*International Journal of Engineering & Technology*, 7 (4) (2018) 4862-4865

International Journal of Engineering & Technology

Website: www.sciencepubco.com/index.php/IJET

doi: 10.14419/ijet.v7i4.27440

**Research paper**

# Effect of temperature on corrosion behavior of dissimilar weldments of Inconel 718 vs ASS 316 with mixer of sodium sulfate and vanadium pentoxide deposit

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## Abstract

The effect of temperature on corrosion behavior of dissimilar weldments of Inconel 718 Vs ASS 316 was investigated in the presence of sodium sulfate ($Na_2SO_4$) and vanadium pentoxide ($V_2O_5$) salt mixer at 950ºC, 1050⁰C and 1150⁰C for 1hr heating followed by 20min cooling in the room temperature. The results indicated that the initial sodium sulfate ($Na_2SO_4$) and vanadium pentoxide ($V_2O_5$) salt coating caused acceleration in oxidation, resulting in the formation of scales developed by the reduction in oxidation rate due to the evaluate of $CO/CO_2$ gas. The weight change of parent metal and weldment were recorded as the temperature. The morphologies of deposits were also analyzed, using SEM.

***Keywords***: *Inconel 718; ASS 316; Sodium Sulfate ($Na_2SO_4$); Vanadium Pentoxide ($V_2O_5$); Oxidation; Corrosion.*

## 1. Introduction

Hot corrosion is the main problem in the present days. The combinations of Inconel 718 and ASS316 can be employed in high temperature including corrosive environments as in the about case of chemical processing types of equipment and oil gasification plants etc. While in addition, a mixture of controlled oxidation resistance and creep energy extends their application to steam dynamo tubing and additional components performing at temperatures up to 550°C in traditional fossil-fuel power plants. Dissimilar metals, generally used in critical high-temperature applications. Hence the reasoning on their weldments has increased importance in the recent events. Usually, the mixture of low alloy steel and austenitic stainless steel weldments are widely used for boiler tubing purpose at raised temperatures because of its comparatively moderate cost, good weldability and creep permanence [1]. Evaporators and fire exchangers perform at raised temperatures with corrosive environmental circumstances that create low-alloy steels, ASS, and their compounds the best choice. Since those steels are different physical, thermal, mechanical, and metallurgical aspects, they are defects during the welding as well as the in-service environment. As differences in the metals of physical, mechanical, and parent metals are involved, asymmetric metal welding is generally more challenging than these metals. Due to chemical composition differentiation and thermal expansion coefficients, the combination of the similar and dissimilar challenging metals. The major problems likely occur during welding is Weld's illegal mergers. The substances used as coatings for the high-temperature surface are consistent, Slow-growing surface oxide, to produce smart surface behaviors [2]. Superalloys are defined as a group of metals exhibiting high strength at raised temperatures. The superalloy class can be additional cracked down according to their base element. Iron-based superalloys (generally heat-resistant stainless steels), cobalt-based superalloys and nickel-based superalloys are the mainstream [3-4].

Inconel 718 (INCONEL718) is a storm strengthened nickel alloy, with an FCC, ‘γ’ matrix, with strengthening γ’ ($Ni_3$ (Al, Ti, Nb)) and γ’’ ($Ni_3Nb$) phases. The use of primarily γ’’ strengthening aids in avoiding Strain Age Cracking, due to the significantly slower aging rate for γ’’. Applications for IN718 include components in liquid-fueled rockets, rings, castings, aero, and land-based turbines and cryogenic containers. Although developed as a “weldable” the alternative to many γ’ reinforced alloys, it does not exhibit the same forgiving welding behavior as INCONEL625, although its mechanical properties exceed those of INCONEL625 [5-6]. The standard aging procedure for alloy 718 consists of couple steps: (i) aging at 720⁰C for 8 hr served by furnace cooling to 620⁰C, and then (ii) aging at 620⁰C for 8hr served by air cooling to room temperature. However, several kinds of heat treatment have been received for maximizing specific features like fracture toughness [7]. Among those possible fusion welding methods, GTA including EB welding is most generally used methods for alloy 718. LB Welding is including being increasingly used. Solid state joining processes like friction welding and friction stir welding appear to be more attractive for joining alloy 718 as they can produce joints free of Nb division and Laves phase [8-9]. Some research has also been under taken into the performance of $Na_2SO_4–V_2O_5$ salt in causing high-temperature oxidation attack. A limited amount of work has also investigated the process of $Na_2SO_4–V_2O_5$ -induced hot corrosion attack. The previous research on pulsed GTA welding was still centering on the study of pulsed wave shapes, the investigation of pulsed GTA welding parameters [10]. The effect of GTA welding on the microstructures or mechanical properties of the weldments. In this study of pulsed GTA welding in the residual force of weldments was limited. By the detailed investigations, the object of this report to study the influence of pulsed GTA welding on the residual stress in austenitic stainless steel weldments and also to try to find a proper explanation of the results [11-12]. Several investigations have designated out that some detrimental defects, such as division of niobium, the performance of inter metallic laves phase including liquation cracking, could explain in either heating zone (HZ) or HAZ of Inconel 718 behind welding. Thus, many kinds of research have concentrated on the different microstructures and errors in FZ and HAZ of the Inconel 718 welds by using various welding methods [13].

