Microstructure of Induction Brazed Interface between Cobalt-based Alloy and Martensitic Stainless Steel using Ag-Cu-Zn Filler Metal

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Abstract

Erosion shield plate made of Cobalt-based alloy (Stellite Grade 6) was joined to Martensitic stainless steel (SUS410) by induction brazing using Ag-Cu-Zn filler alloy at 650-790 °C and investigated. The interfacial microstructures across the brazed joint were comprehensively evaluated. The intermetallic phases were founded in thin layer and phase transformation principle was used for explanations. This could be beneficial to the joining of the sandwich structure in the last state stream turbine.

Keywords*: Cobalt alloy, Martensitic stainless steel, Ag-Cu-Zn filler metal, Induction brazing*

1 Introduction

Turbine blades of last stage steam turbine engine were made of martensitic stainless steel (SUS410). This material [1] has good high temperature properties for elevated temperature suitable for steam turbine engine such as good creep strength, good erosion resistance, etc. However, high velocity mass of steam condensed in last stage can be destroying to the edge (largest momentum point) of martensitic stainless steel. In order to prevent this, many power plants have developed the erosion shield strip made of Cobalt-based alloy, in this case was Stellite Grade 6 (CO-Cr-W alloy) [2] which was affixed to the edge of martensitic stainless steel. Suitable process for joining martensitic stainless steel and Stellite 6 strip together was the brazing in order to prevent two base metals from melting. In addition, the strips can be removed at the end of life time parts (eroded) and replaced by new parts.

During the last few years, many researchers were focused on the studies of interfacial microstructure behaviors of brazed joint. Recently, TiAl/Steel joint by Vacuum brazing technique [3, 4, 5] were investigated on microstructure and mechanical of these brazed joint. These were founded complex microstructures on the form of intermetallic compound layer of brazed Ag-Cu-Zn filler metal and both substrates in which it caused interface cracking. The induction vacuum brazing technique [6] aimed to study microstructure and kinetic at interfacial of TiAl/Steel joint by Ag-Cu filler metal with effect of brazing time and temperature. It was founded Ti diffused to molten brazed which promote $AlCu_2Ti$ (Brittle phase) intermetallic compounds. Most researches were focused on brazing by vacuum atmosphere. However, for repair of steam turbine attached to the rotor, it’s not possible to create vacuum atmosphere.

This study aimed to investigate the interfacial microstructures of brazed joint of martensitic stainless steel SUS410 and Cobalt-based alloy Stellite 6 strip using Ag-Cu-Zn filler metal in normal atmosphere (air) by induction brazing process. Expectedly, the research outcome was only morphology of the brazed interface after inductively headed by electromagnetic heating.

2 Methodology

2.1 *Brazing Specimens Preparation*

Materials used in experiment were martensitic stainless steel SUS 410 with thickness of 10 mm and cast Cobalt-based alloy Stellite 6 strip with thickness of 2 mm. Chemical compositions of both materials were showed on table 1 and table 2, respectively. Ag-Cu-Zn Braze filler metal was used with chemical composition shown on table 3 and its thickness of 200 mm. This filler metal was specified brazing temperature between 690-850°C. Lap joint was suitable design for actual brazing and control lap distance was 25 mm. Pressure clamping on lap joint was constant controlled at 4 Bar-gage by pneumatic piston. Experimental setup of the brazing joint was prepared as shown in Figure 1.

Table 1: Chemical compositions of martensitic stainless steel SUS 410.

C	Mn	Si	P	S	Cr	Ni
0.15	**1.00**	**1.00**	**0.040**	**0.030**	**13.5**	**0.75**

Table 2: Chemical compositions of cast Cobalt-based alloy Stellite 6 strip.

Co	Cr	W	C	other
Balance	32	6	1.9	Ni, Fe, Si, Mn, Mo

Table 3: Chemical composition of Ag-Cu-Zn Braze Filler Metal.

Ag	Cu	Zn	Other
50.0	**15.0**	**17.0**	**Balance**

2.2 *Induction Controlling*

The induction machine for used in this experiment was LAVA 10 kW and operating frequency range was 90-130 kHz. The induction coil was 5 turns and fixed distance between coil to specimen surface was 10 mm. The induction process parameters for produce heating were consists of 90 seconds for heating time and actual power (induced) of 5 kW.

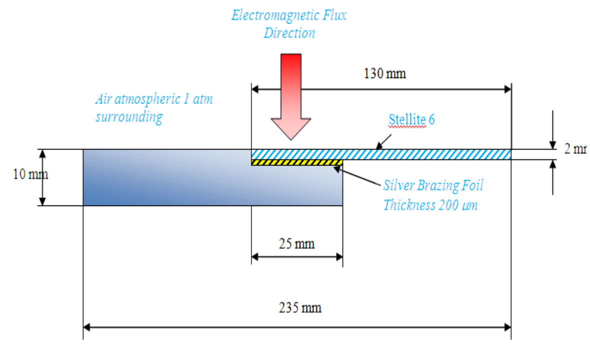

Figure 1: Experimental setup for martensitic stainless steel SUS 410 and Stellite 6 strip using Ag-Cu-Zn filler metal by induction heating.

