

A Study of Tribological Behaviour for 321 Austenitic Stainless Steel

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Abstract

The basis of intergranular corrosion in austenitic stainless steel is examined by relating the grain boundary composition to the corrosion properties. Grades 321 is the basic 18/8 austenitic steel stabilized with Titanium. It has high resistance to intergranular corrosion results in a material that maintains its structural integrity. It can withstand temperatures up to 1500°F and resists oxidation up to 1500°F. The substrate was heat treated in the temperature limit of (700-890 O C). After that heated samples have quenched using the water medium and reduce the temperature from approximately 900°C to below 400°C. Water is an effective medium when the go allies to have steel to reach maximum hardness. Sequentially, quenched samples were weighed using weighing machine. Then samples were dipped on the prepared chemical solution as per practice – F intergranular corrosion test. After that intergranular corrosion conducted samples were once again weighted. Comparing the both results of before and after intergranular corrosion tested sample weight, from that sample which was heated up to 890 O C not reduce its weight compare to other heat treated samples. Type 321 Stainless Steel can be easily fabricated, making it an ideal material for food processing equipment and storage for high temperature service and where wear conditions are present. 321 is the grade of choice for applications in the temperature range of up to about 900°C, combining high strength, resistance to scaling and phase stability with resistance to subsequent aqueous corrosion.

Keywords: Intergranular, Corrosion, Fabricated, Austenitic

I. INTRODUCTION

Alloy 321 (UNS S32100) is a titanium stabilized austenitic stainless steel with good general corrosion resistance. It has excellent resistance to intergranular corrosion after exposure to temperatures in the chromium carbide precipitation range of 800 – 1500°F (427 – 816°C). 321 is a titanium stabilised chromium-nickel austenitic stainless steel with good strength and excellent corrosion resistance, as supplied in the annealed condition with a typical brinell hardness of 175. Characterised by high corrosion resistance in general atmospheric corrosive environments it exhibits excellent resistance to most oxidizing agents, general foodstuffs, sterilizing solutions, dyestuffs, most organic chemicals plus a wide variety of inorganic chemicals, also hot petroleum gases, steam combustion gases, nitric acid, and to a lesser extent sulphuric acid.

A. Heat Treatment Process

Heat treating (or heat treatment) is a group of industrial and metalworking processes used to alter the physical, and sometimes chemical, properties of a material. The most common application is metallurgical. Heat treatments are also used in the manufacture of many other materials, such as glass. Heat treatment involves the use of heating or chilling, normally to extreme temperatures, to achieve a desired result such as hardening or softening of a material. Heat treatment techniques include annealing, case hardening, precipitation strengthening, tempering, carburizing, normalizing and quenching. It is noteworthy that while the term heat treatment applies only to processes where the heating and cooling are done for the specific purpose of altering properties intentionally, heating and cooling often occur incidentally during other manufacturing processes such as hot forming or welding.

B. Quenching

Quenching is a process of cooling a metal at a rapid rate. This is most often done to produce a martensite transformation. In ferrous alloys, this will often produce a harder metal, while non-ferrous alloys will usually become softer than normal. To harden by

quenching, a metal (usually steel or cast iron) must be heated above the upper critical temperature and then quickly cooled. Depending on the alloy and other considerations (such as concern for maximum hardness vs. cracking and distortion), cooling may be done with forced air or other gases, (such as nitrogen). Liquids may be used, due to their better thermal conductivity, such as oil, water, a polymer dissolved in water, or a brine. Upon being rapidly cooled, a portion of austenite (dependent on alloy composition) will transform to martensite, a hard, brittle crystalline structure. The quenched hardness of a metal depends on its chemical composition and quenching method. Cooling speeds, from fastest to slowest, go from brine, polymer (i.e. mixtures of water + glycol polymers), fresh water, oil, and forced air. However, quenching a certain steel too fast can result in cracking, which is why high-tensile steels such as AISI 4140 should be quenched in oil, tool steels such as ISO 1.2767 or H13 hot work tool steel should be quenched in forced air, and low alloy or medium-tensile steels such as XK1320 or AISI 1040 should be quenched in brine.



Fig. 1.1 Quenching

Quench hardening is a mechanical process in which steel and cast iron alloys are strengthened and hardened. These metals consist of ferrous metals and alloys. This is done by heating the material to a certain temperature, depending on the material. This produces a harder material by either surface hardening or through-hardening varying on the rate at which the material is cooled. The material is then often tempered to reduce the brittleness that may increase from the quench hardening process. Items that may be quenched include gears, shafts, and wear blocks.

C. Corrosion

In a previous post, we discussed the basics of corrosion from the fundamental chemical reaction to the types of environments in which corrosion can occur. As corrosion most often occurs in aqueous environments, we now explore the different types of degradation a metal can experience in such conditions.



