Vacuum Brazing

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Brazing is a process of joining metals in which molten filler metal is drawn by capillary attraction into the space between closely adjacent surfaces of the parts to be joined. In general, the melting point of the filler metal is above 500°C.

Brazing could be carried out by Resistance Brazing, Dip Brazing, Torch (Flame) Brazing, Induction Brazing, Salt bath brazing and furnace Brazing. Furnace Brazing is a process in which brazing heat is obtained by putting a complete workpiece into a furnace which may contain a protective atmosphere.

Vacuum Brazing process is classified under Furnace Brazing and could be considered as a logical extension of the processes involving brazing without a flux in special atomospheres with the work enclosed in a chamber.

Theory of Brazing :

A capillary gap is a must in brazing and this is illustrated by glass and water analogy. Consider a clean piece of plain glass sheet lying flat with a little pool of water on it as in Fig. 1. If another clean piece of glass is laid on the first and if its edge is brought into contact with the water, some of the water will immediately flow into the narrow gap between the glass surfaces for an appreciable distance.

That water is propelled by capillary attraction. The gap penetrated is a capillary gap. If the gap is made too wide by placing a spacer between the glass sheets, the water penetrates only a little way or not at all. If the gap is small, the effect will be obtained even when the glass sheets are vertical and the water will not fall out unless they are separated.

Exactly the same effect occurs when a joint is brazed, except that instead of glass sheets there are opposing surfaces of the components being joined and instead of water, molten brazing material.

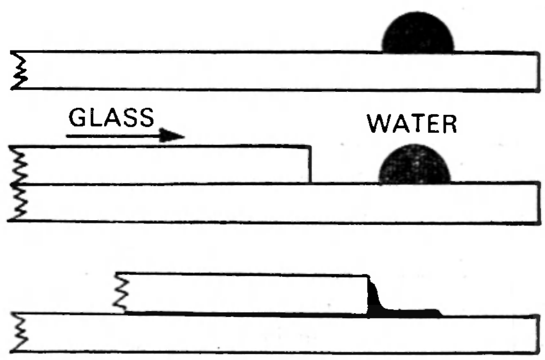

Fig. 1. The effect of capillary action.

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Vacuum Brazing :

In this process, many metals which cannot be brazed satisfactorily in atmosphere can be brazed. In Vacuum brazing, there is no need for a flux and clean joints are made without possibility of flux inclusions. A resistance heating technique is used in the furnace to braze several joints of an assembly in one operation without any necessity for subsequent internal cleaning.

Vacuum Brazing Process :

This is done in the vacuum furnace by keeping the component inside the chamber, creating vacuum by mechanical and diffusion pumps, heating to the brazing temperature and cooling the chamber.

Preparation of Component :

In common with other joining processes such as welding, care is taken in the preparation of the work before vacuum brazing. Oxidised material is acid-pickled or cleaned by scratch brushing. As far as practicable, components for vacuum brazing are designed to be self-jigging. For example, many parts can be held together by rivetting or spot welding. However, many components, particularly those made from light gauge material, having low creep strength at high temperatures require support to prevent distortion. When a separate jig is used, it is made of heat-resisting material and should be as light as possible and preferably not shield the joints from heat radiated from the elements.

The filler metal is applied to the work as powder, foil or wire, or by plating. The amount of filler required varies widely, depending upon the base metal, the joint clearance, the length of capillary and the type of alloying which takes place between the base metal and the filler.

Order of vacuum :

The prepared work is loaded into the furnace which is first evacuated and then heated to the appropriate temperature. Depending on the base metal, certain order of vacuum is maintained during the process. For stainless steel generally vacuum of 10^{-2} mm of mercury is satisfactory, and for high temperature alloys, containing aluminium and titanium such as certain of the Nimonics, a vacuum better than 10^{-3} mm of Mercury is required.