2.3 *Metallurgy specimen preparation*

Finished brazing specimen was cut parallel to length of piece by cooling fiber cutter. Roughs grinding was performed to 1200 grit by sandpaper followed by final polished by 0.05 micrometer of alumina powder. Specimen was etched by nitric acid (10 % diluted) for 10 minute immersion.

3 Result and Discussion

3.1 *Microstructure of brazed zone*

The microstructure of brazed zone was showed in Figure 2. Four differently phase occurred in the brazed seem between martensitic stainless steel SUS 410 and Cobalt-based alloy Stellite 6 strip. For convenient, they were marked by A, B, C and D, respectively. It should be noted that Zone A, B and C were mixed one another in the brazing seem, While Zone D was continuous reaction layers adjacent to both martensitic stainless steel SUS 410 and Cobalt-based Stellite 6 strip. They showed very thin layers along the brazing interface boundaries.

Referred by Huijie J et al [3], Phase A was identified as Ag-based solid solution in which it was occurred as matrix phase of brazed joint. This phase was desirable for finished braze joint because it could maintain uniformly properties of joint for service. The morphology of phase B was considered as a product from typical eutectic reaction. Therefore, phase B possibly was the decomposition of Ag-Cu eutectic. Although the content of Zn element in raw (not-melted) filler metal had was somewhat high, during induction heating-up to the brazing temperature (800 °C), Zn was evaporated by higher heating rate exerted on joint gap. In this case, the amount of Zn in completed braze seem was expected to be low.

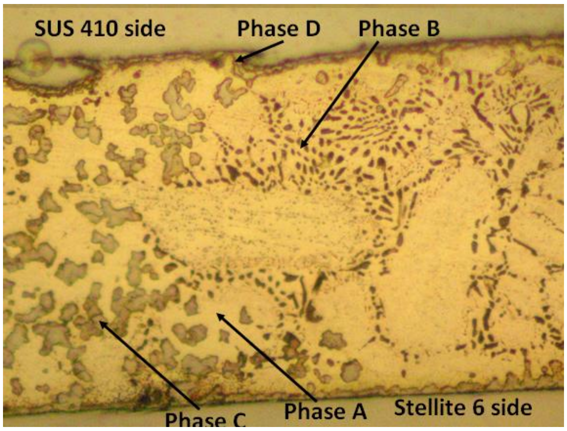

Figure 2: microstructure of brazed seem

Phase C showed granular morphology separated and scattered throughout the brazed seem. This could result in ternary composition (Ag-Cu-Zn) [3]. Phase D formed banding along boundaries of both substrate base metals.

To be note that at the middle area of brazing zone, phase B and phase C were not showed at any point along the brazing seem as can be seen in Figure 3 showed that microstructure at middle seem. More of phase C could be seen as compared to phase B. This was believed to be the effect of pressure exerted on the brazing joint in which it could be considered as point load at the middle and pressure was gradually decreased along the brazing seam. On the other hand, in Figure 4 showed phases at the edge of brazing seam. There were showed all phases expected. Phase B was now again showed in this area. This was believed to be the solidification morphology of filler material under the influent of high frequency of induction as this area was close to the center of the induction coil together with capillary action from the setup of brazing seam.

Phase D (black banding on both interfaces) shown in Figure 2, and Figure 3 cloud be the intermetallic compound [6] resulting from diffusion process along the interface between filler metal and both substrates which were SUS410 and Cobalt-based Alloy Stellite 6.

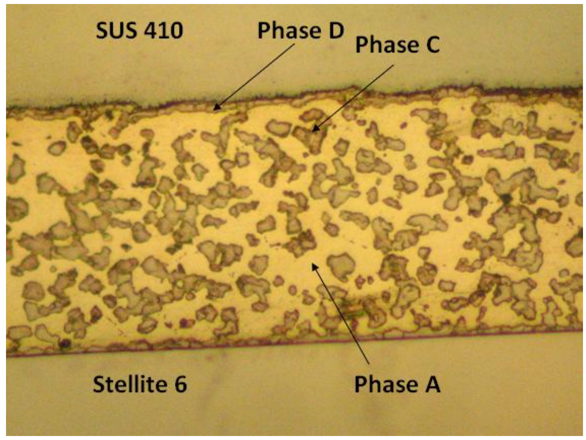

Figure 3: microstructure of Ag-Base Solid Solution matrix (White Phase) granular phases (Black phase), and Banding at middle brazed seem

Figure 4: microstructure of Ag-Base Solid Solution matrix (White Phase) and Eutectic constituent at the edge of brazed seem.

4 Conclusions

From the study of the interfacial microstructures of brazed joint of martensitic stainless steel SUS 410 and Cobalt-based Alloy Stellite 6 strip using Ag-Cu-Zn filler metal at normal atmosphere (air) by induction brazing process, It could be concluded as the following ;

- Four difference phases were occurred in brazed joint by induction heating.
- Ag-Base Solid Solution was matrix of brazed joint.

- Eutectic products of Ag-Cu could be observed
- Granular morphology of (Ag-Cu-Zn) could be observed.
- Intermetallic compound phases were occurred along brazed joint of both SUS410 and Cobalt-based Alloy.

Acknowledgments

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