



Vacuum Brazing White Paper

Vacuum Brazing - Proven High Performance Additive Manufacturing

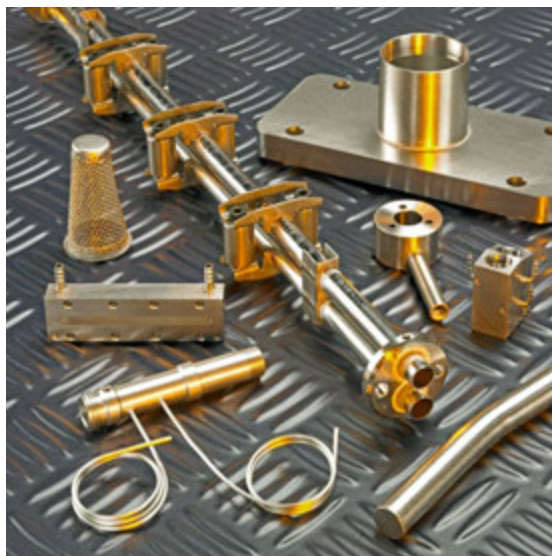
There is considerable hype around additive manufacturing. At the 2016 Singapore Air Show one advocate was even suggesting that whole planes could be produced by 3D printing in the not too distant future. This is probably a little over optimistic given the pioneering nature of the technology and technical and compliance issues involved.

Vacuum brazing, on the other hand, is a fully developed and proven additive technology. It has many of the advantages of additive manufacturing and offers a flexible route to the production of highly complex components. It is available now, accredited by leading international standards bodies and is able to meet multiple technical challenges in aerospace, motorsport, nuclear, medical and other demanding engineering fields.

Peter Cookson, technical specialist in vacuum brazing at Wallwork Metal Technology, outlines the scope and capability of this 'here and now' technology.

What is Vacuum Brazing?

Vacuum brazing is a process that enables the creation of complex components by joining simpler parts using a braze metal with a lower melt point that flows by capillary action into the space between the parts. The filler metal or alloy is heated to a temperature above 750°C and up to 1200°C and distributed between two or more close fitting parts by capillary action to form an exceptionally strong sealed joint.





Vacuum Brazing

This is a clean and flux-free process that produces high strength components with excellent dimensional stability, free of voids or inclusions, resistant to shock and vibration and able to withstand high pressures.

By comparison to joining by welding it has several advantages:

- ▶ the base metal does not melt, ensuring close tolerance assembly without the need for post finishing
- ▶ heats the entire part uniformly, causing less distortion
- ▶ lower temperature jointing prevents discolouration and stress in the completed component
- ▶ highly suited to the assembly of multi-part complex components
- ▶ permits joining dissimilar materials, or even non-metals (ceramics for example)

The technique can join miniaturised components or large fabrications. These may be simple with few components or complex, perhaps combining hundreds of components in a single process. The parts to be joined may be produced by a variety of methods; cold stamping and forming, casting, forging, extrusion, fabrication or machining and could be made from almost any metal, alloy or even ceramics.

Vacuum Brazing Process

Process design depends to a large extent on the final function of the component and the environment in which it operates. This governs the manufacturing method and material of the component parts, the braze material to be selected and the joining process. It is a good idea to involve the vacuum brazing company as early as possible to benefit from their advice and experience on the best possible way of achieving the desired goal.

All parts must be thoroughly cleaned and degreased. A degree of surface roughness, imparted by mechanical cleaning, will assist capillary flow of the braze material to produce stronger bonds.

Parts are assembled to assure the desired gap with the selected braze material inserted in the spaces between. Assemblies are then placed in a vacuum furnace where, following a carefully prescribed time and temperature cycle, components are heated to the braze material melt point, held at this temperature for a specified time, then subject to controlled cooling.



Vacuum Brazing

The melted braze material will soften and wet out to flow and fill in all voids and bond with the parts. Conducting this process under vacuum ensures that no oxidation occurs on the surfaces and the resulting bonds are exceptionally strong.

Dual processing is often possible. Using suitable materials for the components of the assembly the heating and cooling cycle can be designed to age harden or harden and temper the component as the brazing takes place, saving significant time and cost.

Materials

Many materials can be joined by vacuum brazing. This includes 300 and 400 series alloys of stainless steel, nickel based super alloys such as Inconel and Hastelloy, copper, beryllium, zirconium and other exotic metals and many more as well as carbides and other ceramics. Dissimilar metals can be joined as can non-metallic materials.

Braze materials vary according to technical requirements but these are typically alloys of nickel, gold, silver or copper depending on the base materials to be joined and the in-service requirements of the component. Various formats of braze materials are used to meet different needs including wire, strip, powder or paste. Strip or wire may be pre-formed to optimise flow and contact with the component.

