Effect of mechanical vibration on TLP brazing with BNi-2 nickel-based filler metal

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Transient liquid phase (TLP) brazing has been explored extensively as a method of producing joints for high-strength high-temperature applications [1–5]. In this process, which has been described in detail elsewhere [6], an interlayer of alloying metal containing melting point depressants (MPD) is inserted between the faying surfaces to be joined. Upon heating, a thin liquid film forms either because the brazing temperature has exceeded the melting point of the interlayer or because a reaction between filler and parent metals has resulted in the formation of a lower melting liquid alloy. The liquid thus formed fills the voids formed by the

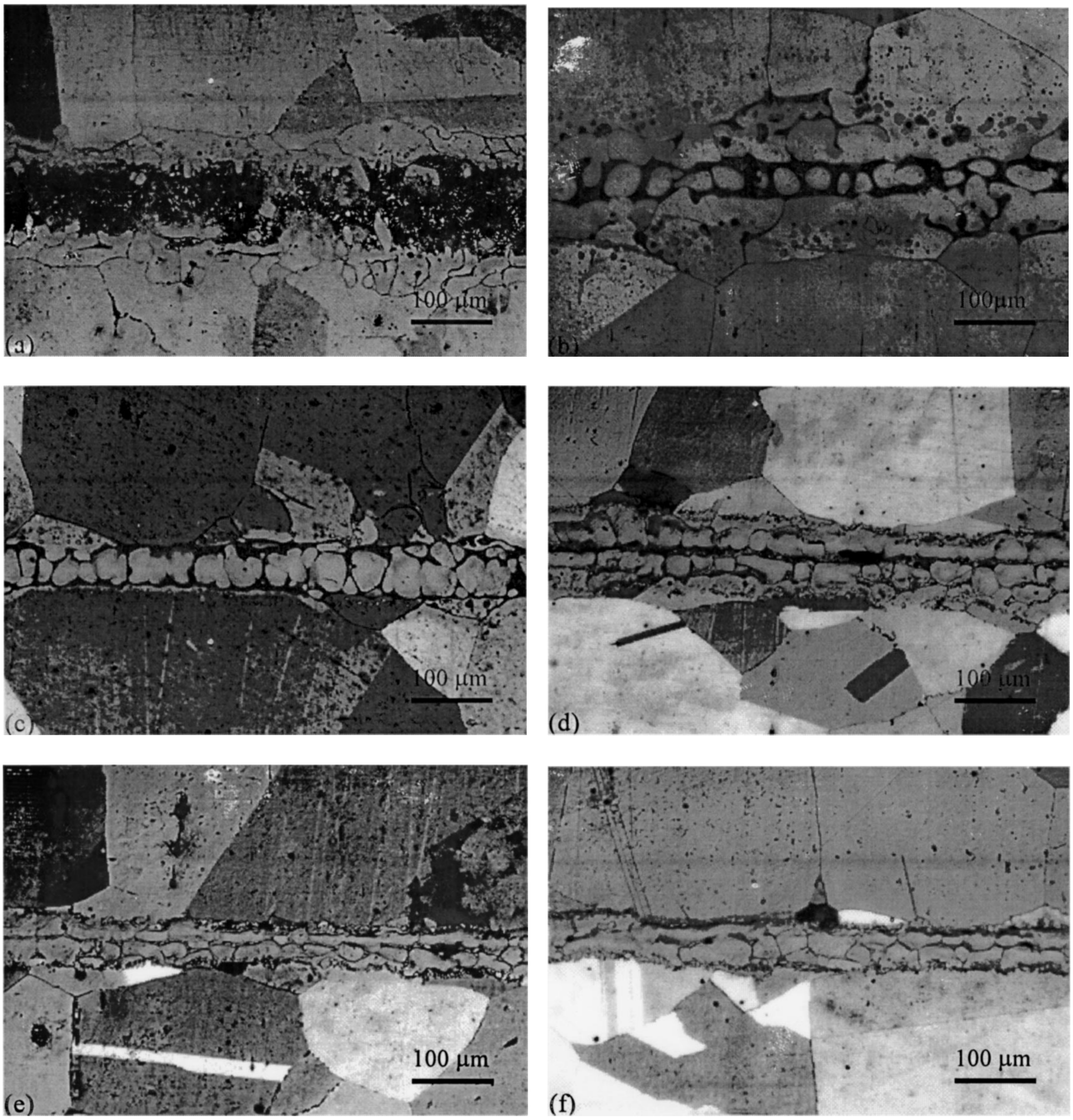

Figure 1 Microstructure of nickel-to-nickel joints induction brazed under mechanical vibration with amplitude of 20 μm: (a) 0 Hz, (b) 10 Hz, (c) 50 Hz, (d) 200 Hz, (e) 300 Hz, and (f) 400 Hz.

unevenness of the mating surfaces and can sometimes dissolve residual surface contamination. These melting point depressants diffuse into the parent metal, resulting in isothermal solidification. Upon cooling, there remain no traces of liquid phase and a joint with chemical composition and microstructure indistinguishable from the parent metal is produced.

Applications of mechanical vibration to the processing or treatment of materials have been of particular interest in past few decades. Some researchers have pointed out that solidification under vibratory condition results in grain refinement, suppression of pipe and porosity formation and improved mechanical properties [7–11]. The effect of vibrational energy on aluminum alloys [7], 430 stainless steel [9], cast iron [10] and IN 738LC [11] showed grain refinement during solidification and a reduction in the extent and distribution of shrinkage, gas porosity and total solidification time, as well as improvement in mechanical properties. Recently, Tewari and Shanker [12, 13] studied the effect