Fig. 1.2 Corrosion

II. LITERATURE REVIEW

G.H. Aydogdu, M.K. Aydinol (2006) discussed about the study, double loop electrochemical potentiokinetic reactivation (DLEPR) test was applied to determine the degree of sensitization in 316L type stainless steel, where obtained results were correlated with revealed microstructures after oxalic acid test and weight loss measurements of Streicher and Huey acid tests. Best agreement was provided with test parameters which are 1M H₂SO₄ and 0.005 M KSCN at 0.833 mV/s scan rate at 30°C. Specimens were classified structurally as absence of chromium carbides – step, no single grain completely surrounded by carbides – dual and one or more grain completely surrounded by carbides – ditch, in the as-etched structure, if the I_p:I_a (x100) ratios were obtained to be between 0 and 0.2, 0.2 and 5.0 and 5.0 and higher, respectively. It was also found that at high KSCN concentrations, reactivation current profile skewed to higher potentials where this was attributed the formation of metastable pits, during the anodic scan of the test procedure. Gray, J.C. Turchi, et al (2012) Corrosion rates for temperatures at 600°C and below were found to lose less than 16µm of metal per year. Under these conditions it was found that 347SS corroded at a rate of 30-40% less than 321SS. Spallation of corrosion products occurred at 600°C on 321SS and may be the reason for differing performance. At temperatures of 680°C corrosion rates among both alloys were found to be nearly the same, indicating that no protective barrier is being formed at these

temperatures. Corrosion rates increased exponentially with temperature. Oxidation mechanisms varied with temperature. Corrosion products observed at 500°C were primarily iron oxide on the outer surface with oxides of iron and chromium on the inner surface. Data at 600°C indicated that iron oxide and sodium ferrite were both present in the outer surface, while mixed oxides were again present near the base alloy and oxide interface. Corrosion at 680°C had similar morphology in relation to the 600°C with corrosion rates two orders of magnitude larger. Paris P. Erdogan, et al (2008) the constants of the Paris-Erdogan law (C and n) correctly describe the fatigue crack propagation measured on CT specimens with parallel holes. The fatigue crack propagation characteristics were different at different testing temperatures. Stable crack propagation and/or crack tip blunting can be detected during the hold time at nominally 300°C testing temperature. Following our earlier works and methodology, the determination of the fatigue crack propagation limit or design curves requires further investigations. V Zatkalíková, et al (2020) Intergranular corrosion is very dangerous local corrosion form that often leads to the dislodgment of individual grains and to the intensive negative influence on the mechanical properties of the material. The susceptibility of the austenitic stainless steels to the intergranular corrosion is connected with their exposition in the temperature range of 500-800 °C (“critical temperatures”) and with consequent slow cooling in the air which leads to the precipitation of chromium-rich carbides at the grain boundaries. Bhise, S. and Kain, V. (2012) Austenitic stainless steels like SS 304L are prone to intergranular corrosion (IGC) in boiling nitric acid media. A major cause is sensitisation induced in the heat affected zone of the weldments. Developments in sensitisation resistant materials have lead to the minimisation of degradation due to IGC. Corrosion in nitric acid medium is essentially controlled by oxidising potentials in the transpassive potential regime. The corrosion potential of stainless steel in nitric acid is a function of the concentration of acid, temperature and concentration of specific oxidising ions. In this work, a 'master curve' for the dependence of corrosion rates on the applied potentials was generated for type 304L stainless steel (nitric acid grade) in 6M nitric acid at near boiling (95°C) condition. The master curve was validated by measuring the corrosion rates at 48 h exposure in 6M near boiling nitric acid, in which various oxidising ions had been added. It was illustrated that there is a threshold potential (at transition to transpassivity) above which the non-sensitised stainless steel also undergoes IGC. A methodology for the prediction of corrosion rate has thus been proposed that can be applied to austenitic stainless steels at any given operating condition/component in operating plants where nitric acid media are used as process fluid. The effect of the temperature/area ratio of stainless steel on corrosion has been illustrated. Miha Cekada et al (2002) A series of chromium nitride, carbide and carbonitride coatings were prepared by ion plating using nitrogen and acetylene as reactive gases. The depositions were made at different partial pressures of the reactive gases while maintaining other parameters constant. The crystal structure and microstructure were studied by TEM. The CrN and Cr₂N phases were detected in the chromium 2nitride coatings. In the carbide coatings, orthorhombic Cr₇C₃ and the metastable cubic CrC phase were confirmed. For oxidation studies, the samples were annealed at 750°C. Afterwards, the depth profile was measured by glow discharge optical emission spectrometry(GDOES). A complex diffusion was observed involving out diffusion of nitrogen and segregation of carbon at the substrate-coating interface. Jiang, et al (2012) Chromium carbide (Cr-C) and chromium nitride (Cr-N) powders were compared with a chromium metal powder (Cr-metal) to evaluate their chemical stability in solution. All three powders were exposed in five different synthetic biological solutions of varying pH and chemical composition simulating selected human exposure conditions. Characterization of the powders, using GI-XRD, revealed that the predominant bulk crystalline phases were Cr₇C₃ and Cr₂N for Cr-C and Cr-N respectively. The outermost surface of Cr-C, determined by XPS, contained Cr₇C₃ and Cr₂O₃ and the corresponding measurement on Cr-N revealed Cr₂N and CrN apart from Cr₂O₃. The presence of Cr₂O₃ was verified by XPS investigations of the Cr-metal powder. The mean particle size was similar for Cr-metal and Cr-N but slightly smaller for Cr-C. All three powders were poorly soluble and released very low amounts of chromium (<0.00015µgCr/µg loaded particles) independent on test solution. Óscar Martín et al (2012) The work optimizes the application of electrochemical potentiokinetic reactivation (EPR) to assess the degree of sensitization (DOS) of AISI 316L and compares the large-scale and small-scale EPR with the aim of improving the study of the different zones of AISI 316L welded joints by using an electrochemical mini cell. The optimized EPR allows to discriminate better than the standardized EPR among different DOS. Small-scale EPR shows greater sensitivity to assess the DOS than large-scale EPR: (i) at lower deformation levels; (ii) for shorter sensitization times; (iii) when localized microstructural regeneration is caused by the combined effect of deformation and subsequent sensitization.

