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USING ENERGY DISPERSIVE SPECTROSCOPY (EDS) FOR A STAINLESS STEEL-BRASS WELDING INTERFACE CHARACTERISATION

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Abstract
A welded sample of SS-brass was polished and the resulting mirror-like surface was analysed (without chemical etching) to determine the main element's variation. The gradual elemental transition indicated a good metallurgical bond. The elemental maps (e.g. Fe, Cr and Ni for stainless steel and Cu and Zn for brass) showed a gradient rather than an abrupt cutoff, which often indicates solid-state diffusion and a potentially coherent or semi-coherent interface. A smooth transition area usually indicates limited intermetallic formation, which is favourable for mechanical strength and interface stability. Zinc penetration into stainless steel suggests interdiffusion to some extent, but excessive zinc at high temperatures could cause porosity or weaken the steel matrix. As the elemental distribution maps showed a continuous and graded elemental transition with no visible cracking or voids, the interface was likely to exhibit coherent or semi-coherent bonding, which is consistent with controlled brazing and suggests good mechanical integrity.

Keywords*: stainless steel-brass; welding interface; EDS; TIG.*

1. INTRODUCTION

Welding stainless steel to brass is challenging due to the significant differences in their chemical, thermal and physical properties. The key issues are: different melting points (stainless steel: ~1400–1450°C; brass: ~900–940°C depending on the composition), meaning that in this case, the brass can melt or vaporize (especially zinc) before the stainless steel even begins to melt; thermal expansion, whereby brass expands more than stainless steel when heated, leading to stress and warping at the joint; electrochemical compatibility, as dissimilar metals can create galvanic corrosion, especially in humid or marine environments.

Analyzing the chemical composition of alloys is essential for determining the elemental composition of metallic materials, as well as assessing their quality, performance and compatibility. One of the most widely used methods is optical emission spectrometry (OES), which enables the rapid and accurate analysis of metallic elements by measuring the radiation emitted by electrically excited atoms [1]. Inductively coupled plasma mass spectrometry (ICP-MS) is often used for superior accuracy and sensitivity, as it is capable of detecting trace elements at ppm or even ppb levels [2,3]. X-ray fluorescence spectrometry (XRF) is also an effective, non-destructive method for the qualitative and quantitative identification of elements in a variety of alloys, and is commonly used in quality control [4]. For local, small-scale analysis, energy dispersive X-ray spectroscopy (EDS), which is integrated into scanning electron microscopes (SEM), provides information about the distribution and chemical nature of elements in cross-

sections or metal surfaces [5, 6]. Depending on the analysis requirements — such as accuracy, sensitivity, spatial localisation, or non-destructive character — each technique has its advantages and limitations. In practice, they are often used as complementary techniques to provide a full characterisation of alloys.

EDS (energy dispersive spectroscopy) is a semi-quantitative method of localised chemical analysis based on the detection of X-rays emitted by excited atoms in the electron beam of the SEM. The main advantages of the technique are rapid elemental identification and spatial mapping. It enables linear or surface analysis and is ideal for elements with $Z > 5$ (from boron upwards). However, the main accuracy limitations derive from the limited spatial resolution (~1-2 μm), which is greater than the thickness of the thermally affected zone in some cases. Additionally, the detection of light elements ($Z < 10$; e.g. C and O) is less accurate, and spectral line interference (e.g. Cr and Mn) can occur. The results are semi-quantitative; for accurate values, WDS analysis or wet chemical methods are required.

2. EXPERIMENTAL

The experimental welding was performed using a modern arc welding machine. The process involved electric welding in a shielding gas environment with a non-fusible electrode (TIG 316L) for stainless steel. For the TIG procedure, a welding machine equipped with inverter technology and high-frequency arc initiation was used. These features ensure a stable and controlled arc, which is essential for obtaining a homogeneous weld bead. TIG 316L rod was used for welding 304L stainless steel, containing a high percentage of Cr (18%) and Ni (12%), as well as additions of Mo and Cu, to ensure increased corrosion resistance and good performance at high temperatures. Surface chemical analysis was performed using two established modes of analysis: Line and Mapping.

3. RESULTS AND DISCUSSION

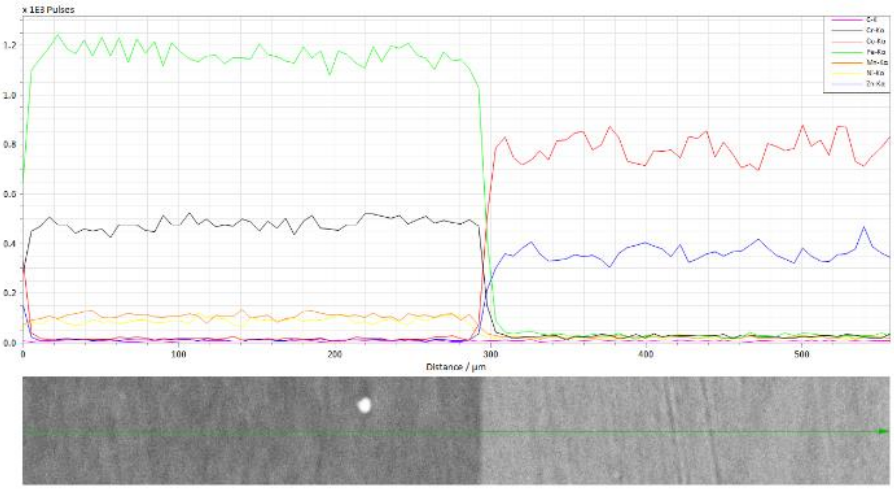
A clear transition area separates the two materials. The central area shows a gradual change in composition, indicating that diffusion between the materials occurred during welding. No large porosities or cracks were visible in the image, suggesting good weld quality. Figure 1(b) shows the linear distribution of elements across the interface.