Metallurgical Expertise

Development of a suitable vacuum brazing process for each application requires substantial metallurgical knowledge and experience. The following all have a significant impact on the resulting component:

- ▶ surface preparation and finish of the parts
- ▶ correct joint geometry
- ▶ design of suitable arrangements to hold components during build-up and furnace treatment
- ▶ selection of the best braze material and format
- ▶ design of the optimum heat, hold and cooling cycle

It is essential therefore that the vacuum braze contractor has qualified and experienced metallurgists who can understand, interpret and often improve the process to deliver the required technical performance or achieve efficiency savings.



Vacuum Brazing

Overcoming Manufacturing Issues: Two Examples

Using a proven process technique difficulties were experienced in achieving satisfactory bonding of components, despite thorough degreasing and surface preparation. Only on close examination of the components, using a high power electron beam microscope, were our metallurgists able to identify deep impacted contamination of the components by aluminium compounds that were invisible to the human eye.

The customer was asked how the components were prepared before they left their factory and it was discovered that they were de-burred in a barrel rolling process using pellets with an aluminium oxide component. Changes to the de-burring process subsequently solved the problem.

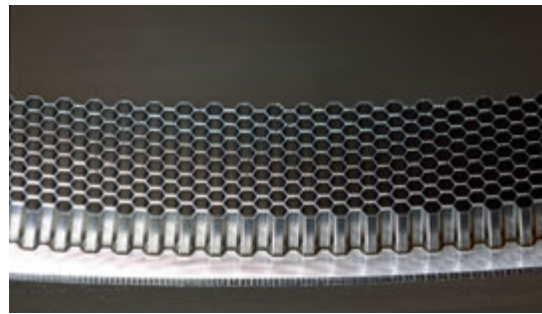
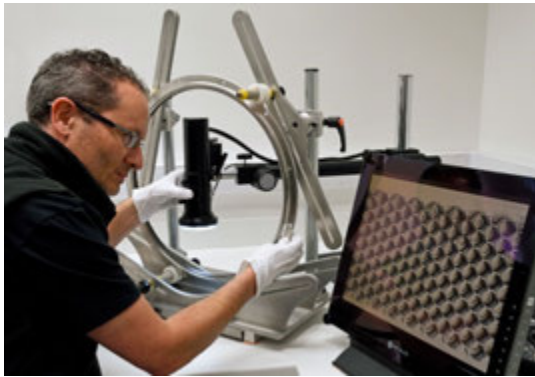
As our second example shows, developing the correct vacuum brazing technique is often an iterative process, where previous experience is a guide to developing the best technique. This arose in a case where we were asked by a manufacturer of flow measurement equipment, for whom we already assembled small and mid-range equipment, to look at bonding a high volume unit. This comprised several parts each exceeding two metres in length.

When in use the unit generates resonant vibration and so any kind of clamping was out of the question. Welding was also precluded because the high temperatures would have required post-treatment of the component. Vacuum brazing is therefore the ideal joining method proving a high strength joint at low temperatures that remains ductile and vibration tolerant.

The first prototype parts were supplied having been manufactured to drawings created without any advice from the Wallwork team. On examination several issues were identified that could affect the bonding. The first prototypes were joined by vacuum brazing with the predicted outcome. Bespoke jiggling was designed and supplied by Wallwork Cast Metals and the parts were then modified to our advice and a second prototype vacuum brazed with 90 percent bonding achieved. The parts were then further modified, vacuum brazed, tested and found to meet all the required criteria and be fit for use in the field. Seeking our advice at the earliest design stage can often shorten the development cycle.

Testing

Various testing procedures are followed to validate the effectiveness of the vacuum brazing. For medical devices, for example, helium leak testing detects even the smallest defect. Similarly, water testing is commonly used. High magnification visual inspection is used to ensure effective bonding has been achieved.



A good example of this is the fitting of honeycomb seals to rings within aero engines and gas turbines where one hundred per cent bonding is vital to prevent hot gas leakage between sections of the engine operating at different pressures. Various hardness testing techniques can also be applied to assess the effectiveness of the heat treatment part of the process. Destructive testing of prototypes or samples is also available to see the metallographic structure of the joint and assess the diffusion bond between the jointed parts.

Clients are welcome to visit site to see the facilities and appreciate the scope of work undertaken and thoroughness of the operation.

Equally suited to one off or prototype development, a vacuum brazing process, once proven, can be replicated reliably and scaled up for mass production using high vacuum heat treatment furnaces of varying capacities up to a maximum single load of four tonnes.

Conclusion

The issues around additive manufacturing are not about the deposition of material to create components of any given size or shape. They are more to do with basic issues of material science, such as material selection, bonding and performance in the field so considerable research will be required to prove long term performance in a range of challenging environments before we can have the level of confidence that we have in established materials and practice.



Vacuum Brazing

Vacuum brazing is a highly adaptable additive technique that is available now. It enables components of great complexity, operating in extreme situations, to be reliably produced with the assurance that performance in the field will be dependable.

Where a customer is thinking of using vacuum brazing for the first time, Wallwork engineers are happy to work collaboratively to design and develop the most appropriate technique, produce and test prototypes and then scale up to meet their technical and commercial needs.

More Information

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