Frequently asked questions #3

Which filler material is best for brazing carbide tips to circular saw blades?

Despite the very distinct technical advantages that accrue from the use of low-temperature silver brazing filler materials it is also an established fact that various copper-zinc filler materials are employed for the joining of tungsten carbide to steel in the manufacture of tipped tools. There is little doubt that the motivation for this move ***from*** silver-bearing filler materials ***to*** the use of silver-free alloys was prompted by the 'first cost' consideration that automatically attends their use. The situation that exists in the field of D.I.Y where carbide-tipped twist drills are to be used for a variety of jobs about the home is one of the instances where the long-life, and high joint-strengths that characterise those that have been made with a silver-bearing filler material are not of supreme importance. This is because the typical householder tends to drill so few holes in a given time scale it is often the case that the drills are used only once or twice, and put to one side. When, perhaps 6-8 months later they need to be used again, they are found to have rusted, and so are scrapped and replaced with new ones. As a result it is relatively rare for manufacturers of twist drills to select silver-containing filler materials for their D.I.Y range of product. In such situations the fact that the required joint strengths are lower than those that characterise the more expensive tools that are used by craftsmen, or Industry, explains the reason why the use of a copper-zinc, (brass), filler material is the norm in such cases!.

In cases where a company manufactures a carbide-tipped tool whose product-name is synonymous with 'quality' and 'reliability', it is almost always the case that the manufacturer in question opts for the use of a filler material that will provide a consistently high joint strength, so making it close to impossible for the joint to fail during the life of the tool. Where the brazing of cemented tungsten carbide is concerned, this often means the use of a silver-containing brazing alloy, and ***always*** means the use of an alloy that contains nickel. (We shall return to the reason for the presence of nickel in the filler material later in this article).

In certain specialised cases, carbide-tipped rotary hammer-drills for example, use is frequently made of special-purpose, copper-base alloys. These materials are formulated to have working temperatures that are similar to the heat-treatment temperature of the steel shank, typically 980ºC, and contain both nickel and manganese to provide enhanced wetting of the carbide. The requirements of metallurgy demand the presence of these elements in the alloy to impart good wetting characteristics, toughness, and to provide the desired solidus and liquidus values! By this means, and when brazing is carried out in specially designed reducing atmosphere continuous conveyor furnaces, it is possible to undertake both the brazing and a hardening process as a single operation. Such a procedure enhances the life of the tool due to the fact that the whole tool is through hardened to the desired level.

As can be seen from the above comments, where the joining of tungsten carbide to steel of tools that will see arduous service conditions, and where simultaneous brazing and hardening is to be undertaken, a required ingredient of the filler material is nickel. It is also of major significance that the presence of nickel in a filler material also enhances its wetting capability on tungsten carbide. This fact explains why nickel is also a preferred element in the formulation of the low melting-point, relatively free-flowing silver-bearing filler materials. The presence of manganese in such materials also enhances their wetting capability, particularly the softer grades of carbide than often contain traces of free carbon. There is strong evidence to suggest that the manganese mops up the free carbon, producing particles of manganese-carbide in the joint which enhances both the strength of the joint and the wear resistance of the filler material

On the other hand, brass is an alloy of copper and zinc and, containing no nickel, will inevitably produce joints that are less satisfactory in terms of their strength and resistance to fatigue-failure than those produced with their ' silver- and nickel-bearing cousins'. So, while it is possible to effect joints on tungsten carbide with brass, there are a number of disadvantages along the way that need to be mentioned.

These are:

1. Wetting performance of the brazing alloy
2. Potential difficulty with fluxing
3. Brazing temperature considerations

It will be helpful to discuss each of these criteria in some detail.

1. Wetting performance

It has been known for many years that the presence of nickel in a brazing alloy enhances its capability to wet cemented tungsten carbide. It is believed that this is due to the fact that the chemistry of nickel and cobalt, this latter element being the cementing material in the tungsten carbide, are very similar. This is not particularly surprising since, together with iron, they form the three Transition elements in the Periodic Table.

It is also a fact that the efficiency of wetting of a brazing alloy onto a substrate is generally indicative of the strength of the finished joint. i.e. the better the wetting, the stronger the joint. This is not true in all circumstances, only in those situations where there are no harmful products created at the interface between the filler alloy and the substrate over which it is flowing. For example, copper: phosphorus alloys wet steels very well, but the formation of iron phosphide at the joint interface results in the joint being extremely brittle. Fortunately, such phenomena do not affect joints made with nickel-containing alloys on tungsten carbide.

We have already mentioned that brass will wet tungsten carbide. However brass contains a large amount of zinc, and this has the potential to produce a reasonably high level of inter-granular penetration in the carbide, seriously weakening the portion of the carbide so 'penetrated' in the process. The degree of inter-granular penetration is governed by a time-temperature relationship and so is not a matter that can be forecast. Due to its metallurgical structure each surface will be affected by a different amount to its fellows. This means that in any situation where there are a series of joints, each one will almost certainly exhibit a shear-strength that is different, and sometimes *very* different, to that of its fellows. It therefore becomes quite difficult to use the attainment of a specific strength value by one or two joints to reach the conclusion that a given component is acceptable. Because of the large differences in strength that can be typical of two nominally similar joints, there is very little alternative but to test all joints, or test one or two and, if they meet some arbitrary strength value, *assume* that all joints are acceptable! Clearly, this approach is not one that can be seen as a very satisfactory position for a manufacturer of carbide-tipped circular saw-blades in which to find himself. This is particularly the case because of the use to which the product is put, and the potential for serious injury that might occur to a user, or one of his colleagues, if either were to be struck by a tip that had parted from its seating and flown off into the shop during use! The only people likely to benefit from this situation would be lawyers!

