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## Influence of Brazing Condition on Shear Strength of Alumina-Kovar Joint Made with Amorphous $\text{Cu}_{50}\text{Ti}_{50}$ Filler Metal†

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In recent years an increasing effort has been expended towards the joining of ceramics to metals. Sound bonds between oxide ceramics and metals are commonly achieved by some form of intermediate layer, which couples two materials. Glass-forming compounds are widely used, but suffer from limited bond strength and insufficient resistance to thermal shock. Joining of metals to ceramics necessitates the use of special brazing alloys containing an active component because oxides are generally not wetted by commonly used alloys. An example is the molybdenum-manganese process<sup>1), 2)</sup>, where manganese, the active component, reacts partially with the oxide ceramics. Recently, a new method for obtaining excellent bonds between ceramics and metals was introduced<sup>3)</sup>. It was found that high alumina ceramics can be joined to metals using amorphous active metal brazing foils. The amorphous brazing foils are highly flexible and can be bent to the contours of complex geometries or punched to different size of preforms, and this adds simplicity to the brazing method. After cooling and solidification of the brazing melt, a strong bond between metal and ceramic is established. Stresses and strains in bonded structure during joining are introduced because of the different thermal expansion of the two materials. In order to reduce the stress between ceramics and metals, the metals have to possess similar thermal expansion as ceramics.

In this paper an attempt is made to join alumina to Kovar (Fe-Co-Ni) alloy that possesses similar thermal expansion characteristic as alumina using amorphous  $\text{Cu}_{50}\text{Ti}_{50}$  filler metal.

In order to prepare the amorphous  $\text{Cu}_{50}\text{Ti}_{50}$  filler for brazing, the liquid alloy of desired composition was ejected onto the outer surface of a rapidly rotating wheel (Fig. 1). The number attached to the filler designates the atomic percent. The amorphous filler was 5 cm wide and 65  $\mu\text{m}$  thick. The formation of an amorphous structure

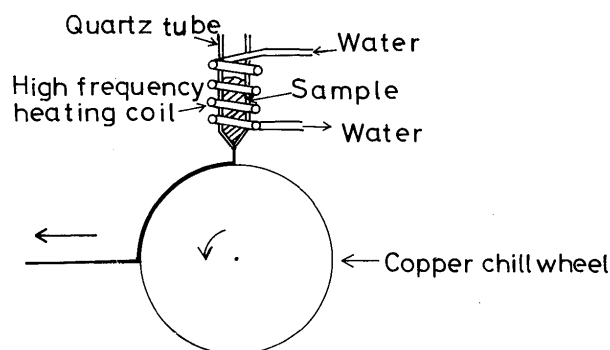


Fig. 1 Apparatus for producing amorphous filler metal.

was confirmed by the diffused X-ray diffraction pattern. Alumina (99.6 wt%  $\text{Al}_2\text{O}_3$ ) of 6 mm diameter and 3 mm thickness, and Kovar (29wt%Ni-17wt%Co-Fe) of 10 mm diameter and 3 mm thickness were used to make a lap joint. Prior to brazing the joint surface of the specimens were polished mechanically with silicon carbide paper to No. 1000 and were fixed in position using an organic binder. Superior flexibility of the amorphous foil adds simplicity to the joining method. The heating rate up to brazing temperature was  $20^\circ\text{C}/\text{min}$  in  $5 \times 10^{-5}$  torr, and the cooling rate after brazing was about  $19^\circ\text{C}/$

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min up to 600°C and then about 1°C/min up to room temperature. Joint strength was determined by fracture shear loading using a special fixture at a cross head speed of 1 mm/min. The microstructures of brazed specimens were determined by scanning electron microscopy.

Various types of Al<sub>2</sub>O<sub>3</sub>/Kovar joints were produced using amorphous Cu<sub>50</sub>Ti<sub>50</sub> filler metal. A brazed butt joint specimen of alumina rod to Kovar rod and a brazed butt joint specimen of alumina pipe to Kovar pipe are shown in Fig. 2. The brazing temperature dependence of

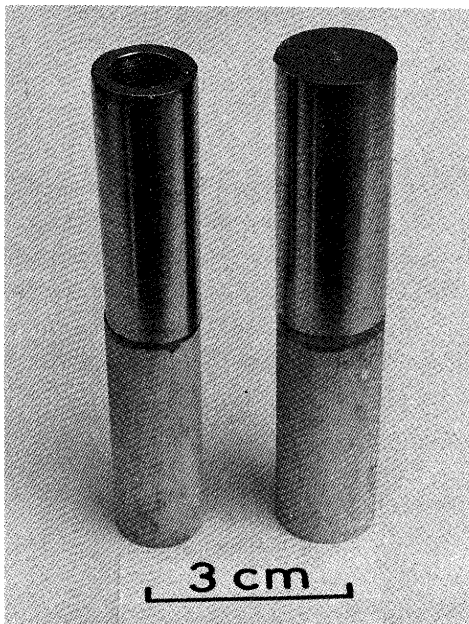


Fig. 2 Brazed butt joint of Al<sub>2</sub>O<sub>3</sub> rod to Kovar rod (right), and brazed butt joint Al<sub>2</sub>O<sub>3</sub> pipe to Kovar pipe (left). The upper and lower parts in the specimens are Kovar and Al<sub>2</sub>O<sub>3</sub>, respectively.

