30/6/2013

A.V.SALDATURE

BRAZING TECHNOLOGY IN AUTOMOTIVE

The state of the art in automotive components brazing technology |

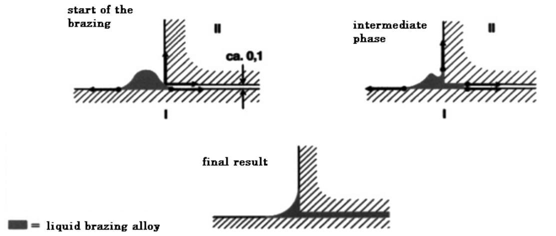
Written by Roberto Aprile

1 State of the art in the brazing production of automotive company in the European industry

The brazing of the automotive component is a well know process, with a consolidate knowledge coming from a long experience, studies and productions. Generally speaking we can divide their brazing operations following some parameters as: **brazing technologies, brazing material and base material**. Most of the automotive companies have standardized the production of these components imposing some material choice instead of others; the same companies chosen this material during the project, selecting the material that will be used in production, the brazing alloys and the brazing technology. It is quite common in this industry to come across a belt furnace with reducing atmosphere like endothermic, exothermic with pure H_2 or a mix of H_2 N_2 the reason and the nature of the choice will be explained later.

2 **brazing technologies**

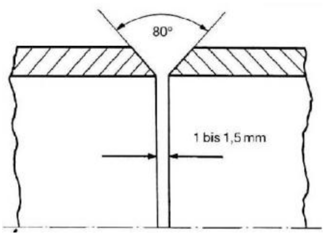
As simple process standpoint, all the **brazing methods** are identical: two base metal parts are brought into close contact with one another in a conventional joint configuration, i.e., butt or lap. A suitable filler metal is placed along the seam or fed into the joint along with a flux. The whole assembly with the filler metal is then heated to a temperature that allows the filler metal to liquefy and fill the joint gap via capillary action. Heat is removed and the assembly is then cooled or allowed to cool to ambient temperature before further processing.



Furnace brazing, however, offers distinct **advantages** over flame brazing, especially in the areas of control, automation, repeatability, and flexibility. The advantages of furnace brazing are many, including:

• Multiple joints on the same assembly can be brazed simultaneously
• Complicated jigging is normally unnecessary – usually gravity or minimal fixture is sufficient
• Undesirable atmosphere constituents can be controlled or eliminated
• The process is highly repeatable, ideally lending itself to automated production and data acquisition, e.g., SPC.
• Usually does not require chemical fluxes
• Minimal or no post-braze cleaning is required
• Provides close temperature control, for optimum and uniform results

The **disadvantages** of furnace brazing have to do mainly with furnace issues, e.g., the cost of equipment (versus flame brazing), higher power consumption, and furnace maintenance requirements. In addition, somewhat more attention has to be paid to **joint design** because the brazing takes place in the furnace chamber, and is not easily observable. In the past also, a degree of process control skill is required to manage the variables of atmosphere composition, fuel flow, and cross-contamination, outgassing, and heating and cooling; today it possible to program most of the variable into the furnace computer and change it from one part number to another. Generally we can say that Furnace brazing is not optimal for low volume production of components. When we talk about belt furnace we usually mean a controlled-atmosphere processing.



The most common atmospheres used in controlled-atmosphere furnace brazing operations are classified as exothermic, endothermic, dissociated ammonia and industrial gas-based (generated or delivered). What all of these atmosphere types have in common is that they are used for moderate- to **high volume** production applications, mostly in a continuous furnace. Typically, these controlled-atmosphere furnaces will be of a multi-chamber design, all of the brazing atmosphere types reduce oxide formation after precleaning and control the formation of oxides during brazing. They help to control **wettability** and braze flow, and assist in optimal microstructure formation.