## 2. Experimental procedure

The base metals are Inconel 718 plate and ASS 316 was cut by using diamond cutter as proper dimensions. The nominal chemical composition of base metals and filler metal are shown in below tables.

**Table 1:** Nominal Chemical Composition of INCONEL 718

| Element | Ni | Cr | Fe | Mo | Ti | Al | C | Si | S |
|---|---|---|---|---|---|---|---|---|---|
| Wt.% | 53 | 17.5 | Bal | 3.13 | 0.97 | 0.51 | 0.03 | 0.1 | 0.002 |

**Table 2:** Nominal Chemical Composition of ASS 316

| Element | Ni | Cr | Fe | Mn | Ti | P | C | Si | S |
|---|---|---|---|---|---|---|---|---|---|
| Wt.% | 10 | 18 | Bal | 2.0 | 0.80 | 0.04 | 0.08 | 1.0 | 0.03 |

**Table 3:** Conditions of Galvanized Tungsten Arc Welding

| Welding parameters | Peak current (I) | Background current (I) | Speed | Voltage | Flow rate | Polarity | Pulse frequency | Heat input |
|---|---|---|---|---|---|---|---|---|
| Selection | 75 A | 37 A | 149 mm/min | 12 V | 40 lit/min | DCEN | 6 Hz | 271 J/min |

After cleaning the two metals, then welded with GTA welding method and then cut into three pieces by using diamond cutter. Base metals separately and Heat Affected Zone (HAZ) metal separately, the Heat Affected zone piece is called Weldment. These metals are polished with grit size 220, 320 and A46 and to clean 1/0, 2/0, 3/0 and 4-grade papers. Finally, the metals are cloth polishing carried out with 1µm alumina in dry suspension. Initially the pieces are heated 2hr due to air partials were cleared. Apply the salt past ($Na_2SO_4$ + $V_2O_5$) for a weldment and base metals with the brush as shown in fig 1, and these metals are one hour heating 950$^0$C, 1050$^0$C and 1150$^0$C in a furnace followed by twenty minutes cooling at room temperature. And remove the metals from the furnace, measure the weight by using a weighing machine shown in fig. 2, with a sensitivity of 1mg for each cycle. The maximum level was added during the measurement of weight change to determine the total deterioration. The kinetics of hot corrosion analyzing from the weight loss or weight gain measures and the specimens are analyzing for phase identification and XRD surface morphology and composition analysis for Scanning Electron Microscopy/EDAX as shown in fig 3. Repeat the same process 50 cycles at deferent temperatures.

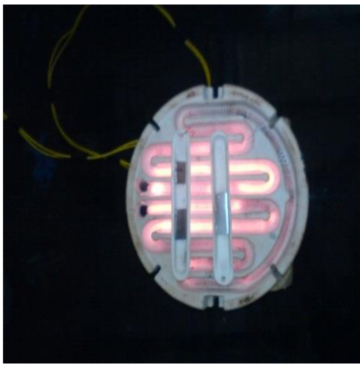


**Fig. 1:** Specimen With Al Boat In Furnace

**Fig. 2:** Weighting Machine.

**Fig. 3:** Scanning Electron Microscope.

**Table:** Specifications of Scanning Electron Microscope

| Sample viewing at normal pressure or high vacuum, with or without conductive coating (Gold or Carbon) |
|---|
| Resolution : 30 nm ( HV SE) |
| Magnification: upto 10,00,000 X |
| Max. sample Dimension : Dia. - 200 mm, Height - 100 mm |
| Sample navigation : 5 axis motorized (X, Y,Z, Tilt and rotation) |
| Imaging mode : SE, BSE and X-ray mapping |
| Image Store : Standard graphic file format like TIF,BMP or JPG with pixel resolution of 3072 X 2304, 16 bit |

## 3. Results and discussions

### 3.1. Visual examination

The oxidation kinetics (mass change vs. Number of cycles) of Inconel718, ASS 316, and GTAW weldment exposed to $Na_2SO_4$+$V_2O_5$ at 950$^0$C and 1050$^0$Cfor 50 cycles for 1hr, oxidize at different temperatures of 950$^o$C and 1050$^0$C are shown in Figure 4 & 5 up to 50 cycles, there was an increased in mass gain for Weldment but base metals are Inconel 718 weight is slowly decreased and ASS316 Weight is Gradually increased due to Oxidation effect. The increasing weight of the samples during the first some cycles are an active form of oxides (the form of $Cr_2O_3$) at the ends and within the open pores due to the spread of the oxidizing species. A further subsequent increase in weight is gradual. Values of the metaphorical rate constant kp were received from the inclination of the straight regression fitted line.