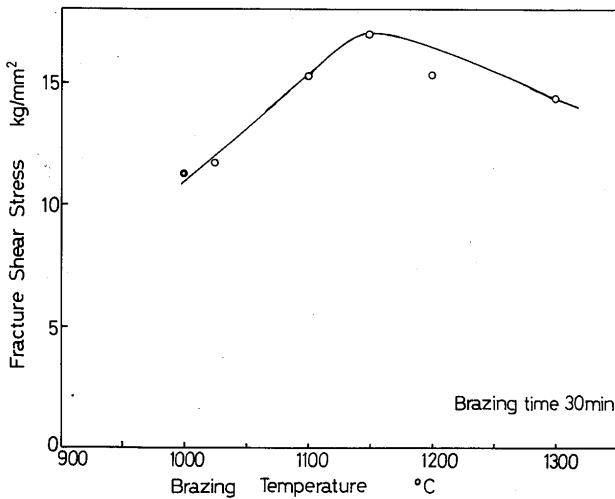


Fig. 3 Dependence of shear strength on brazing temperature at 30 min brazing time.

room temperature shear strength of the lap joint at constant brazing time of 30 min exhibits a maximum value of 17 kg/mm<sup>2</sup> at 1150°C, and the strength decreases with higher brazing temperature as shown in Fig. 3. The maximum fracture shear stress of the joint corresponds to one half of alumina that is treated with the same heat cycle as the alumina/Kovar joint. Fig. 4 shows the brazing time dependence of shear strength at the constant brazing temperature of 1025 and 1150°C. The brazing time of 30 min provides the maximum shear strength and the strength decreases with longer time. In all specimens the fracture took place at the interface between alumina and the solidified filler metal irrespec-

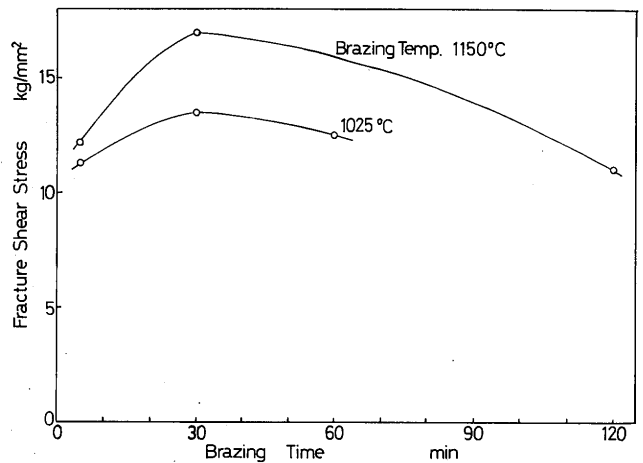


Fig. 4 Dependence of shear strength on brazing time at 1025° and 1150°C.

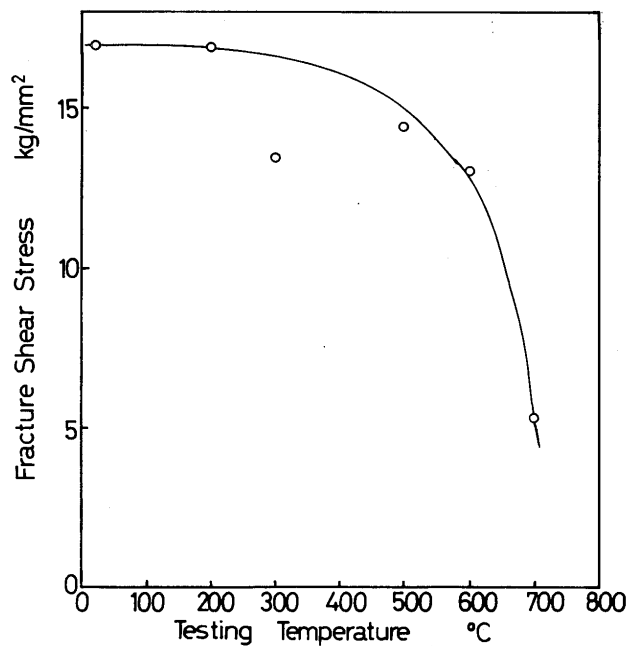


Fig. 5 Dependence of shear strength on testing temperature.

tive of the brazing condition. The shear strength of joints brazed at 1150°C for 30 min were also measured at high temperature up to 700°C and the results are shown in Fig. 5. The shear strength gradually decreases from 17 kg/mm<sup>2</sup> to 13 kg/mm<sup>2</sup> up to 600°C, and becomes lower than 5 kg/mm<sup>2</sup> at 700°C.

