

Hot corrosion Studies on Gas Tungsten Arc Welded AISI 304 and AISI 4140 Dissimilar Metals

Arivarasu M ^a, Manikandan M ^a, Gokulkumar K ^a, Karthikeyan S ^b, Devendranath
Ramkumar K ^a, Arivazhagan N ^{a,*}

^aSchool of Mechanical and Building Sciences, VIT University, India

^bCenter for Nano Biotechnology, VIT University, India.

*Corresponding author: narivazhagan@vit.ac.in

Telephone Number-0416-220-2221,

Fax: 0416-224-3092, 224-0411.

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Abstract

Hot corrosion of Gas Tungsten Arc Welded (GTAW) AISI 304 and AISI 4140 dissimilar weldment exposed in air as well as molten salt environment of Na₂SO₄-60%V₂O₅ and K₂SO₄-60% NaCl are discussed. Weight gain studies were done for composite specimens containing both weld metal and heat-affected zone. The results indicated that the specimens were more corroded in molten salt environment as compared to air oxidation. Also weld interface of the samples showed more attack than base metals.

1. Introduction

Dissimilar metals are widely used in critical high service temperature applications. Hence studies on their weldments have gained importance in recent past. Generally, combination of low alloy steel and austenitic stainless steel weldments are extensively used for boiler tubing application at elevated temperatures because of its relatively low cost, good weldability and creep resistance [1, 2]. In power plant engineering applications it is necessary to join low alloyed ferritic steels to austenitic chromium–nickel–molybdenum stainless steels. Primary boilers and heat exchangers operate at high temperatures with corrosive environmental conditions that make low–alloy steels and austenitic stainless steels the best choice [3]. Primary boilers and heat exchangers operate at high temperatures with corrosive environmental conditions that make low–alloy steels and austenitic stainless steels the best choice [4]. The role played by chlorides [5], which enter through ingressed air in marine atmospheres, is also important in deciding the degree of corrosion. The role of NaCl in hot corrosion by Na_2SO_4 has been discussed in detail [6, 7]. In this article, the effect of air as well as mixture of Na_2SO_4 –60% V_2O_5 and K_2SO_4 –60% NaCl on hot corrosion behaviour of GTA welded AISI 304 and AISI 4140 specimens are studied. Studies by the authors involving detailed metallurgical and mechanical properties of GTA welded samples are published elsewhere [4].

2. Experimentation

To facilitate the hot corrosion tests, the samples are cut into rectangular pieces (20 × 15 × 5 mm with weld zone in the middle of the specimens and mirror polished.

Immediately, a coating of uniform thickness with 3–5 mg/cm² of salt mixture was applied on the preheated sample (250 °C). On these specimens, cyclic studies were performed in the air as well as molten salt (Na₂SO₄–60%V₂O₅ and K₂SO₄–60% NaCl) for exactly 50 cycles and the duration of each cycle is for 1 h 20 mins in which heating is for one hour at 650 °C in a silicon carbide tube furnace followed by 20 mins of cooling at room temperature. During the corrosion tests, the weight change measurements were taken at the end of each cycle. The spalled scale was also retained during the measurement of the weight change to determine the total rate of corrosion. The samples after corrosion tests are subjected to characterization studies using SEM/EDAX, XRD and EPMA for surface and cross-sectional analysis of the scale.

3. Results and Discussions

Metals and alloys undergo oxidation when exposed at elevated temperatures in air which may be protective or non-protective. Whereas the metals exposed in molten salt environment could accelerate the corrosion rate due to combined form of oxidation, chloridation and sulphidation. The macrographs for hot corroded samples dictate that the weld interface is more prone to hot corrosion (Fig 1.). Fig 2 shows the plot of weight gain per unit area vs function of time (number of cycles). These figures indicate that the weight gain kinetics under air oxidation shows a steady-state parabolic rate law, whereas the molten salt environment is a multi stage weight-gain growth rate. The parabolic rate constants K_p for weldment after exposed in air oxidation, Na₂SO₄–60% V₂O₅ and K₂SO₄–60% NaCl were 2.96, 7.72