Perhaps most importantly, controlled-atmosphere brazing eliminates the need for fluxing in most applications, which means lower labor costs since parts can be finish-machined or used immediately without post-braze cleaning. Also, the **absence of flux** residue is a benefit for parts with complex geometries where flux can become entrapped or threaded holes where complete removal of flux is difficult or impossible.

Nitrogen

Nitrogen (N_2) constitutes 78.03% of the air, has a gaseous specific gravity of 0.967, and a boiling point of -320.5° F (-195.8° C) at atmospheric pressure. It is colorless, odorless, and tasteless. Nitrogen is often used as an "inert" gas due to its nonreactive nature with many materials. Sometimes it may cause an undesirable **nitriding** effect in certain stainless steels (although nitride inhibitors are available). Fast cooling may also help to prevent this unwanted nitriding.

Hydrogen

Hydrogen (H_2), the lightest element, has a gaseous specific gravity of 0.0695 and a boiling point of -423° F (-252.8° C) at atmospheric pressure. It is a colorless, odorless, tasteless, flammable gas found at concentrations of about 0.0001% in air. In brazing applications, hydrogen is commonly used as a reducing (fluxing) agent to break down surface oxides and prevent them from reforming during the brazing cycle. Water vapor is produced as a byproduct of the oxide reduction process, requiring the addition of more dry hydrogen as needed to control the dew point, which varies with the type of metal oxide present.

H2 red immagine

Methane

Methane (CH_4) in the brazing chamber is often present as a constituent byproduct of generated exothermic or endothermic atmospheres, or may be outgassed from brazements containing residual oil. It is also sometimes added intentionally (for example,
As a source of carbon to counter the decarburizing effect of carbon dioxide and water vapor).

Carbon dioxide

Argon

Argon (Ar) is a chemically inert, colorless, odorless, and tasteless gas composing slightly less than 1% of the air. Its gaseous specific gravity is 1.38 and its boiling point is -302.6° F (-185° C). In brazing, argon is used to inhibit volatilization and to prevent hydrogen embrittlement in sensitive materials, such as titanium, zirconium, niobium, and tantalum alloys.

Exothermic atmospheres

A common type of atmosphere used in furnace brazing applications is the exothermically generated atmosphere. It is a relatively low-cost process suitable for mild steels and some non-ferrous metals, and is typically used where quality and reliability are not major concerns. Exothermic atmospheres can be formulated to be either "lean" or "rich" in hydrogen. However, because they are a byproduct of hydrocarbon combustion, their composition cannot be relied on to be pure or consistent. Their high carbon monoxide component and dew point make them unsuitable for most stainless and high carbon steels.

Endothermic atmospheres

Commonly used in brazing of carbon steel with copper, endothermic atmospheres are sometimes diluted with nitrogen and used to braze high-carbon parts and prevent decarburization. Similar to exothermic atmospheres in composition, they are also not recommended for stainless steels.

Vacuum furnace brazing

The applications for vacuum furnace brazing have grown considerably as improvements in equipment design were developed to overcome the problems experienced in early efforts. Frequently, vacuum processing and atmosphere processing are used to complement each other. For example, vacuum is sometimes used as a purging atmosphere before brazing with dry hydrogen, and inert gas or dry hydrogen is sometimes used as a purging agent before brazing in a vacuum furnace or as a partial pressure during brazing. Brazing in partial vacuum furnaces may be equipped to allow the introduction of a gas (generally inert gas or Sometimes hydrogen) to increase the pressure to create a so-called partial vacuum atmosphere. This environment is useful for minimizing or preventing the volatilization of base metals or filler metals that tend to outgas at brazing temperatures. When brazing in total vacuum, essentially all gases are removed from the brazing environment and a negative pressure ranging from 0.013 to 0.00013 Pa (10^{-4} to 10^{-6} torr) is maintained. Gases are used, however, for quenching the heated parts after brazing. Generally, nitrogen or argon is used for quenching, but sometimes helium or hydrogen gas is used based on production and metallurgical considerations. Vacuum brazing is an ideal application for base metals such as heat-resistant nickel- and iron-based alloys containing aluminum and/or titanium. Good results may also be obtained with metals such as zirconium, niobium, titanium, and tantalum that could become brittle when brazed in a low-purity hydrogen (dissociated) atmosphere.

