*Vacuum brazing of ceramics and graphite to metals

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ABSTRACT

JOINING OF METALS TO CERAMICS AND GRAPHITE IS IMPORTANT IN MANY APPLICATIONS SUCH AS X-RAY TUBES, MICROWAVE DEVICES, NUCLEAR FUSION REACTORS AND SO ON. SOME OF THE BASIC REQUIREMENTS OF SUCH JOINTS ARE ELECTRICAL INSULATION, THERMAL CONDUCTION, VACUUM COMPATIBILITY, MECHANICAL STRENGTH ETC. SEVERAL TECHNIQUES ARE IN USE AND NEW ONES ARE BEING DEVELOPED TO MEET STRINGENT REQUIREMENTS. MOLY-MANGANESE METALLISATION IS PROVEN TECHNIQUE FOR BRAZING CERAMICS TO METALS. RECENTLY THE SO-CALLED ACTIVE BRAZING ALLOYS HAVE BEEN INTRODUCED IN ORDER TO REDUCE THE NUMBER OF STEPS INVOLVED IN BRAZING. ANOTHER TECHNIQUE, WHICH IS USED IN THE PRESENT WORK, IS TO COAT CERAMIC WITH TITANIUM AND THEN USE CONVENTIONAL BRAZING ALLOYS. TITANIUM IS DEPOSITED ON CERAMICS USING A CATHODIC ARC PLASMA SOURCE IN VACUUM. INDIGENOUSLY PREPARED COPPER SILVER EUTECTIC ALLOY FOILS ARE USED AS FILLER MATERIAL. BRAZING IS CARRIED OUT UNDER HIGH VACUUM AT ABOUT 900 ^{0}C. THESE TECHNIQUES HAVE BEEN USED TO BRAZE STAINLESS STEEL-ALUMINA, TITANIUM-ALUMINA, AS WELL AS COPPER-GRAPHITE. IN ALL THESE CASES MECHANICALLY STURDY JOINTS HAVE BEEN OBTAINED. THESE TECHNIQUES CAN ALSO BE USED TO BRAZE METALS TO METALS AND CERAMICS TO CERAMICS. SOME OF THE RESULTS OF THE WORK IN PROGRESS WOULD BE PRESENTED.

Keyword: Vacuum; Brazing; Ceramics; Graphite.

1. Introduction

Brazing is a technique of joining two materials using a filler material whose melting point is below the melting points of the materials to be brazed. A typical brazing procedure involves cleaning of the surfaces to be joined, interposing a filler material between the two surfaces, holding the parts to be brazed with suitable fixtures and heating to a temperature slightly above the melting point of the filler material. Heating cycle should ensure that thermal equilibrium is maintained between the filler material and the components to be brazed. The components react with atmospheric gases like nitrogen, oxygen, moisture etc. When this is not acceptable brazing will have to be carried out under a protective environments like inert gas, hydrogen gas or vacuum. Brazing is possible only if the molten filler material wets the surfaces and flows properly. This depends on the properties of the filler material as well as the surfaces to be brazed. Commercially a number of filler materials are available in the form of wires, foils, powders and pastes. Choice depends on the properties of the materials to be brazed and the temperature and other environmental factors in which the brazed components are to be used.

2. Brazing of ceramics

Ceramics are widely used in industries due to their electrical, thermal and mechanical properties. But joining of ceramics to metals and to themselves is not straight

* This work was carried out under a works contract from the Institute for Plasma Research , Bhat, Gandhinagar, Gujarat.

forward. There are basically two problems. First, the usual brazing fillers do not wet the surfaces of ceramics. Second, there is a big difference in the thermal expansion coefficients of metals and ceramics. This induces tremendous stresses in the brazing process which can lead to cracking. Special techniques have been developed for brazing ceramics. Moly-manganese metallisation is the standard practice for brazing ceramics. Here a paint of the refractory metal molybdenum with 10% manganese is applied to the ceramic and sintered around 1400^{o}C. In this process manganese oxidises and diffuses into ceramic forming transition layer between the ceramic and the molybdenum layer. This reduces the thermal mismatch between ceramic and molybdenum [1]. It is then protected from oxidation by plating with nickel. Brazing is then carried out using conventional filler materials either in vacuum or in an inert atmosphere.

Active brazing is a relatively new technique. A family of brazing alloys called active brazing alloys are made by adding a small percentage of titanium or vanadium to conventional filler material compositions. Brazing is carried out under high vacuum in clean conditions. During brazing titanium is oxidised by the ceramic forming titanium oxides and liberating some aluminium atoms. This interlayer forms some kind of chemical bridge between ceramic and the metal [2]

An alternate way is to have a titanium coating on the ceramic and then carry out regular brazing. At high temperatures titanium reacts well with ceramics as well as other metals. Usual brazing alloys wet titanium surface well leading to a good brazed joint.

