A Review of the Fundamentals of Stainless Steel Brazing in a Continuous Style, Controlled Atmosphere Brazing Furnaces

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Figure 1. Controlled Atmosphere Brazing Furnace.

Abstract

The use of continuous style, controlled atmosphere brazing furnaces to braze stainless steels is becoming more common as the aerospace and automotive producers increase the use of stainless steel components on existing designs and explore new designs. Although much of the metallurgy and thermodynamics of Iron, Chrome, Nickel and their compounds are well understood, a review of the application of the fundamentals to the current practices and equipment technology can help with improved product quality, expanded applications, and the optimization of costs for a net improvement in competitiveness.

Introduction

The brazing process begins by placing a source of filler metal in close proximity to the base-metal joint that is to be brazed. The assembly is then placed in a fixture or directly on a belt that carries the product through a continuous, controlled atmosphere brazing furnace.

A brazed joint is formed by the filler metal melting and flowing via a capillary effect into the pores of the closely fitted surfaces of the joint to form an alloy of the metals upon solidification.

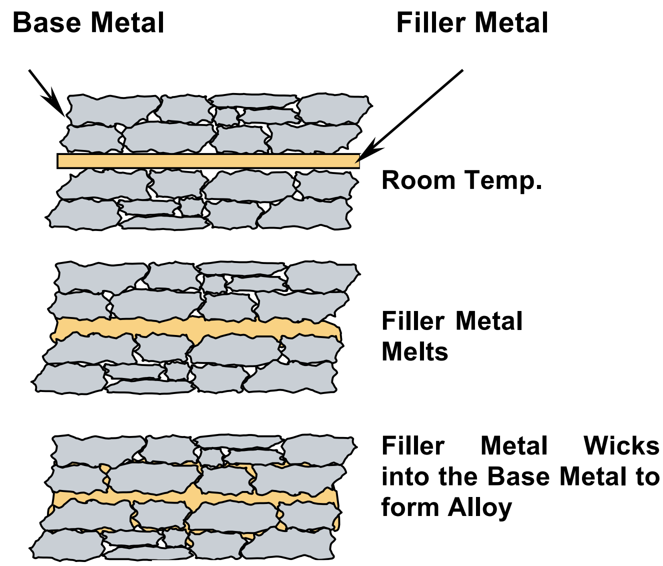

Figure 2.   Brazing Schematic

Brazing Furnaces

The goal of a brazing furnace is to provide a time, temperature, atmosphere relationship that is accurate, repeatable and economical in meeting the requirements of the brazing process.

The Time – Temperature Relationship

The time – temperature relationship is the first step in achieving a good quality product. The thermal energy provided by the furnace serves a number of functions. The product must first be heated to a temperature at which the surface oxides of the base metal can be reduced. For 300 series stainless steel, this is typically above 1900^{o}F in a high Hydrogen atmosphere. Additional energy is needed to melt the filler metal and form an alloy with the base metal. In the case of Copper and 300 series stainless, the brazing temperature range is between 2050^{o}F and 2090^{o}F. This temperature depends on the form and composition of the filler metal; as well as other operational conditions such as belt speed, part loading, etc. The cooling rate of the part is also important to the potential for distortion and warping. The optimal cooling rate is a strong function of the part geometry and the way in which the parts are loaded onto the belt.

The time – temperature relationship is verified by thermally profiling the furnace. This is done by attaching thermocouples to a standard part and recording the temperature and position of the part as it travels through the furnace.

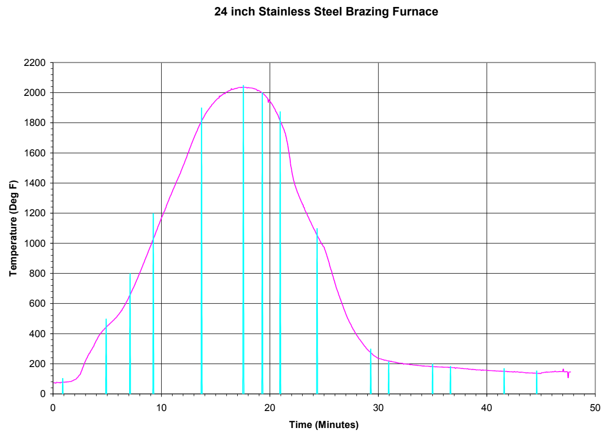

Figure 3. Example of a Temperature Profile

The temperature profile is a very important tool in determining the optimal brazing process as well as troubleshooting future processing issues. A good baseline profile should be kept on hand in the event of a processing problem. By comparing the baseline profile to a profile taken at the time of the problem, the time – temperature relationship can be identified or eliminated as one of the contributors to the processing issue.