Other brazing technologies

Apart from furnace brazing, there are many other types of equipment used for carrying out brazing processes. However, since the focus of this publication is on furnace brazing, they will be mentioned only briefly here:

• **Flame brazing** is a process wherein the heat required to melt and flow the filler metal is applied locally to the joint area and is burnished by a fuel gas flame, usually consisting of natural gas, acetylene, hydrogen, or propane combusted with air or oxygen (oxyfuel). The equipment used is similar to that employed in gas torch welding. Flame brazing requires a chemical flux to minimize oxidation that would interfere with the integrity of the bond and to aid in the filler metal flow (wettability). Use of a chemical flux necessitates post-braze cleaning, which is a secondary operation not generally required of furnace brazements

• **Induction brazing** relies on the electrical energy generated by induction coils to selectively heat the joint area of an assembly to brazing temperature.

• **Resistance brazing** generates heat from passing electrical current through the workpieces, which causes the filler metal to flow and complete the brazement.

• **Dip brazing** uses a salt bath or pot furnace containing molten flux, or filler metal and a layer of flux, into which the parts to be brazed are immersed, cooled, and cleaned. • Diffusion brazing is an extension of conventional brazing in which the filler metal completely diffuses at the base metal interface to the point where the physical and mechanical properties of the joint become the same as those of the base metal. In many cases, the joint "disappears" completely.

• **Exothermic brazing** is a process whereby a chemical reaction provides the heat required to complete the brazing operation. The exothermic filler metals, or it may create a molten filler metal as a byproduct of the reaction itself. • Infrared brazing is similar to furnace brazing; however, heat is supplied by quartz heat lamps rather than electrical heating elements or combusted gas.

• **Electron beam and laser brazing** are two relatively new technologies which use a focused beam of energy to deliver heat to the joint being brazed.

3 **choice of braze material**

The choice of the material is usually done by final use of the component: normally starting from the combustion chamber of the engine , we can say that everything is before must not have strong resistance on corrosion or temperature, while everything that is after it must have corrosion resistance for the nature and for the temperature of the fluids. This simple rule makes the difference on material choice, on brazing alloy and on brazing technology that is possible to use.

We can find two categories of **brazing material**, the first is copper, easy to find in every shape (foil, powder, and wire paste) the copper is suitable for all the join that are located before the combustion. There are huge advantage in using copper, is cheap, easy to find, as all the metals is eutectic (1083 °C) and this will narrow the range time/temperature . On components located after the combustion you must use brazing alloy base on Ni Cr, this alloys can be divided in Ni Cr alloys with P (as 9760 o 9610 cod AV) or Ni Cr alloy without (as 9824 cod AV). The presence of the P will affect many factors that we can sum in the following tab:

	productivity/cost	Cu	Ni Cr P	Ni Cr
Endogas Furnace		Ok	Ko	Ko
Exogas Furnace H_2N_2		Ok	Ok	Ko
Exogas Furnace H_2N_2		Ok	Ok	Ok
Vacuum furnace		Ok	Ok	Ok

The choice depends on a valuation of cost/benefit, excluding those choices that cannot be valid for metal/alloy feature or for kind of furnace to save cost and improve efficiency, thinner wall structures are desirable. In these cases, boron containing filler metals have significant disadvantages because of high base metal erosion and burn through caused by lowering the localized melting point of the substrate.

On the table we are not consider Ni Cr Fe alloy that are still on test and have to show to give real cost effect advantage

4 **choice of the material join**

Component material: usually is made of stainless steel but the nature of the alloy has to fit on the final position in to the engine as we said before. The composition of the base material will also affect brazing alloy and technology. When we are brazing with a furnace we are also making a heat treatment, so we have to considerate how this treatment will affect the final component, if this will change or jeopardize the final result on the automotive component. The need for corrosion resistance material as we said has practically restrict the kind of material suitable for automotive company on stainless steel, this help us when we have to project the **thermal protocol** of the component.