III. PROBLEM DESCRIPTION

High Corrosion in flange coupling, Material life time is less due to corrosion, Due to some leakages, Frequently maintenance

IV. CHARACTERIZATION TECHNIQUE

A. Intergranular Corrosion:

Intergranular corrosion (IGC), also known as intergranular attack (IGA), is a form of corrosion where the boundaries of crystallites of the material are more susceptible to corrosion than their insides. Chromium carbides can be precipitated if the stainless steel is sensitized in the temperature range 550–850°C (1020–1560°F), for example during heat treatment or welding.

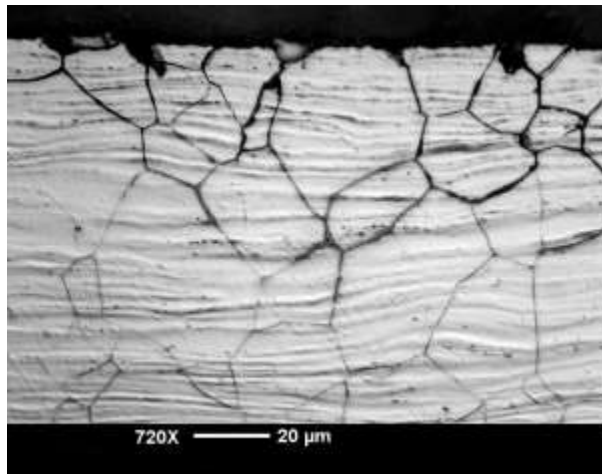


Fig. 4.1: Intergranular Corrosion

B. Microscopic:

Metallography is the study of the microstructure of all types of metallic alloy typically using microscopy. It can be more precisely defined as the scientific discipline of observing and determining the chemical and atomic structure. Metallurgical sample preparation is a key step in performing reliable metallurgical testing.



Fig. 4.2: Microscopic

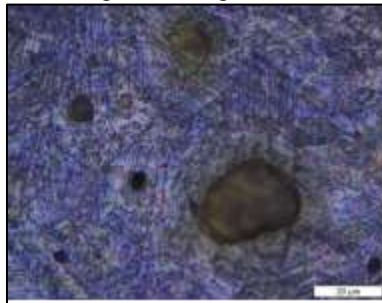


Fig. 4.3: Microscopic HT1

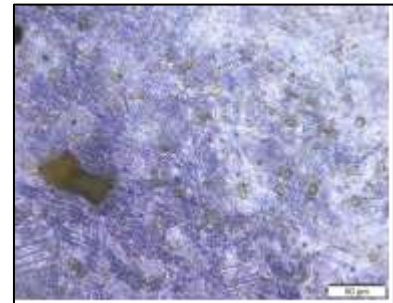


Fig. 4.3: Microscopic NHT1

C. SEM/EDAX:

The EDAX spectrum for manganese-coated sand is illustrated in Mn, Si, and Au signals can be observed; these have been known as the principal elements of freeze-dried samples of manganese-coated sand. A high level of background Au as a support on which the sand electroplated was found in the spectrum. EDAX analysis thus yields indirect evidence for the mechanism of manganese oxide on the surface of manganese-coated sand. The elemental distribution mapping of EDAX for the sample of manganese-coated sand is illustrated. Bright points represent the signal of the manganese element from the solid sample. Manganese was spread over the surface of coated sand. Results indicated that manganese permeates the interior of quartz; in other words, manganese oxide was spread over the surface of manganese-coated sand. Thus, manganese was a constituent part of the solid sample. The direct evidence of the mechanism on coated sand appears. The distribution of element con. EDAX spectrum of manganese-coated sand. EDAX mapping analysis of Mn element for manganese-coated sand. Centration for line scanning of SEM/EDAX, indicates the analysing area of the specific element.