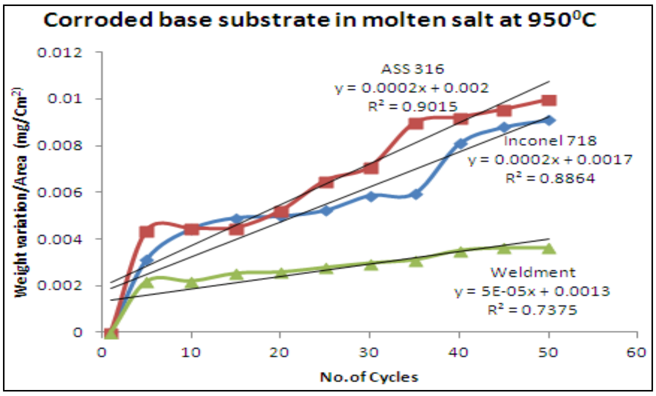



**Fig. 4:** Weight Gain Plot for Different Regions of Inconel718, ASS316, and GTAW Weldment Exposed to $Na_2SO_4+V_2O_5$ at 950⁰C for 50 Cycles.

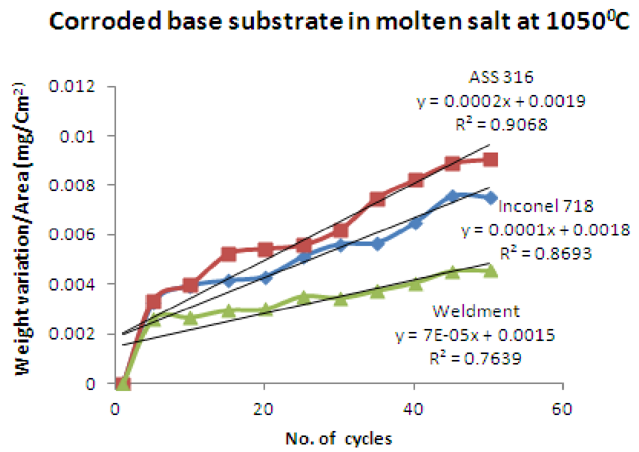



**Fig. 5:** Weight Gain Plot for Different Regions of Inconel718, ASS316, and GTAW Weldment Exposed to $Na_2SO_4+V_2O_5$ at 1050⁰C for 50 Cycles.

The oxidation kinetics (mass change vs. Number of cycles) of Inconel718, ASS 316, and GTAW weldment exposed to $Na_2SO_4+V_2O_5$ at 1150⁰Cfor 50 cycles for 1hr, oxidize at different temperatures of 1150⁰C are shown in Figure 6, up to 50 cycles, there was an increased in mass gain for Weldment and base metals are also increased the weight is Gradually due to Oxidation effect. The increasing weight of the samples during the first some cycles are an active form of oxides (the form of $Cr_2O_3$) at the ends and within the open pores due to the spread of the oxidizing species. These results are indicating that the weldment has good performance as compared to Inconel 718 and ASS 316.

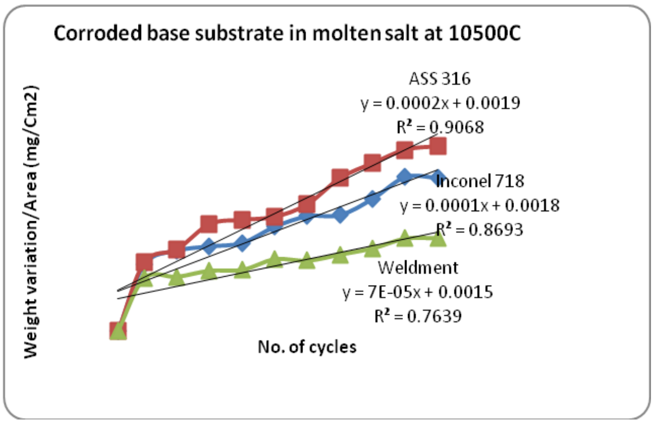
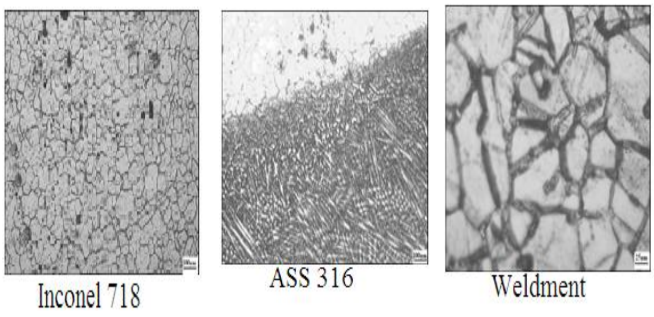


