First, thermal stresses caused by a volumetric change, either expansion or shrinkage, associated with phase transformation. For these stresses arise from a phase change, the temperature must change to cause the phase change.
- Second, thermal stresses caused by a difference in CTE mismatch between two materials joined together. For these stresses to arise from a difference in coefficients of thermal expansion the temperature may be changing or it may have stabilized.
- Third, thermal stresses caused by a thermal stress caused by a temperature gradient resulting in the thermal differential rates within the volume of the material or within the structure and potentially lead to cracking.

The change in material closure, as well as the mismatch in the CTE and different material transformations of the joining partners in combination with different elastic plastic material properties, makes the generation of residual stresses inevitable. Generally, the material with the lower CTE experiences compressive stresses while the other is under tension.

B. RESIDUAL STRESSCALCULATION

The residual stresses produced in the ceramic metal joint could be estimated for full elastic conditions according to this equation[7]:

$$\sigma_C = \frac{\Delta\alpha \cdot \Delta T \cdot E_m \cdot E_C}{(E_m - E_C)} \qquad (1)$$

Where σ_C is the residual stress after the joint cools to room temperature, $\Delta\alpha$ is the difference of thermal expansion coefficient between materials, ΔT is the difference between joining temperature and room temperature, E_m is a Young's model of metal, E_C is a Young's model of ceramic. If the thermal stresses in the metal exceed its yield strength, the residual stresses in the joint could be determined by[7]:

$$\sigma_C = \sigma_{my} + \Delta\alpha . \Delta T . E_{mp} \qquad (2)$$

Where E_{mp} is the linear strain hardening coefficient and σ_{my} is the yield strength of the metal (linear elastic-linear plastic conditions are assumed).

I. METHODS TO OVERCOME THERMALSTRESS

There are few methods used by the researchers in order to reduce the stresses that are generated due to the difference in coefficient of thermal expansion.

A. USE OF TRIMETAL SANDWICHALLOY

The use of trimetal sandwiches- These are typically filler metal/copper/ filler metal. During the brazing process, the copper anneals to a dead soft condition. Brazing strains can be relieved somewhat through the use of trifoil as previously mentioned. A nickel shim will withstand more pounding, but nickel does not have the malleability of copper and will not relieve the brazing strains as effectively. The three layers are bonded together, and the surfaces of the material are impressed with a pattern that helps to retain the flux in position during the brazing operation. This promotes wetting and spreading of the molten alloy[5].

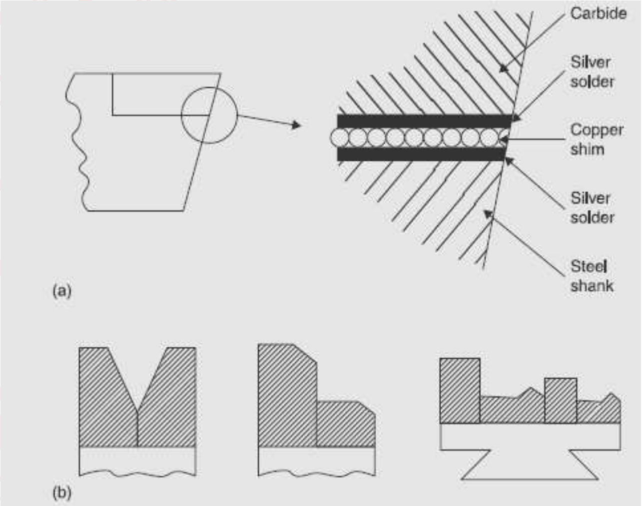

Fig 1 Joint design to accommodate stresses: (a) sandwich braze assembly; (b) use of multiple inserts.

B. MECHANICAL METHOD OF REDUCING THERMAL STRESS IN BRAZEDJOINTS

Where long brazing joints are unavoidable, counter straining, peening, or stress relieving are recommended for reducing stress and strain. A good braze joint seldom fails in shear, and it is possible to reduce tensile forces in the outer edge of a hard metal strip by forcibly overcoming the curvature of the assembly. One example of this is to hold the assembly in a jig during the cooling period. Another method to overcome curvature is to shot peen the steel surface opposite the braze joint, expanding it and setting up counter strain to restore the straightness of the assembly (Fig.2.4).

Minor stress can also be relieved by a thermal soak at temperatures around 200^0C. Major stresses cannot be relieved in this manner since temperatures of around 600 °c would be required and the cooled assembly would again be strained to about the same degree after cooling.

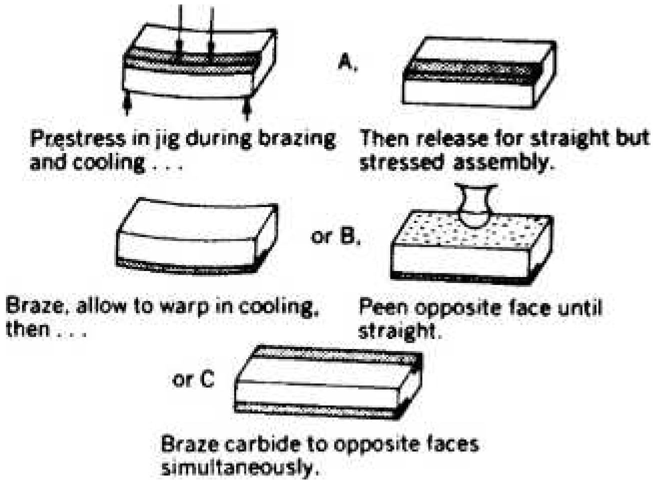

Fig 2 Three methods of counter straining to overcome the curvature of an assembly due to brazing strains [11]

C. CRYOGENICTREATMENT

The process typically involves slowly cooling a mass of parts to – 196 ◦C, holding them at this temperature for 30 h or more, then slowly heating them back to ambient temperature. In case of steels, the benefits are usually attributed to the reduction or elimination of retained austenite from hardened steel and accompanied by the precipitation of small finely dispersed carbides (η-carbides) in the marten site. Figure 1 shows a typical cryogenic treatment temperature sequence for tool steels[8]. Cryogenic treatment improves the mechanical properties like hardness, wear resistance, toughness, and resistance to fatigue cracking. The possible reasons for this improvement are as follows. According to one theory of this treatment, transformation of retained austenite is complete – a conclusion verified by X-ray diffraction measurements. Another theory is based on the strengthening of steels by the precipitation of sub microscopic carbides. An added benefit is said to be a reduction in internal stresses in the marten site developed during carbide precipitation, which in turn reduces tendencies to micro-crack.

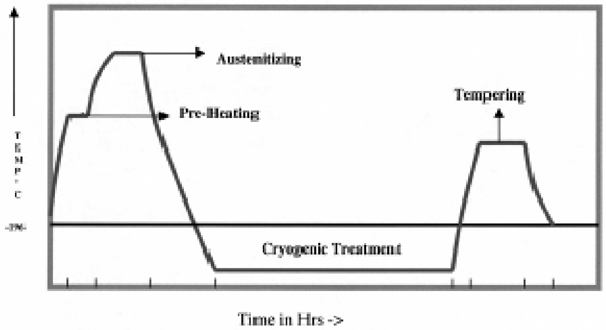

Fig 3 Typical heat treatment cycle using cryogenic treatment

CONCLUSION

It is advised to utilise a sandwich alloy with copper sandwiched between silver to ease the thermal stresses that are created on carbides. The copper works as a buffer between the carbide and the steel, reducing tensions caused by differences in thermal expansion. The strength of cryogenic and non-cryogenic treated samples will be compared in the future.

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