Platinum Alloys for Brazing Tungsten

FABRICATION FOR HIGH TEMPERATURE SERVICE

In normal brazing practice excessive inter-alloying between the brazing alloy and the parent metal is regarded as an undesirable effect, and its extent is usually limited to a minimum by judicious selection of the brazing material and by strict control of the brazing time and temperature. Some alloying at the parent metal/brazing alloy interface is unavoidable, but the composition of the bulk of the brazing alloy in the joint remains—as a rule—practically unchanged. One of the consequences is that the re-melt temperature of a brazed joint, which determines both its maximum service temperature and the temperature range in which the joint retains its resistance to creep, is set by the solidus, or the melting point, of the brazing alloy.

This seldom detracts from the usefulness of brazing as a method of fabricating parts for high-temperature service. Most of the engineering metals and alloys can be safely brazed at temperatures approaching their melting points and—since brazing alloys with correspondingly high melting points are available—brazed joints with high re-melt temperatures and creep properties matching those of the parent metals can be readily produced with the conventional materials and techniques.

Tungsten is an exception, because it cannot be brazed at temperatures higher than its recrystallisation temperature without suffering a sharp decrease in strength and ductility. The choice of brazing alloys suitable for joining this metal is therefore limited in practice to those with melting points lower than 1200°C. This, in turn, limits the re-melt temperature of joints brazed in tungsten with the conventional brazing alloys, and makes it difficult to attain the high-temperature joint strength comparable with that of tungsten itself.

One way of overcoming this difficulty is to depart from conventional practice and to use a brazing alloy which at the brazing temperature readily reacts with tungsten to form a new alloy with a much higher melting point. In this way a low melting point brazing alloy can produce joints with a high re-melt temperature and with high-temperature properties considerably better than those of the original brazing alloy. The possibility of using the boron-platinum alloys for this purpose has recently been investigated at the Research Laboratories of the Solar Aircraft Company, San Diego, California. The results of this work are described in a paper by C. W. Haynes (U.S. Bureau of Naval Weapons Report AD 27616).

The boron-platinum alloys were chosen because a eutectic melting at approximately 830°C is formed in this system at approximately 3.6 per cent boron, and because it was expected that inter-alloying between tungsten and an alloy of this type would lead to the formation of a new alloy (the W_2B intermetallic compound dispersed in a platinum-tungsten solid solution) with a melting point higher than 2400°C.

The composition of the alloys tested ranged from 1.0 to 4.5 per cent boron. The experimental, single-lap joints were resistance-brazed in vacuum at 2000°F (1093°C), the duration of the brazing cycle varying between 5 and 60 seconds. The brazing alloys, all of which were very brittle, were pre-placed in the form of powder between the two brazed tungsten strips. The joint gap thickness ranged from 0.0005 to 0.0015 inch. In some experiments tungsten powder was added to the brazing alloy to facilitate the formation of the new alloy. The re-melt temperature of a brazed joint was determined by recording the temperature at which the test piece was pulled apart when heated under a shear stress of 20 lb/sq. inch.

It is remarkable that under the conditions employed (relatively low brazing temperature, very short brazing cycle) joints with re-melt temperatures of 2100 to 2150°C were consistently produced. Although the optimum composition of the brazing alloy was at approximately 2.0 per cent boron, satisfactory joints were made with all the other alloys tested. Addition of tungsten powder to the brazing alloy had little effect on the re-melt temperature of the joint, except when joint gaps near the top limit (0.0015 inch) of the range studied were used.

Although relatively high, the re-melt temperatures of joints made under the standard conditions were lower than expected. One possible explanation was that the brazing cycle was too short to ensure complete alloying between tungsten and the brazing alloy. The effect of diffusion annealing (3 or 24 hours at or below the brazing temperature) was therefore investigated. Some of the brazed joints heat-treated in this manner had higher re-melt temperatures and higher strength. The results, however, were inconsistent and the improvement, observed only in test pieces diffusion-annealed at the brazing temperature, marginal.

The results of X-ray diffraction analysis and metallographic examination confirmed that the product of alloying was, in fact, a two-phase Pt(W)-W_2B alloy, and indicated that the presence of a large proportion of the latter constituent, melting at 1899°C, was the factor limiting the maximum attainable re-melt temperature of joints made with the boron-platinum alloys.

Attempts were made to counteract the harmful effects of W_2B by the introduction of small quantities of titanium and zirconium to the boron-platinum alloys, and by using 2.7 per cent boron-iridium alloys with and without small additions of osmium, rhenium and ruthenium. The results, however, were disappointing.

More promising results were obtained when a different, rather ingenious, approach to the problem was tried. It was based on the idea of mixing the brazing alloy powder with a compound which would react with boron during the brazing operation to form volatile products; since brazing is done in vacuum, these would be driven off leaving behind a platinum-tungsten alloy with a sufficiently low boron content and a correspondingly high melting point. The effect of additions of chlorides and fluorides of sodium, potassium and lithium was tentatively investigated. The results varied, but boron-platinum alloy/NaCl (or NaF) mixtures produced joints with re-melt temperatures of 2315°C.

Some indication of the high-temperature strength of joints brazed in the normal way with the 2.15 per cent boron-platinum alloy was provided by the so-called separation temperature. This was determined by stressing a test piece in shear at 200 or 800 lb/sq. inch, heating it in argon at a rate of 8°C per second and recording the temperature at which the joint broke. The separation temperature of joints tested at 200 lb/sq. inch ranged from 2015° to 2100°C, the brazing cycles used in the separation of the test pieces ranging respectively from 200 seconds at 982°C to 15 seconds at 1093°C. Joints tested at 800 lb/sq. inch failed in the 1180° to 2090°C range, the brazing cycles corresponding to the lower and upper limits being 480 seconds at 870°C and 60 seconds at 1200°C.

The investigation reviewed in this note was of an exploratory character and it would be desirable to have more data on the effect of various factors on both the re-melt temperature and the mechanical properties of the joint at elevated temperatures. Nevertheless, the results obtained so far demonstrate clearly the advantages offered by the boron-platinum alloys as filler materials for brazing tungsten parts operating at high temperatures.

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