In order to investigate the effect of thermal shock on the lap joint between alumina and Kovar the joints were air-cooled or water-quenched. The shear strength of water-cooled joint abruptly drops down at 450°C compared with the air-cooled joint as shown in Fig. 6. The bigger

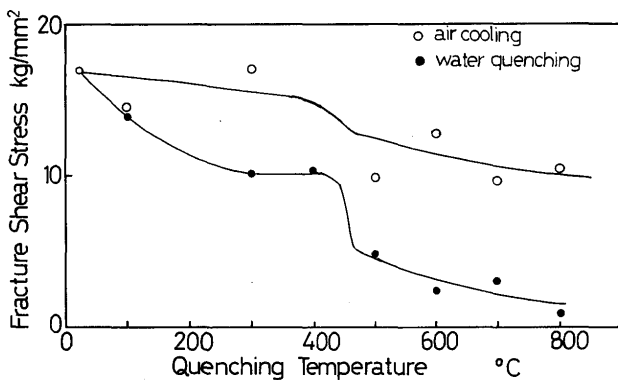


Fig. 6 Dependence of shear strength on quenching temperature and quenching medium.

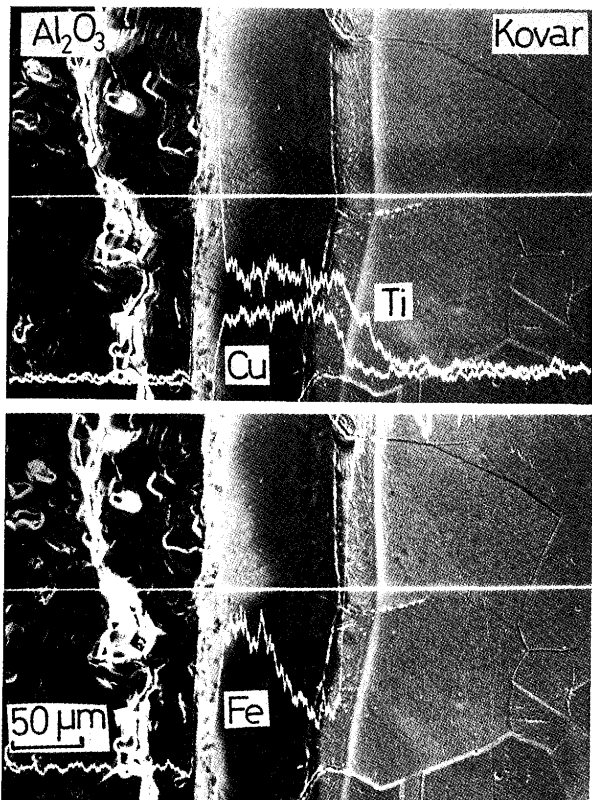


Fig. 7 Microphotographs and line analyses of joint interface made at 1150°C for 120 min.

difference of thermal expansion of water cooled joint leads to a bigger drop in the strength. The abrupt drop in the shear strength arises from the embrittlement of alumina ceramics as alumina itself gets brittle at 450°C due to water-quenching. Surface crack appears on the alumina when it is quenched from high temperature in excess of 400°C.

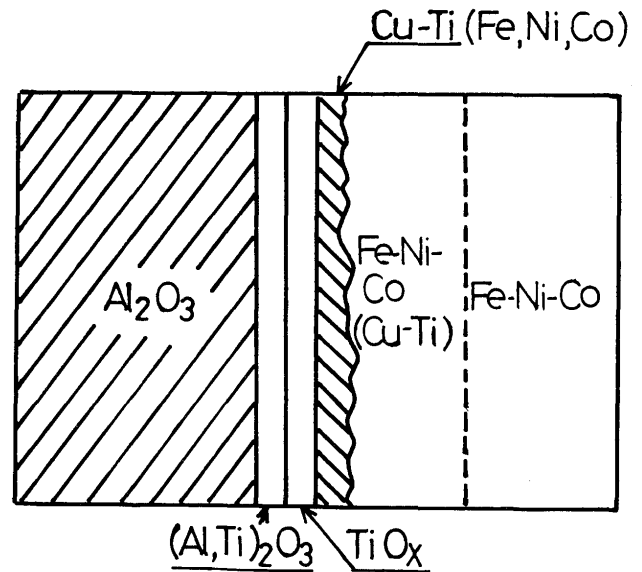


Fig. 8 Schematic diagram of the structure of the interface between alumina and Kovar made with Cu<sub>50</sub>Ti<sub>50</sub> filler.

Fig. 7 shows the microphotograph and the line analyses of the interface between alumina and Kovar joined at 1150°C for 120 min. During brazing the isothermal solidification process (TLP) takes place. Iron, cobalt and nickel, first dissolve into the liquid filler and then precipitate from the liquid during brazing. Further, titanium rich alloys containing iron, cobalt and nickel solidify from the remaining liquid during cooling to room temperature. The revealed surface of alumina dissolved from the alumina/Kovar joint in concentrated hot HCl demonstrates the presence of titanium oxide by X-ray photoelectron spectroscopy. The results give the interface between the alumina and Kovar joint using Cu-Ti filler metal a structure as shown in Fig. 8. The joint strength is dependent on the extent of joining of the intermediary titanium oxide to alumina.

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