Atmosphere Control

The key to successfully achieving a good brazed connection is surface preparation. The presence of contaminants or oxides prevents the filler metal from coming into contact with one of the surfaces to be brazed. In the case of minor oxidation, the pores of the surfaces to be brazed will be sealed by the oxide. This prevents the capillary action and, ultimately, the brazing from occurring. Hence, the initial cleanliness of the surfaces to be brazed is extremely important, but it is equally important that the cleanliness of these surfaces be maintained during the brazing process.

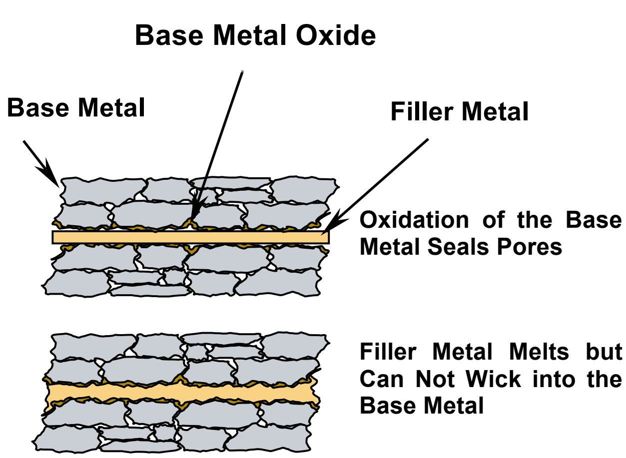

Figure 4. Effect of Oxidation on Brazing

level of clea inless steel components than brazing steel components. The Chromium in the stainless steel forms a much more stable oxide at a much lower Oxygen level than Iron.

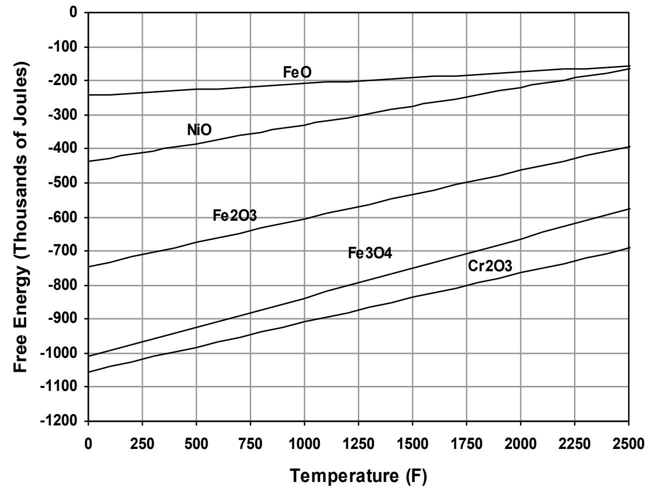

Figure 5. Oxide Stability

The oxides present on the surface must be reduced prior to the part reaching the melting temperature of the filler metal. The reduction is typically achieved through a reaction of Hydrogen with the Oxygen present in the oxide to form water vapor.

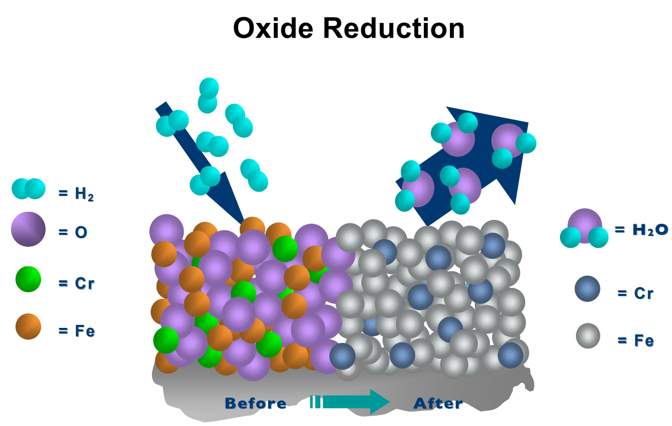

Figure 6. Oxide Reduction Mechanism

The presence of too much water vapor or Oxygen in the system will prevent the reaction from proceeding. The dew point is used to determine the amount of water vapor in the system at given conditions. The dew point is the temperature at which an amount of water vapor in the system will saturate the atmosphere. The typical dew point required for brazing stainless steel joints in 100% Hydrogen is –50^{o} F.