and $37.85 \times 10^{-6} \text{ (g}^2 \text{ cm}^{-4} \text{ s}^{-1}\text{)}$ respectively. It is noted that, the hot corrosion in molten salt environment was observed to be more extensive. Moreover, higher corrosion rate is observed during initial hours of study and is mainly attributed to the rapid oxygen pick up by diffusion of oxygen through the molten salt layer and is found to be identical to the results reported by Sidhu and Prakash [8], Tiwari and Prakash [9] during their hot corrosion studies. As revealed by XRD, different phases of various reaction products were formed on the weldments after corrosion cycles. Air oxidation at 650 °C, Fe_2O_3 has been predominated with small amount of NiCr_2O_4 , NiO and FeNi . Hot corrosion under molten salt environment at 650 °C shows that Fe_2O_3 and Cr_2O_3 as the predominant phases and NiCr_2O_4 , $(\text{Cr, Fe})_2\text{O}_3$, FeNi and FeS are observed with low intensity. Many researchers have pointed out that the formation of sodium chromate (Na_2CrO_4) could result from oxy-chloridation even the temperature is lower than the melting point of salt deposits [10–12]. As Na_2CrO_4 is formed, the salt will wet the specimen surface which eventually leads to a mechanism of hot corrosion dominated by molten salt and is further validated by XRD analysis (Fig 3). The analysis of the scale shows predominant Fe_2O_3 with low intensities of Cr_2O_3 , Na_2CrO_4 , SO_3 and MoO_3 . This is in confirmation with past studies on the hot corrosion studies in molten salt environment on boiler tube steel [13].

SEM/EDAX analysis of the corroded sample shows, Fe_2O_3 in the scales of weldment after the corrosion cycles signifies non-protective conditions in Na_2SO_4 –60% V_2O_5 and K_2SO_4 –60% NaCl at 650 °C (Fig 4–6). Corrosion morphology of the weldment exposed in K_2SO_4 –60% NaCl shows that the weld interface is more prone

to formation of fragile scale than base metals. This implies that NaCl plays a vital role in hot corrosion [14–16]. It is observed that, the corrosion rate in K_2SO_4 –60% NaCl environment is higher in magnitude as compared to Na_2SO_4 –60% V_2O_5 and air oxidation environments.

4. Conclusions

The corrosion rates for the investigated electron beam welded dissimilar metals based on the overall weight gains after 50 cycles in all the environments could be arranged in the following order: K_2SO_4 –60% NaCl > Na_2SO_4 –60% V_2O_5 > Air

Dissimilar weldment suffered accelerated hot corrosion in the chloride mixed molten salt environment in the form of intense spalling and sputtering of its scale.