The degree of vacuum is indicated by the vacuum gauges which give continuous indication of the order of vacuum within the furnace and is closely controlled throughout the brazing cycle.

An example of the temperature and time in brazing cycle for a stainless steel component weighing 100 lb is, heat to 1080°C in one hour, hold at 1,080°C for 5 minutes, and cool to 200°C in 3½ hours. The pressure within the furnace throughout this time will be less than 10^{-3} mm of mercury.

Furnace Description :

The EFCO vacuum furnace in Aero Engines, HINDUSTAN AERONAUTICS LTD., Bangalore consists of furnace chamber heater, vacuum system, control panels, etc., The chamber is of a cylindrical stainless steel vessel with water jacketing and a water cooled dished base. The heater consists of a rigid cage of graphite bars with a connection of 300 KVA, 3 phase delta transformer at a reduced voltage of 55V. The chamber is connected to the oil diffusion pump through a baffle valve and to mechanical pumps. The vacuum piping is arranged with the necesssary pneumatically operated valves to allow the rotary pump and mechanical booster to be connected directly to the vessel for rough pumping, thus allowing the diffusion pump to be kept hot during loading and unloading.

Pressure measurement is done by Bourdon gauge, Pirani and Ionisation gauges. (The gauges are used to measure upto 1 torr, 10^{-3} torr and 10^{-6} torr, respectively and one torr is one mm of mercury). Pirani and ionisation gauges are connected to indicating instruments on the control panel.

Furnace Operation :

The operation consists of placing the component which carries the brazing material in the furnace and closing the lid. The vacuum pumps are then started. At this stage, merely the rotary backing pump and the mechanical booster will be evacuating the furnace. When the pressure reaches approximately 1 torr, the heater is switched on and the pressure is further reduced by connecting the oil diffusion pump in the circuit, which gives a pressure of less than 10^{-3} torr, (between 10^{-3} and 10^{-6} torr).

The temperature inside the furnace is then raised to some 20°C below the actual brazing temperature and held there for a few minutes to make sure that all the parts (Maximum of 3 parts could be kept inside

Fig. 2. General view of the Vacuum Furnace, showing the chamber Transformer and recording panel.

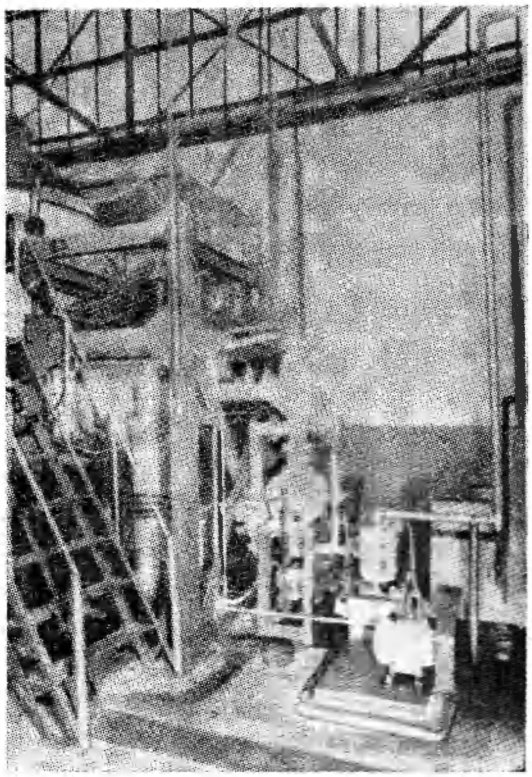

Fig. 3. Arrangement of Vacuum Furnace showing a partial view of the chamber diffusion pump and mechanical pumps (left to right)

the furnace) are at the same temperature. More power is then applied and the temperature is raised to the brazing point. The actual melt can be observed through the window.

The power is then switched off, vacuum system is isolated and the furnace is flooded with a cooling gas such as Argon (if rapid cooling is necessary). The charge is rapidly cooled to a temperature at which the furnace can be opened and the charge is removed.