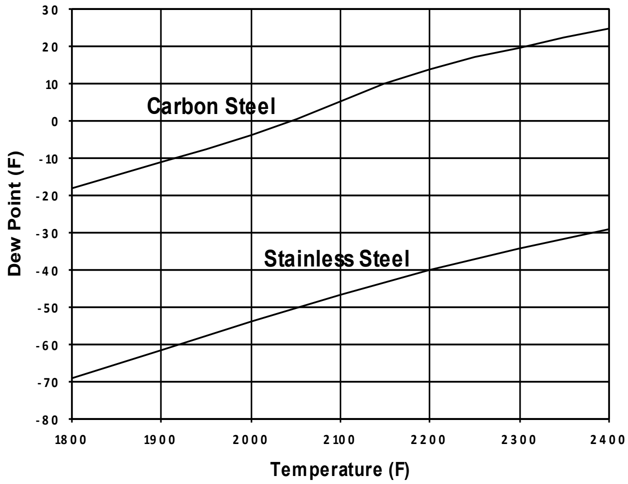

Figure 7. Dew Point Requirements

Producing a brazing atmosphere that is conducive for brazing stainless steel is common in straight through continuous belt furnaces. Techniques such as curtain boxes, directional flow control, proper stacking and door opening design, along with quality manufacturing practices have allowed products that were once only brazed in vacuum to be brazed in a straight through, continuous belt furnace containing a Hydrogen atmosphere. It is not uncommon to see dew points below -60°F in these furnaces.

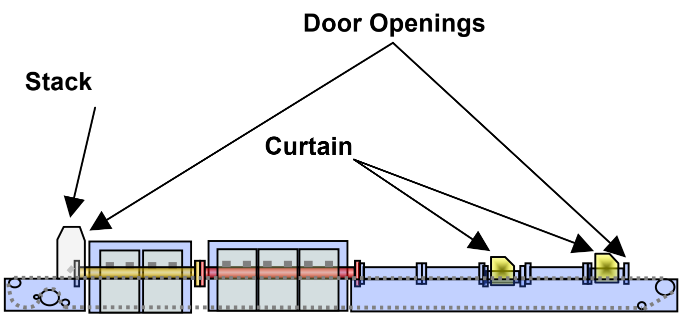

Figure 8. Stainless Steel Brazing Furnace Schematic

The door openings of a furnace are some of the most important areas when considering the furnace atmosphere. A sufficient amount of atmosphere must exit the door to avoid air infiltration into the furnace. The amount of flow needed through the open doors is directly related to the total area of the cross sectional opening of the door. To minimize the amount of atmosphere needed to prevent air infiltration, the doors at the entrance and exit of the furnace should be positioned to allow the highest point of the part to pass under the door with approximately one half inch of clearance.

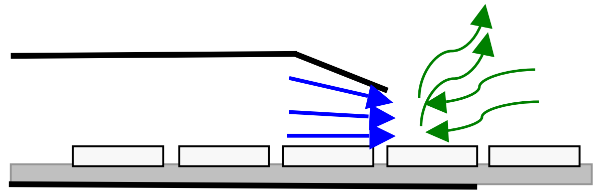

Figure 9. Flow Exiting the Door Prevents Air Infiltration.

When installing the brazing furnace, it is very important to consider the type of stacking design that will be used to vent the effluent from the furnace hoods to the outside. The difference in pressure from the outside to the inside will have a direct influence on the flow through the stack. Down drafts are common ventilation problems. If the stacks are directly coupled to the furnace hoods, these down drafts may be strong enough to overcome the outward flow of the furnace atmosphere and force air into the furnace. It is always a good practice to have a separation between the furnace hood and the stacks. This allows air exchange between the inner building and the outside, without influencing the atmosphere flow of the furnace.

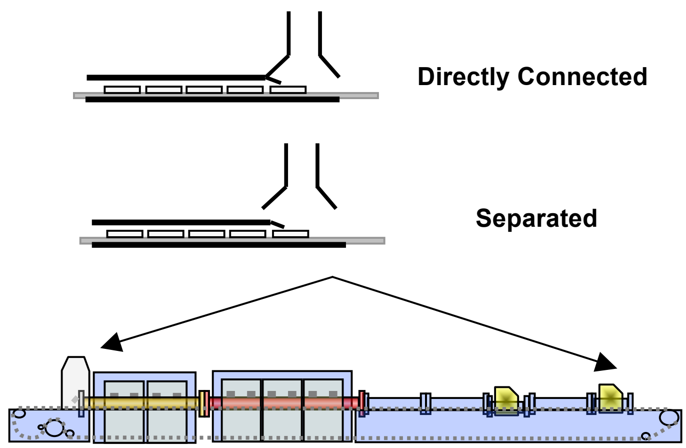

Figure 10. Furnace Stacking

Attention must also be given to the surroundings of a furnace. Large open doors, exhaust fans, and personal fans are just a few examples of outside influences that can cause issues with a furnace.