Chromium (Cr) and nickel (Ni) predominantly appear on the stainless-steel side (left), gradually decreasing towards the right, while copper (Cu) and zinc (Zn), elements specific to brass, are absent on the left and increase significantly towards the right. There is a region of diffuse overlap where all these elements are present in varying amounts, indicating significant interfacial diffusion.

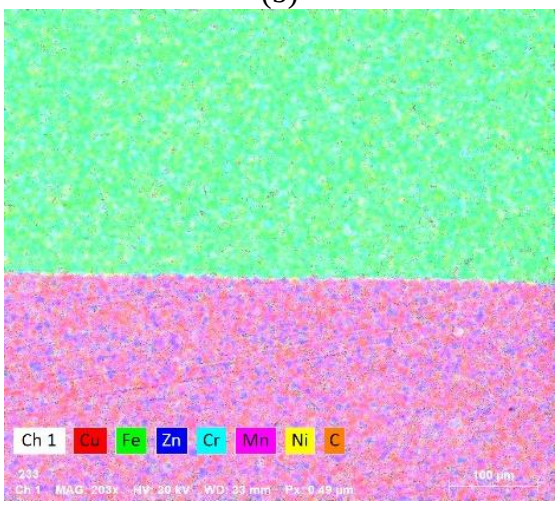
The presence of low levels of Fe or Cr diffusion in brass suggests that sufficient atomic mobility occurred during the brazing or solid-state welding process to lead to atomic-level bonding. A narrow interdiffusion region of less than 10–20 μm is common in well-controlled brazing operations. However, zinc-rich zones at the interface may pose a risk of void formation due to zinc evaporation. Sharp interfaces (i.e. no gradient) could imply weak mechanical bonding or a lack of metallurgical interaction, which would likely lead to delamination under stress. The formation of Cu-Zn-Fe or Cu-Cr intermetallics can embrittle the interface if cooling is too slow or if peak temperatures are too high.

The distribution map for the entire area (Fig. 1c) corroborates the findings of the linear analysis. The elemental maps suggest that there is no significant contamination between the pure zones of each material, with the transition being relatively steep but sharp. A limited mixing zone is indicated, which is most likely the result of the low thermal conductivity of the brass.

(a)



(b)



(c)

Figure 1. Surface images of the welded samples: (a) the area where the chemical composition analysis was performed; (b) the linear distribution of the elements of the welded materials (stainless steel on the left and brass on the right); (c) the distribution of the characteristic elements of the two materials.

The results of the chemical analysis revealed that the elements chromium (Cr) and nickel (Ni) were present in high concentrations on the left (304L stainless steel), decreasing towards the interface. The elements Cu (copper) and Zn (zinc), which are characteristic of brass (on the right), increased significantly beyond the interface. An interfacial diffusion zone is present where all these elements are found together, indicating thermal reactions at the atomic level in the molten zone and partial

mixing between the two materials, probably occurring in the rapid solidification zone of TIG welding.

The lack of sharp variations in the distribution curves indicates good local accuracy of the EDS. However, to accurately assess the exact composition (e.g. atomic percentage or mass percentage), calibration with a standard or ZAF corrections (Z = atomic number, A = absorption, F = fluorescence) is required. Regarding spatial resolution, it is sufficient for the fused zone (visible diffusion of 10–100 μm). For elemental sensitivity, it is effective for Cr, Ni, Cu and Zn (heavy elements with a clear signal). The quantitative accuracy is average without standardisation or mass percentage reporting, but the practical relevance is high as it clearly differentiates between welded zones and diffusion detection.

4. CONCLUSION

- TIG welding between 304L stainless steel and brass resulted in a high-quality joint without any macroscopic defects. Elemental distribution analysis revealed a clearly defined transition zone with bidirectional diffusion of the characteristic elements of each material.
- The EDS technique was suitable for this analysis, which involved observing the elementary transition between two materials in the welded zone. It provided relevant data on the chemical composition and revealed an area of metallurgical mixing, which is essential for characterising welds. The accuracy is adequate for qualitative and semi-quantitative analysis, but complementary techniques would be needed for more accurate data (e.g. WDS, ICP-OES or microanalysis with standards).

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