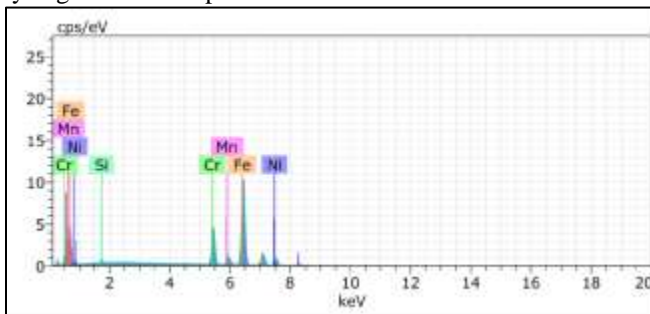


Fig. 4.4: SEM EDAX

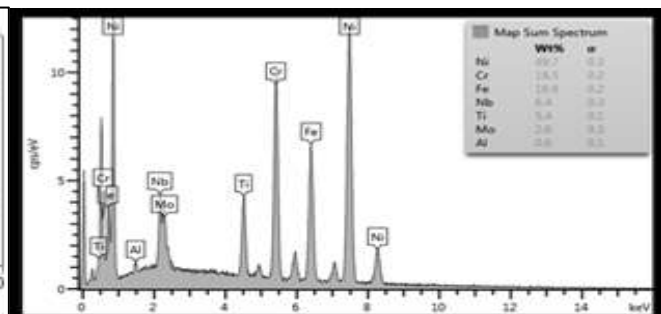


Fig. 4.5: Elemental mapping

D. Elemental Mapping:

Characteristic x-ray intensity is measured relative to lateral position on the sample surface. Variations in x-ray intensity then indicate the relative elemental concentrations across the surface. Maps are recorded using image brightness intensity as a direct function of the local concentration of the element or elements present. Lateral resolution of about 1µm is possible. EDAX elemental mapping allows for all detectable elements to be analysed at the same time, making a fast analysis possible in a variety of settings. Example of typical data output/display of elemental mapping is seen in the following images. A spectrum considering the entire field analysed is also included with the qualitative data. Spectra may also be recreated from a smaller area from the existing map data at a later point in time if required.

V. RESULT AND DISCUSSION

A. Heat Treatment Result

Table - 5.1
Weight Losses in Heat Treatment before and After

BEFORE HT		AFTER HT	
SAMPLE	WEIGHT(g)	SAMPLE	WEIGHT(g)
HT1	6.04	HT1	6.00
HT2	6.30	HT2	6.26
HT3	6.54	HT3	6.52
HT4	6.38	HT4	6.36
HT5	6.21	HT5	6.18

B. Corrosion Testing Result

Table - 5.2
Weight Losses in Ferrous Test

FERROUS TEST			
BEFORE		AFTER	
SAMPLE	WEIGHT(g)	SAMPLE	WEIGHT(g)
HT1	6.04	HT1	6.02
HT2	6.30	HT2	6.27
NHT2	7.00	NHT2	6.99

C. Weight Losses in Strauss Test

Table - 5.3
Weight Losses in Strauss Test

STRAUSS TEST			
BEFORE		AFTER	
SAMPLE	WEIGHT(g)	SAMPLE	WEIGHT(g)
HT3	6.54	HT3	6.52
HT4	6.38	HT4	6.35
NHT1	6.00	NHT1	5.98

VI. CONCLUSION

It is clear that the percentage weight loss of the non-heat treated substrate in is 0.2966%. Whereas the percentage weight loss for 700oC substrates shows less weight loss compared to that of UN heat treated steel. Comparing to the previous result (700oC), for 800oC the weight loss percentage again reducing 0.0383% respectively. Finally the percentage of weight loss for 900oC heat treated steel is 0.0363% respectively. From the above data, it is clear that 900oC shows more resistance to weight loss compared to Non Heat Treated, 700oC and 800oC. Studied about corrosion behaviour of 321austenitic stainless steel. This type of 321 Stainless Steel can be easily fabricated, making it an ideal material for food processing equipment and storage for high temperature service and where wear conditions are present.

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