5. References

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List of Figures



Figure .1

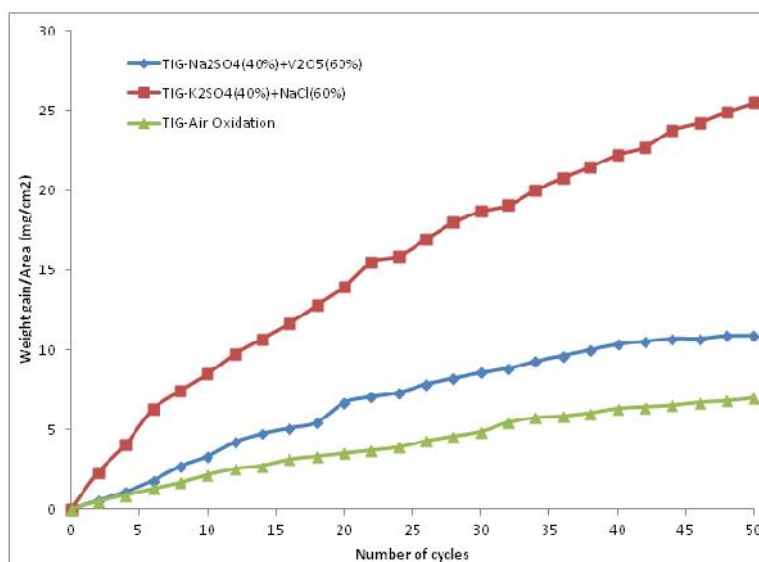


Figure.2

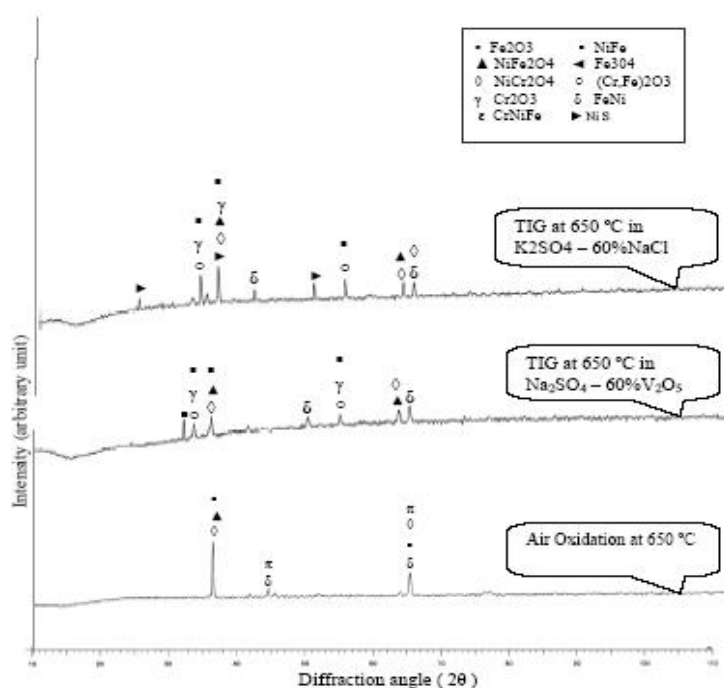


Figure.3

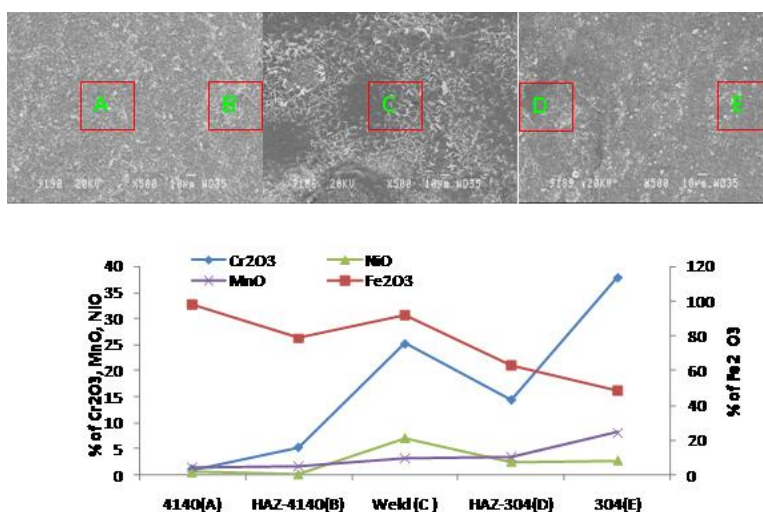


Figure.4

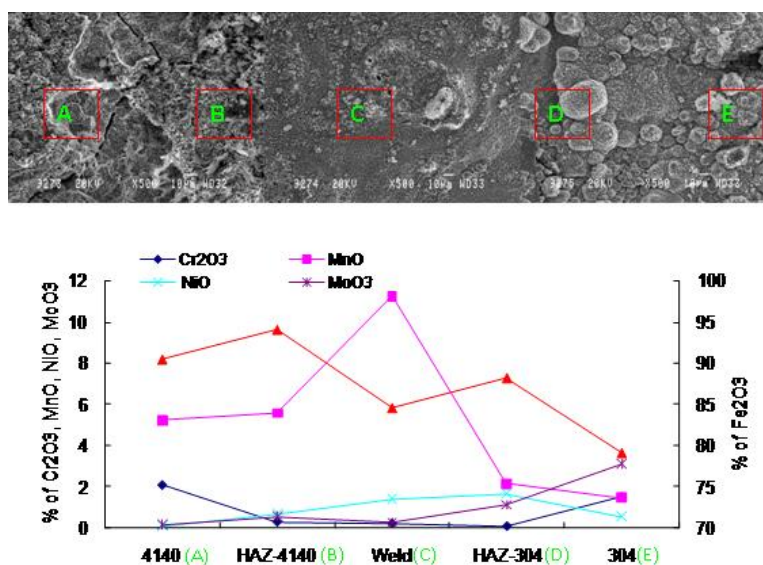


Figure.5

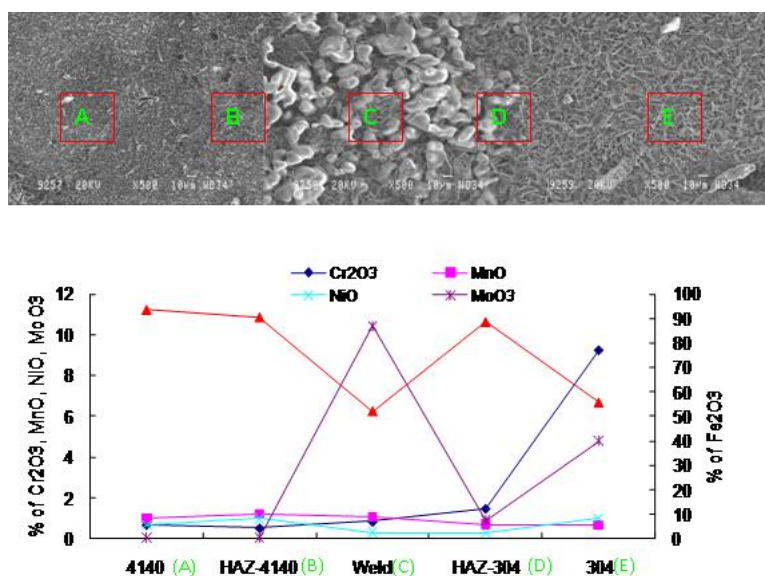


Figure.6

Legends for Figures

Figure. 1 Macrographs dissimilar TIG Welded AISI 4140 and AISI 304 subjected to cyclic hot corrosion at 650 °C. (i) Air oxidation, (ii) $\text{Na}_2\text{SO}_4 + \text{V}_2\text{O}_5$ (60%) and (iii) K_2SO_4 –60% NaCl after 50 cycles.

Figure. 2 Plots of cumulative weight gain (mg/cm²) as a function of time (number of cycles).

Figure. 3 X-Ray diffraction patterns for hot corroded dissimilar TIG weldment of AISI 4140 and AISI 304 exposed in air, $\text{Na}_2\text{SO}_4 + \text{V}_2\text{O}_5$ (60%) and $\text{K}_2\text{SO}_4 + \text{NaCl}$ (60%) at 650° C for 50 cycles.

Figure 4. SEM/EDAX shows the GTAW weldment of AISI 4140 and AISI 304 exposed in air at 650° C after 50 cycles.

Figure 5. SEM/EDAX shows the GTAW weldment of AISI 4140 and AISI 304 exposed in $\text{K}_2\text{SO}_4 + \text{NaCl}$ (60%) at 650° C after 50 cycles.

Figure 6. SEM/EDAX shows the GTAW weldment of AISI 4140 and AISI 304 exposed in $\text{Na}_2\text{SO}_4 + \text{V}_2\text{O}_5$ (60%) at 650 °C after 50 cycles.