of longitudinal vibration on the weldment and reported significant improvements in grain refinement and uniform grain size distribution. They also found improvement in mechanical properties such as yield strength and ultimate tensile strength. Although considerable research has been carried out on the effect of vibration on the solidification of castings and welds, to date very little effort has been devoted to the study of the effect of the same on brazements. Therefore, this research is intended to study the effect of mechanical vibration on transient liquid phase (TLP) brazing.

In this study, nickel bars (0.55 wt % chromium, 1.32 wt % molybdenum, 0.71 wt % aluminum, 0.12 wt % manganese and 97.4 wt % nickel) were used in the form of 25 mm in diameter from which discs 5 mm thick were sliced. Brazing foil BNi-2 containing 7 wt % chromium, 3 wt % iron, 4.5 wt % silicon, 3.2 wt % boron and 82.3 wt % nickel was chosen as filler metal. In this filler metal the silicon and boron act as melting point depressant. The faying surfaces used for TLP brazing were prepared by grinding down to 1000-grit SiC

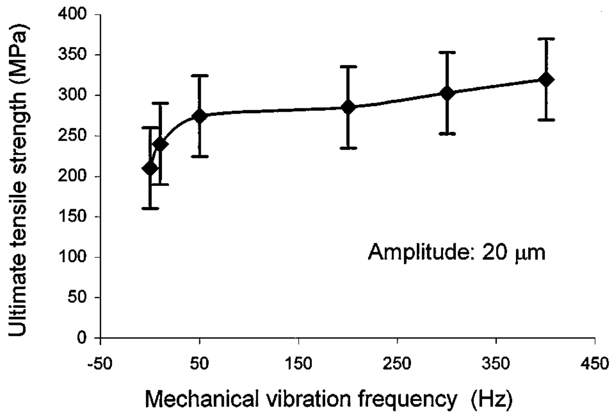

Figure 2 The effect of vibration frequency on shear strength of brazed joint.

paper finish to ensure flatness and minimize the effect of surface oxidation, and then polished on a cloth with 1 μm diamond paste to reduce roughness and cavitation. Prior to brazing operation, specimens were ultrasonically cleaned in acetone both for 10 min and dried by hot air.

The brazing was carried out using induction chamber of the assembly in an argon atmosphere. Brazing temperature and time were 1423 K and 20 min, respectively and the joint clearance was 100 μm. The mechanical vibration clearance was 100 μm. The mechanical vibration frequency varied from 0 to 400 Hz and amplitude was 20 μm. After TLP brazing, a shear test was performed to evaluate the joint strength and microstructure was examined using polarized optical microscope. The microhardness distribution at the brazed joint was measured by the Vickers hardness tester.