Temperature °C	phenomena	Heat treatment	Alloys
350°		Distension	
450°	Precipitation of Chrome carbide on austenitic granules borders	Sensibilization: elements will add on the alloy lower C in the matrix this will avoid carbide forming (Ti,Nb elements)	Not stabilized alloys Not low C
850°		Ideal range for stabilization	321 (316,304,347)
1000 °C 1100 °C		Ideal range for solubilization	201, 202, 301, 302,303,304,305,308,309,310,316,317,321

Of course another aspect in the thermal protocol is the γ phase that is require to finish the heat treatment, during the cycle project you must consider the temperature of the component and the speed of the belt.

5 **Trouble shooting**

As brazing is one of the elements that you need to produce automotive pipes and components you might consider that every producer has found their own way to solve the problems that they find on their way, basically most of the problems were solved operating on different level until a solution had been found. Let' see some example

Joint design and preparation

While furnace brazing usually eliminates the **need for cleaning** parts to remove flux and surface contaminants after processing, it is extremely important that pre-cleaning and/or degreasing take place. This ensures that joint surfaces are free of oxides, oil, and other undesirable artifacts that could interfere with proper wetting and filler metal flow. In certain applications, the components to be brazed are pre-processed in an attempt to break down the transparent oxide on the surface of the parts.

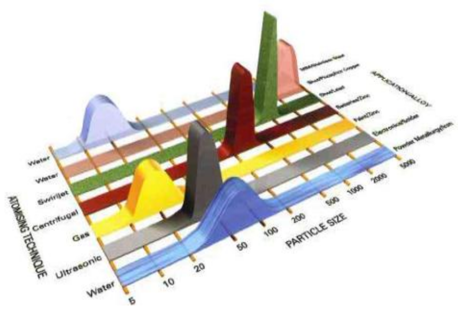
In addition to cleaning, **the gap** between the base metals being joined (referred to as **clearance**, or the distance between the opposing, and fating, surfaces) is critical for many reasons, especially when joining two dissimilar metals, because of the differences in the metals' temperature coefficients of expansion. At brazing temperatures, this difference can cause the joint clearance to widen or narrow unacceptably. Therefore, the join must be designed to have the proper clearance at brazing temperature.

Proper joint clearance, sometimes called "**fit-up,"** is also important because it has a bearing on the final mechanical performance of the joint, such as stress loading. Generally speaking, clearances should be as tight and as uniform as possible to optimize capillary attraction and minimize the chance of voids occurring in the molten filler metal.

Ref	AV paste			competitor		
	PRODUCTION	FAIL	%FAIL	PRODUCTION	FAIL	%FAIL
HFV62	28474	358	1,26	15930	650	4,08
462 G3	30151	281	0,93	46027	3494	7,59
W19	2989	7	0,23	7555	741	9,81
FSI	8468	319	3,77	1833	185	10,89
INDEX 75	3436	131	3,81	2413	1222	50,64
M47TU	29210	866	2,96	29821	897	3,01
C15-I	2362	0	0	2230	26	1,17
O38	35585	262	0,74	1191	126	10,58
NG4	8741	24	0,27	10951	16	0,15
LION V6	2200	2	0,09	4900	0	0

Is it possible to increase the production quality without changing the composition of the brazing alloy and of the join?

This was asked to A.V.Saldature s.r.l. from an automotive company, on the table you can compare the result between our paste and a major competitor paste. Basically the better performance is due to an accurate choice of the copper powder, the right mix of purity of Cu, atomization method and particle size is able to give an excellent performance, the secret touch of A.V.Saldature is to make a paste 92% copper and only 8% of binder, this means that when you are apply a dot of paste you are on average 10% to 15% more copper in the joint: so you can chose to save money by using less paste or save money by reducing the failing part



Summary