3. Brazing of graphite

Graphite is an important material in nuclear industry - both the conventional fission reactors and the fusion reactors under development. In the latter it is used as a first wall material to minimise impurities in the reactor. The graphite tiles used there face enormous heat load. Unless there is an efficient heat removal mechanism in place, temperatures rise beyond tolerable levels. The practice is to attach water cooled sheets of copper or copper alloys to graphite tiles. It is imperative that thermal contact between graphite and copper be very good in order to reduce thermal resistance. This can be achieved only by brazing the two.

Brazing of graphite is as problematic as brazing ceramics. It has very low thermal expansion coefficient. It reacts with very few materials to form carbides.

Brazing of graphite to TZM – an alloy of molybdenum - has been realised [3, 4]. Brazing filler materials like Cu-Ti-Ag, Cu-Ti, Ti, Zr and Zr alloys have been used. Russians [5] have developed several filler alloys in the form of flexible ribbons for brazing copper and beryllium based alloys with graphite. There are several groups engaged in developing suitable technologies.

4. Present work

One can see from the above discussion that titanium promotes good brazing in ceramics as well as graphite. This is due to the fact that at high temperatures titanium easily reacts with oxygen, carbon and many metals. It was therefore decided to coat both ceramics and graphite with titanium and then attempt brazing with usual brazing fillers.

4.1 Experimental

4.1.1 Coating

The coating facility at Bangalore Plasmatek was used for titanium coating. It consists of a rectangular vacuum chamber of 1000x1000x600 mm (fig.1). A magnetically steered titanium cathode is used for producing intense titanium plasma in high vacuum.

Alumina ceramic blocks of >99% purity of size 70x13x7mm and high density graphite blocks of about 25x25x25mm and other sizes are used for trials. An area of 68x5 of one of the 70x7 faces as well as all the remaining faces were masked before coating. Thus a rectangular frame of 1 mm width was coated on one 70 x 7 mm face of ceramic piece. Similarly, all the faces except one face of the graphite block were also masked. Alumina (95% purity) ceramic strips of size 5x0.3x50 mm are also coated. Cleaned samples are mounted inside the coating chamber with suitable fixtures. Samples were further cleaned by argon glow discharge plasma.

Titanium plasma was produced by striking the arc on the cathode. An arc current of 90 A was used. The arc consists of multiply charged titanium ions up to about 150 ev energy. This results in very dense and adhesive coatings. Coating thickness was between 10 to 15 microns.

4.1.2 Brazing

Ceramic blocks were brazed to titanium blocks of size 100x30x40mm with a through slot and a step to place the titanium coated ceramic block. Eutectic alloy (CuSil) of copper(28%) and silver was taken in the shape of thin wires and placed between titanium and coated ceramic surfaces.

Figure 1. A view of the coating chamber

The coated ceramic disc was brazed to stainless steel (SS 304) disc while graphite block was brazed to a copper block. The same eutectic alloy CuSil was taken in the form of thin foils and interposed between surfaces of the materials to be brazed.

Brazing was carried out in a vacuum furnace. A pressure of 10^{-5} mb was maintained. The temperature was raised at the rate of 10^{0}C per minute. It was held constant at 750^{0}C for ten minutes and then raised to 880^{0}C at 20^{0}C per minute. Temperature was kept constant at 880^{0}C for two minutes and then reduce slowly.

4.2 Results

All brazed samples showed evidence of good flow of the filler material. Some are shown in Figs.2 and 3. Mechanical strength of the joints is excellent. The joint between the rectangular ceramic block and the titanium block was meant to be vacuum tight. But it showed leaks. This is attributed to rectangular geometry and sharp corners rather than any inherent brazing problem.

4.3 Conclusions

It has been clearly demonstrated that a coating of 10-15 μm of titanium is sufficient to braze ceramics and graphite to various metals using an eutectic alloy of copper and silver. For vacuum joints special care may have to be taken in the presence of sharp corners or other special features. The same technique can also be used to braze ceramic to ceramic, graphite to graphite, ceramic to graphite and metals to metals which may be dissimilar.

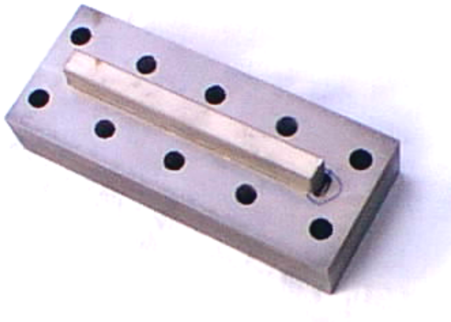

Figure 2. Ceramic piece brazed to titanium block

(a) (b)

Figure 3. (a) Graphite block brazed to copper

(b) Ceramic strip brazed to stainless steel

References

[1] D.M.Mattox & H.D.Smith, Ceram Bull. 64(1985)1363-1367

[2]A.Murari, H.Albrecht, A.Barzon, S.Curiotto and L.Lotto, Vacuum 68(2003)321-328].

[3]Kotzlowski et.al(19911)USpatent 5,023,043,

[4] I.Smid et.al. JNM171(1990)165

[5]B.A.Kalin et.al. Fusion Eng. & Design 28(11995)119-124