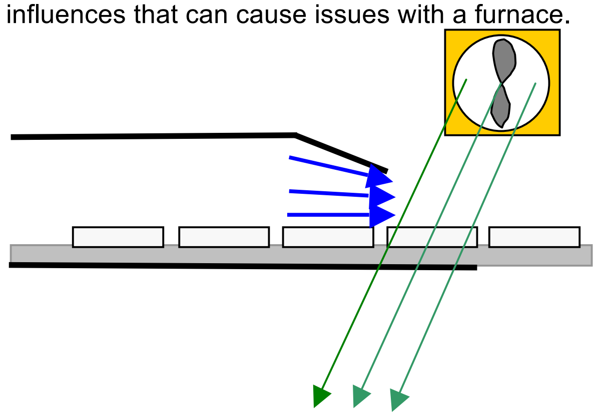

Figure 11. Outside Influences May Cause Air Infiltration

The strong air currents that are often generated by these items are frequently the source of air that is getting into the furnace. Whenever possible, fans and building drafts should be kept away from the doors of the furnace. In cases where this can not be avoided, an increase in the amount of atmosphere flow through the furnace can sometimes help.

Maintaining the atmosphere integrity over the life of a furnace requires some simple routine maintenance. Operators should visually check the condition of the curtains on a daily basis. The curtains inside of the curtain boxes act as mechanical barriers to flow. The need for atmosphere flow is greatly reduced in the rear section of the furnace if the curtains are maintained at a level that is in contact with the belt. This will have a direct impact on the operating cost of the furnace.

The curtains also help with the directionality of the atmosphere flow. Since the path of least resistance is now toward the front of the furnace, the flow of the atmosphere will tend to travel forward. The warm atmosphere helps to heat the incoming parts and flush any volatiles given off during the brazing process.

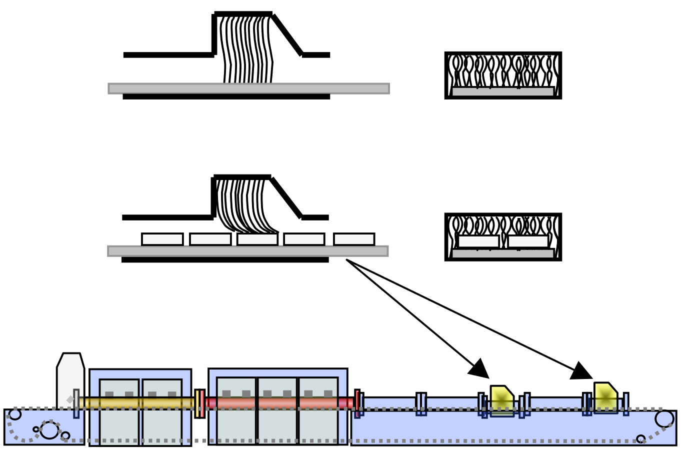

Figure 12. Schematic of Curtains and Curtain Boxes

Over time, the curtains are worn away as the parts pass through them. This leaves a gap in the curtains when parts are not present; resulting in air infiltration into the rear of the furnace. The curtains should be adjusted down to close these gaps and re-establish contact with the floor of the opening across the width of the curtain box.

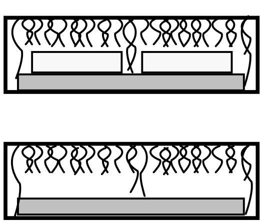

Figure 13. Effect of Curtain Wear

Conclusion

A continuous, controlled atmosphere furnace is the most economical means for brazing stainless steel components in larger volumes. The time – temperature – atmosphere relationships provided by these furnaces are now capable of providing a brazing environment that was once only possible in a vacuum furnace. The current technology uses Hydrogen to reduce the oxides on the surface of the base metal to allow good capillary flow of the melted filler metal. Through innovative designs and simple routine maintenance, these furnaces are capable of producing products at a lower capital and operating cost.

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