2. Fluxing

Brasses have working temperatures around 930ºC. This temperature demands the use of either borax, or potassium metaborate as the flux. Neither of these flux types blend 'happily' with water to produce a smooth paste, consequently their application proves troublesome. However, they function well as fluxes, but are annoying to use, and even more annoying when one tries to remove the residues during post-braze cleaning!

Brazing temperature considerations

Silver brazing alloys specifically recommended for the brazing of tungsten carbide operate at temperatures that are typically in the range 670 - 730ºC whereas brass needs to be raised to around 930ºC. Obviously, this increase of approximately 200ºC will have an adverse effect upon the production rate. If the current heating time per saw-tip is, say 5 seconds, it is not unreasonable to suppose that this would increase to about 7 seconds were brass to be used as the filler. This, in effect, means **a 40% increase in heating time**, with a consequent similar reduction in the output rate!

It is also necessary to examine the matter of the effect of the brazing temperature on the brass itself. Zinc boils at 913ºC, i.e. about 10ºC lower than the minimum probable brazing temperature. It is therefore certain that the brazing alloy will tend to 'boil' during use. This, in turn, provides the potential for zinc oxide fume to enter the work-shop environment. However, more critically, the act of 'boiling' will generate 'bubbles' of zinc fume in the brazing alloy. Once the alloy solidifies it is probable that the joint that has been made will be relatively unsound due to the presence of 'frozen' bubbles of zinc vapour in the body of the alloy in the joint. This effect, like inter-granular penetration, will also contribute to a reduction in the strength of the joint.

4 Brazing alloy paste

Brazing alloy pastes are homogenous mixtures of a brazing alloy powder, a flux, and a neutral organic binder. At first sight their use might appear to be the ideal answer to a Production Engineer seeking a solution to a brazing problem. However a process analysis of the production situation often results in quite the opposite conclusion being established!

It is typically the case that where carbide tips are to be brazed to the cutting edges of circular saw blades the brazing filler material is fed to the work in the form of wire. When this procedure is employed the wire is fed to the pre-fluxed joint ***after*** it has been raised to brazing temperature! It is self-evident that if the use of paste is to be possible, it will need to be fed to the seat on the blade ***before*** the application of either the carbide tip or the heat! This is relatively easy to arrange but this is the ***only*** easy part of its use for this application!

A typical paste contains about 70% by weight alloy, 25% flux, and 5% binder. Being an organic chemical, and so of relatively low specific density, the *volume* of the binder present in the paste is relatively large in comparison to that of the flux and, specifically, the powdered filler material. When using a filler metal paste for this type of work, the procedure will be to 'trap' the paste beneath the tip, and then heat the joint area to brazing temperature. One can be **absolutely certain** that if the heating rate is too great the binder will vaporise *extremely rapidly,* this often leading to a small explosion in the vicinity of the joint which results in the tip being 'blown' off the work.! Even if this does not occur, because the paste will be present at the edges of the joint before heating is commenced, and because the mass of individual particles of brazing alloy in the paste will be very low, there will be an ever-present risk of these 'externally located' particles melting long before those under the tip do, effectively sealing around the outer edges of the tip. In these conditions, flux, and binder vapour will be unable to escape, and the resultant joint could be seriously unsound.

Further, it is interesting to observe the faces of operators engaged inflame-brazing their work when they first begin to use a brazing filler metal paste. Because the pastes incorporate an organic binder in their formulation, during application of heat the binder volatilises and, in contact with flame, the vapour ignites. Thus each joint has a small flame issuing from it in the early stages of the process cycle! If induction, rather than flame heating, is employed, the binder does not ignite but boils off from the work as a relatively dense, pungent-smelling, white 'smoke'.

Summary

The use of brass for the brazing of tungsten carbide tips onto circular saw blades is fraught with problems:

- Joint strength will be suspect, and highly variable, due to inter-granular penetration of the carbide by the zinc in the brazing alloy
- The necessary fluxes are relatively 'annoying' to use

- At brazing temperature the brazing alloy will ‘boil’, this will lead inevitably to joint unsoundness, and lower joint strengths
- The heating time will be longer, so leading to lower production rates

- The use of a brazing alloy paste is fraught with a number of technical disadvantages.

On the positive side of a proposal to use brass, rather than a silver brazing alloy to make the joints is that from the point of view of ‘first cost’ brass is substantially less expensive than a low-melting point silver brazing alloy. However in view of the fact that the resultant joints are likely to be slower to make, be of suspect soundness, and of variable, (and lower), joint strength than those made with silver-containing brazing alloys the rational behind any proposed change to the use of brass for certain products seems close to impossible to justify.
Thus, the answer to the question posed at the beginning of this article is:

Use a nickel and manganese-bearing low –melting point silver brazing alloy!