

Sensitization Resistance of Alloy UNS N08825 after different mill-annealing temperatures and times

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ABSTRACT

Designed for applications in the chemical process industry and later also used in the Oil & Gas industry, Alloy UNS⁽¹⁾ N08825 is a fully austenitic nickel-iron-chromium alloy, stabilized by titanium and with additions of copper and molybdenum. It is well known that the susceptibility of the material to intergranular corrosion in the “as delivered” (mill-annealed) condition, so as after the exposure of the material to intermediate temperatures, is strongly dependent on the chemical composition and additionally on the thermal history.

This work consists on the variation of the nickel content within the UNS chemical composition of Alloy N08825 and the variation of the annealing temperatures and times in order to better understand the influence of these variables on the intergranular corrosion resistance of material from large-scale production. Samples were tested according to ASTM⁽²⁾ G28 method A in the “as delivered” condition and after sensitization heat treatment to verify its intergranular corrosion resistance.

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⁽²⁾ American Society for Testing and Materials (ASTM), West Conshohocken, Pennsylvania

Key words: UNS N08825, Alloy 825, Intergranular corrosion resistance, heat treatment, annealing temperature, ASTM G28 A, sensitization behavior

INTRODUCTION

Designed even before the 1960s for applications in the chemical process industry and later also used in the oil & gas industry, Alloy UNS N08825 is a fully austenitic solid solution nickel-iron-chromium alloy, stabilized by titanium and with additions of copper and molybdenum. Due to its excellent corrosion resistance, especially against stress corrosion cracking in aqueous CO₂ and/or H₂S, it is widely used for clad tubes and separator vessels in oil and gas production equipment.¹

With nickel contents that can vary from 38 to 46 % according to the ASTM B424,² the susceptibility of the material to intergranular corrosion, in the “as delivered” condition, so as after the exposure of the material to intermediate temperatures, is dependent on the chemical composition and additionally on the thermal history.³ Such exposures to intermediate temperatures usually happen when the material is clad to steel, which after the cladding process demands a tempering treatment for the elimination of residual stresses that lead to hardness values that can exceed the specified limits. This tempering heat treatment is usually carried out at temperatures between 600 °C (1112 °F) and 850 °C (1562 °F), depending upon the cladding type,⁴ when Alloy UNS N08825 may undergo microstructural changes and become sensitized.

According to W. Z. Friend,³ when Alloy UNS N08825 in the solution-annealed condition – annealed between 1105 °C (2100 °F) to 1204 °C (2200 °F) – is subjected to a sensitizing heat treatment at intermediate temperatures, chromium-rich carbides M₂₃C₆ precipitate at the grain boundaries and the alloy becomes susceptible to intergranular attack. However, the author suggests that if a stabilizing heat treatment is carried out prior to sensitizing heat treatment, at temperatures where diffusion of chromium is sufficiently rapid to prevent significant chromium depletion in the alloy matrix, the material should be resistant to intergranular attack.

In the literature, hot forming temperatures have also been correlated to the susceptibility of Alloy UNS N08825 to intergranular corrosion.³⁻⁶

According to Raymond,⁶ there are some ways to control the sensitization behavior of Alloy UNS N08825. To precipitate the chromium carbides at a temperature where the diffusion of chromium is rapid enough to eliminate chromium depletion, to reduce the carbon content to a value below the solubility limits and to add other carbide formers like titanium or niobium, which are more energetically favorable to form carbides rather than chromium (and thus lower the carbon atoms available in solution) are some of the suggestions given by the author.

This work consists on the variation of the nickel content within the UNS chemical composition of Alloy N08825 and the variation of the annealing temperatures and times in order to better understand the influence of these both variables on the intergranular corrosion resistance of material from large-scale production.

ASTM G-28 method A⁷ was used as testing method. According to M. H. Brown,⁵ it is one of the principally used test methods for detection of susceptibility to intergranular corrosion, being able to detect the sensitization effects due to the precipitation of M₂₃C₆ type carbides.⁵

EXPERIMENTAL PROCEDURE

To carry out the investigation program, hot rolled sheet material from standard production was used. The main chemical composition of the tested materials is shown in Table 1. All tested sheets were (mill)-annealed in an atmospheric, continuous production furnace at different combinations of annealing temperatures and times as summarized on Table 2.

Table 1

Main chemical composition of tested material in weight %

Heat	Cr	Ni	Fe (bal.)	Cu	Mo	Ti	N	C
A	22.67	38.50	31.41	1.86	3.25	0.73	0.010	0.010
B	22.72	39.27	30.71	1.90	3.08	0.76	0.017	0.012
C	22.60	42.29	27.14	2.30	3.21	0.82	0.013	0.008
UNS N08825	19.5-23.5	38.0-46.0	22.0 min	1.5-3.0	2.5-3.5	0.6-1.2	-	0.05

Table 2

Heat treatment parameters used to anneal alloy UNS N08825 for the time vs temperature investigations

Heat treatment condition	Temperature	Holding time	Cooling Media
	[°C]	[min]	
1	980	24	Air
2	980	36	
3	980	48	
4	1010	12	
5	1010	24	
6	1010	36	
7	1010	48	
8	1040	24	
9	1040	36	
10	1040	48	

Post welding heat treatment (PWHT) is a typical treatment carried out on the material after cladding or welding, which can lead to sensitization mostly due to the precipitation of $M_{23}C_6$ type carbides in the grain boundaries. To study the response of the different (mill)-annealing conditions numbered from 1 to 10 to the post welding heat treatments, corrosion samples were heat-treated in an atmospheric laboratory furnace according to Table 3.

Table 3
Heat treatment parameters used to sensitize the corrosion samples of alloy UNS N08825

Start Temperature	Heating Rate	Holding Temperature	Holding Time	Cooling Rate	End Temperature
[°C]	[°C / h]	[°C]	h	[°C / h]	[°C]
350	30	620	15	30	350

The chosen (simulated)-PWHT consists of a process of inserting the material in the furnace at a temperature of 350 °C (662 °F) and heating the material until it reaches the temperature of 620 °C (1148 °F). The material is then held at this temperature for 15 hours and cooled down to 350 °C (662 °C), when it is taken out of the furnace and air cooled to room temperature. The described heat treatment was chosen since it is known that Alloy UNS N08825 sensitizes after exposure to these temperatures for the described times and therefore the comparison between the heat treatment conditions is possible. The described (simulated)-PWHT is also used by several users as requirement for material qualification.

In order to well understand the microstructural changes that happen in the material as a result of the annealing and (simulated)-PWHT, a thermodynamical analysis of the precipitated phases was made by the use of phase diagrams, which were calculated using the software JMatPro⁽³⁾.

The susceptibility to intergranular attack on alloy UNS N08825 was then determined by the application of ASTM G28 Method A, a ferric sulfate – sulfuric acid test. At least two samples were tested per heat treatment condition with and without sensitization heat treatment.

After the corrosion tests, the corrosion rate was reported and the depth of intergranular corrosion on each sample was measured by means of optical microscopy and images were taken for exemplification.

RESULTS

With the use of the before mentioned numerical simulation software, phase diagrams were calculated for low- and high-Nickel chemical compositions of Alloy UNS N08825 and the zoomed area of interest is

⁽³⁾ Trade name. Java-based Materials Properties.