Parent metals brazed :

Most of the metals can be brazed in vacuum. The only metals to be avoided are those which have volatile constituents such as cadmium and zinc.

Brazing alloys for use in Vacuum :

The brazing alloy should wet the parent metals to be joined, it should be sufficiently fluid at the brazing temperature to flow over the surface of the parent metal, and the joint should possess mechanical and chemical properties satisfactory for the intended service application and should not contain constituents which have a high vapour pressure at the brazing temperature.

A filler metal with a narrow melting range tends to flow quite freely and should be used with joint having small clearances.

There are a number of filler metals suitable for vacuum brazing and the alloys available cover the temperature range from 680°C to 1,250°C. A few are copper, silver-copper eutectic alloy, copper-Gold alloy and nickel-base alloys.

Copper :

Copper is widely used as a filler alloy, particularly in atmosphere brazing. It is very convenient to apply by plating, as foil, as wire, or as powder. It is extensively used in vacuum for brazing plain carbon and stainless steels and heat resisting alloys. The vapour pressure of copper at its melting point is quite high, and when it is used in a vacuum furnace the brazing time should be kept as short as possible to prevent excessive volatilization. Joints brazed with copper have only a moderate strength compared with those brazed with some of the nickel-base alloys, and copper should not be used for components required to operate

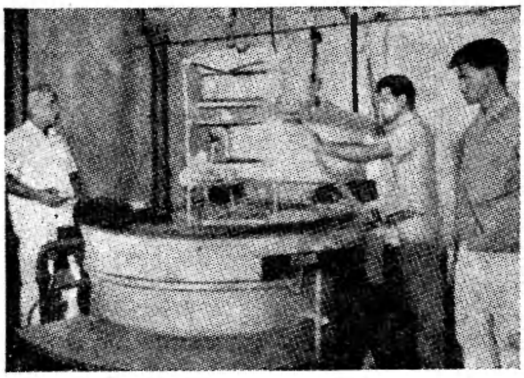

Fig. 4. Unloading of Annealed blast from the furnace showing the fituse.

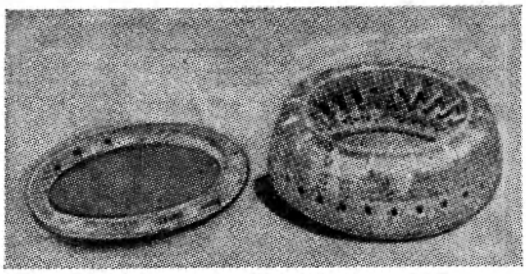

Fig. 5. Two of the Artouste parts Vacuum brazed. I stage diffuser. (left) Bosses and the bottom plates are copper brazed.
Combustion Chamber outer shell Assembly (right). Dilution tubes are Vacuum brazed to the outer shell.

at temperature higher than 400°C. For maximum joint strength the clearance should not exceed 0.001".

Nickel-base alloys :

These could broadly be divided into boron and/or silicon alloys and those containing phosphorus. Boron-silicon alloys are the largest group of brazing alloys. In addition to nickel, boron and silicon they may contain ch-omium and iron with brazing temperature ranging from 1,050°C to 1,190°C. They alloy readily with the base metal and this will cause erosion if present in excess. For this reason, the amount of alloy applied and the brazing cycle must be carefully controlled, particularly when brazing thin material.

All of the nickel-boron-silicon brazing alloys are hard and only readily available in the form of powder. The powder is mixed with an acrylic resin cement to form a slurry and applied to the work with a brush. The resin volatalizes during heating and does not interfere with the brazing.

For maximum strength from the silicon-boron alloys the joint clearance should not exceed 0.004 inch.

Nickel-base alloys containing phosphorus have been developed mainly for use in the nuclear energy industry and this alloy does not erode stainless steel and therefore is suitable for joining thin gauge material.

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