Fig. 1 shows that the difference in morphologies between static and vibratory conditions is noticeable. It can be seen in Fig. 1a that the static joint has microstructures typical of dendritic eutectic phases. The substantial changes occurred when TLP brazing was conducted under mechanical vibration; dendrite eutectic phase disappears and the thickness of brazed joint

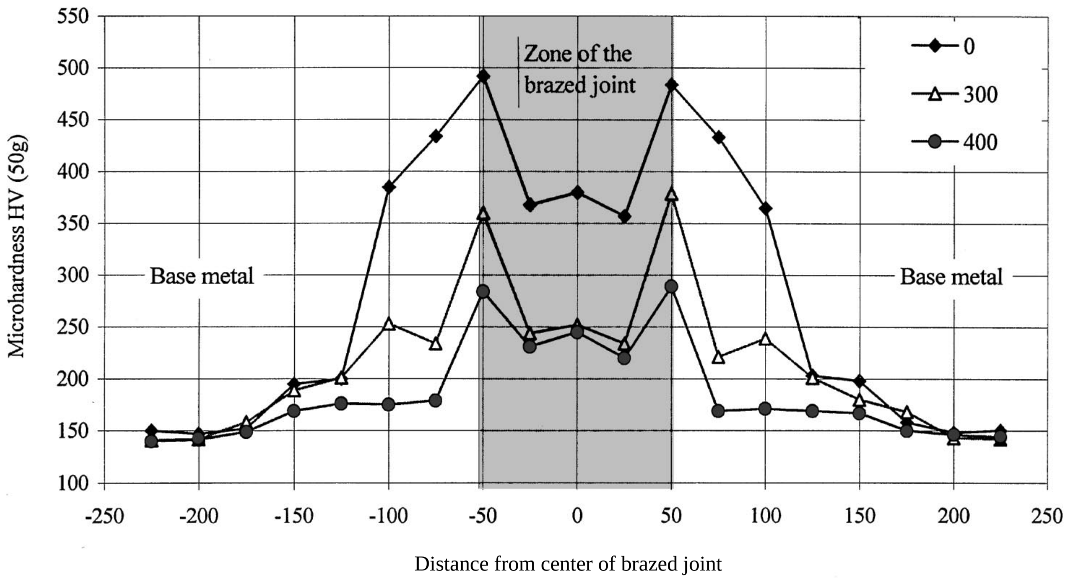

Figure 3 Microhardness distribution through the brazed joint: (◆) 0 Hz, (△) 300 Hz, and (●) 400 Hz.

decreases (Fig. 1b–f). This decrease is accompanied by the disappearance of low melting-point eutectic components in the filler metal microstructure. This disappearance is a result of the partial ejection of liquid phase formed during the filler metal melting. The mechanical vibration produces a compressive pressure which can push out the excess liquid phase to shorten the isothermal solidification time and results in an improvement in the joint strength. Since the melting starts with microstructural components enriched in silicon and boron, the material left in the brazement has a much higher concentration of the nickel- and chromium-rich phase compared to a static joint. The joint with less eutectic phases results in increase in mechanical properties.

The effect of vibration frequency on shear strength of brazed joint is given in Fig. 2, which shows that with an increase in vibration frequency, the shear strength increases. Shear strength of the brazed joint without vibration is 210 MPa whereas shear strength with 400 Hz vibration is approximately 320 MPa. This improvement is probably because when the mechanical vibration is applied, it fragments the dendrites, and consequently causes the refinement of structure of the solidifying joint. In addition to that, the stirring effect of vibration also helps in the escape of gases entrapped in the molten liquid. Both effects can contribute to the increase in mechanical capabilities of the brazed joint.

The effect of vibration frequency on microhardness at brazed joints is given in Fig. 3, which shows that with an increase in frequency, the microhardness decreases and the distribution of microhardness through the joint becomes more uniform. The brazed joint under static condition has higher microhardness result.

From the results of this investigation it might be concluded that when mechanical vibration is applied to TLP brazing of nickel-to-nickel with BNi-2 filler metal, a joint with enhanced and uniform mechanical properties and refined microstructure is obtained.

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