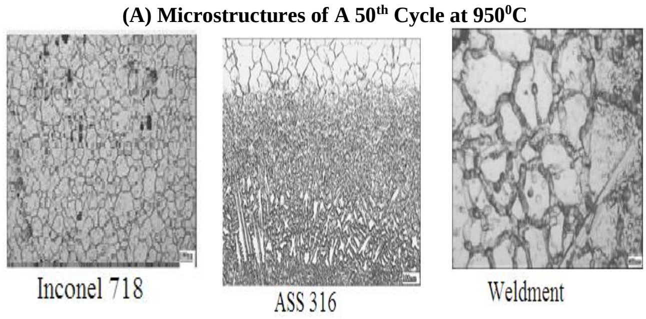

**Fig. 6:** Weight Gain Plot for Different Regions of Inconel718, ASS316, and GTAW Weldment Exposed to $Na_2SO_4+V_2O_5$ at 1150⁰C for 50 Cycles.

### 3.2. Microstructure of evaluation

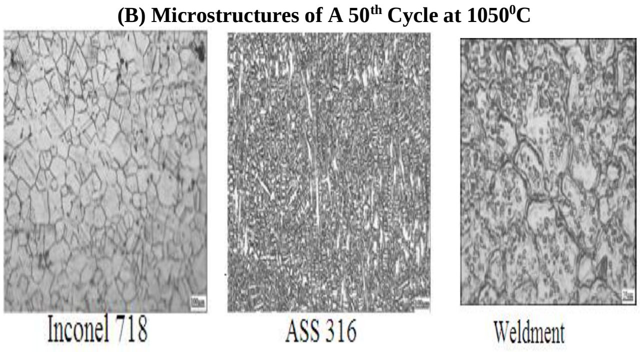
Figures 7(a), (b) and (c) show the SEM of $Na_2So_4$ + $V_2O_5$ coated alloy. The layer of scales is thick, compact and adhered. At 950ᵒC, 1050ᵒC and 1150⁰C the spotted area indicated pitting corrosion and at 1150ᵒC, stress cracking corrosion and badly deterioration was observed.




**(A) Microstructures of A 50th Cycle at 950⁰C**




**(B) Microstructures of A 50th Cycle at 1050⁰C**




**(C) Microstructures of A 50th Cycle at 1150⁰C**

**Fig. 7:** Microstructure of Base Metals and Weldment with Different Temperatures.

Different Regions of Inconel 718, ASS316, GTAW weldment exposed to $Na_2SO_4+V_2O_5$ Salt at 950⁰C,1050⁰C and 1150⁰C Macro morphology of the oxide scale for different regions of GTAW dissimilar weldment after hot corrosion in $Na_2So_4$ +$V_2O_5$ at 950⁰C,1050⁰C and 1150⁰C for 50 cycles is shown in fig 7. Its observations, the curves linearly increases and after few cycles the weight gain almost constant. The oxidation rate small changes in weight may be due to less oxidation of material during that period. There are no changes in the oxidation rate at 1150⁰C but the oxidation rate at 950⁰C and 1050⁰C has been higher but the oxidation rate of weldment is constant.

## 4. Conclusion

The conclusions from the present study on Tungsten inert gas weldment and base metal were subjected have been summarized herewith molten salt ($Na_2SO_4+V_2O_5$) environment. GTA weldments were successfully made in the boiler tube steels with minimum carbide formation. TIG weldment showed the lowest weight gain as compared to unwelded base metal in case of molten salt ($Na_2SO_4+V_2O_5$) environment studies. The corrosion rate is more in the weldment have less quantity of chromium. High-temperature oxidation resistance depends not only on the nature of passive film and is also strongly influenced by the construction of a salt environment and alloys. The find weight gain in welded sample is 0.7557 grams, where as the weight gain in Base metal is

0.9080 grams, Hence Corrosion rate is more in the un welded sample .This may be due to more oxidation of Cr from the base the metal compared to weld metal, because of the weldment contains less quantity of Cr.

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