Visual Observations of Liquid Filler Metal Flow Through a Braze Gap

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Introduction

A visualization technique has been developed to examine braze metal flow and fillet formation through a controlled braze joint gap between similar and dissimilar base materials. Braze flow behavior is typically characterized by area-of-spread testing or post-braze sample cross-sectioning to determine pertinent reactions and structural features that define acceptable wetting and fill properties for given joint designs and materials and processing conditions. Realistic flow rates are difficult to verify using these traditional approaches, which generally fail to represent transient flow conditions through a braze joint. Quantification of this flow behavior is necessary to fully understand and control the fundamental physics behind the flow process, including fillet formation, braze metal run-out, and related capillary flow characteristics. A visualization system has been designed to better capture these dynamic flow properties under representative brazing conditions. The technique is also applicable to similar capillary flow processes, such as soldering, casting, injection molding, and encapsulation.

Procedure

The system consists of a fully integrated, digital, and closed loop control thermal station. Specimens are resistively heated at programmed heating and cooling rates, including steady-state soaks. Thermocouples provide feedback control and monitoring of sample temperatures. Surface temperature distributions can also be measured by infrared pyrometry. A controlled atmosphere (vacuum, inert, or reducing) envelopes the test specimen to promote the necessary metallurgical reactions for braze metal wetting and flow. The test specimen incorporates typical joint design features for brazing applications (gap width, length, filler metal placement, reservoir for braze overflow, and related surface features). The filler metal is positioned along one side of the braze gap and allowed to flow to the opposing free surface at the other end of the joint. The base materials are fabricated with a sharp outer edge along the gap length to minimize edge effects as the liquid filler metal front advances through the gap. When appropriate, braze stop-off can also be applied near this edge to limit braze run-out to the outer surfaces.

Results, Discussion, and Conclusions

The advancement of filler metal flow through the braze gap and fillet formation are imaged with a high-speed, high-magnification video camera that is aligned looking through the gap. Since the test sample is locally heated, the camera is positioned relatively close to the braze flow region and can capture the entire gap filling, fillet formation, and solidification event. Image analysis software is used to extract quantitative data from the stored video images. The video system has the ability to capture up to 8000 frames at a maximum speed of 2000 frames per second. The sampling rate is adjusted to obtain the desired sampling time.

The apparatus provides a very accessible approach for gathering dynamic braze wetting and flow data. An affordable, bench-top system can be designed to satisfy the same test objectives in a production environment. We will describe the general principles behind the test method and discuss test procedures and sample design considerations. Thermal characterization of heated specimens prior to braze flow testing is particularly critical to assure realistic, uniform temperature distributions along the flow region during testing. Once these baseline conditions are established, fundamental braze flow behavior can be consistently observed and measured. Examples are given for both transient and steady-state equilibrium flow conditions for metal-metal joints (Figure 1). Flow velocities, advancing braze front through the gap, fillet formation, contact angles, and braze run-out data are presented and compared to standard braze processing. The work was conducted at Sandia National Laboratories, a multiprogram laboratory operated by Sandia Corporation, a Lockheed Martin Company, for the United States Department of Energy under Contract DE-AC04-94AL85000.

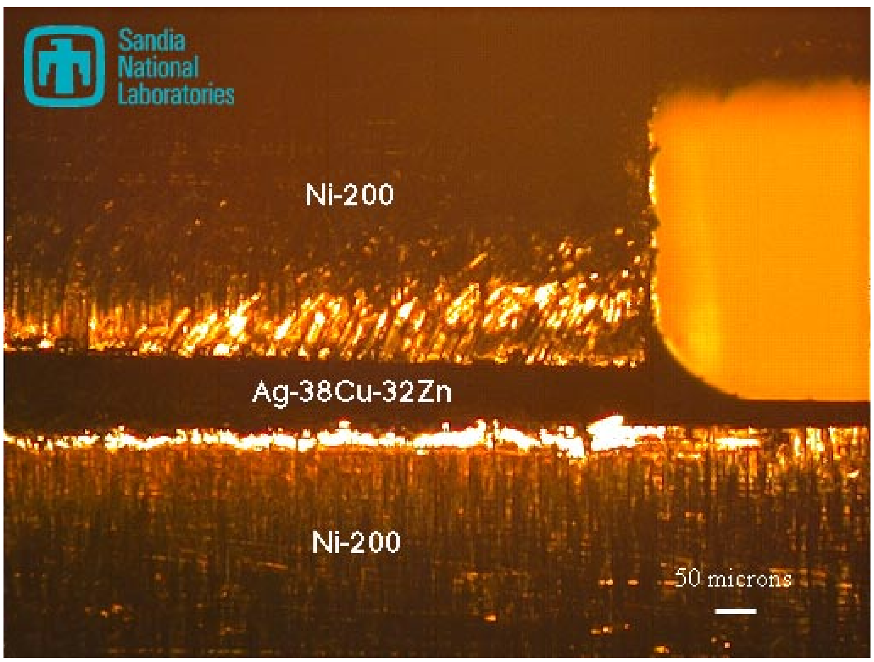

Figure 1. Braze flow transient image for commercially pure Nickel 200 base metal and an AWS BAg-20 filler metal processed at approximately 825°C under an argon-3% hydrogen gas cover.