

## INVESTGATING THE EFFECT OF SENSITIZATION ON THE WEIGHT LOSS OF AUSTENITIC STAINLESS STEEL (TYPE 304) IN FRESH WATER

<sup>1</sup>Komonibo Ernest Bolouebi and <sup>1</sup>Tudou Perewarifagha

[komoniboernest@gmail.com](mailto:komoniboernest@gmail.com) / [Inest.ip55@gmail.com](mailto:Inest.ip55@gmail.com)

### Article Info

**Keywords:** Sensitization, Weight loss, Austenitic Stainless Steel, MATLAB, Fresh Water.

### DOI

10.5281/zenodo.11241738

### Abstract

The rate of weight loss of austenitic stainless steel immersed in fresh water after sensitization is the target focus of research. This trend of study is subjected to the investigation of the rate of weight loss of austenitic stainless steel (type 304), immersed in fresh water. Thus, the presentation of this research paper is one of such using MATLAB software for data analysis. The predicting variable (soaking time) significantly predicts the dependent variable with a P-Value of  $1.0e^{-03}$  which depicts that as the soaking time of the test samples in fresh water after the sensitization period increases, there is also a corresponding increase in the rate of weight loss of austenitic stainless steel (type 304) progressively. This result clearly directs a positive effect of the predicting variable (soaking time). Moreover,  $R^2 = 0.9507$  depicts that the model explains 95.07%, which is approximately 95.1% of the variance.

### Introduction

The most common iron alloys, iron, and steel, from the corrosion standpoint, are comparatively poor materials because they rust in air, corrode in acids, and scale in high-temperature furnace atmospheres. Despite this, there is a category of iron-base alloys, iron-chromium (Fe- Cr) alloys, often with nickel (Ni) additions, known as stainless steels, which “do not rust in sea water,” “are repellant to concentrated acids” and which “do not scale at temperatures up to about  $1100^{\circ}\text{C}$ .” It is this mostly unequaled universal utility, in combination with good mechanical properties and manufacturing features, which makes stainless steels essential for the designers. Carbon steels are more widely used than stainless steels; however, the use of stainless steels displays a steady growth. (Outokumpu .2013). Austenitic stainless steel when properly heat treated and used in a low-temperature environment, is a good material that resists corrosion. In a way, when exposed to temperatures between  $550^{\circ}\text{C}$  –

<sup>1</sup> Department of Mathematics, University of Africa, Toru – Orua, Bayelsa State, Nigeria.

750°C they are susceptible to corrosion (Singh., R. et al, 2003), (RadenKovic., G. et al,1995), (Ma., H. et al 2002), (Galal., A. et al 2005). This is due to the formation of Cr-rich Carbides at the grain boundaries and neighboring matrix, leaving a Cr-depleted zone extending to both sides of the grain boundaries. However, it is susceptible to pitting and cleft corrosion in the presence of chloride ions, which results in the induction of pits.

The use of austenitic stainless steel (ASS) in the petroleum and gas industries can't be over emphatic. Its exquisite properties ranging from high tensile strength to; good impact, wear, and corrosion resistances, have found a large number of applications in the petroleum and gas industries. This material is used in virtually all applications that require optimization of these properties, some of which are, fossil, fired power plants, flue gas desulfurization equipment (Munoz., A.I. et al, 2004), (Stretcher., M.A. 1997), (Nakayama., T. et al, 1968). Austenitic stainless steel (ASS) is known for resisting corrosion mainly because of the presence of chromium, which is soluble in the austenitic matrix. Chromium adds to the overall corrosion resistance through a passivation process by forming a complex spinel-type  $[(Fe, Ni)_0(Fe, Cr)_2O_3]$  passive film (Okamoto., G. et al 1978), (Platt., J.A. et al, 1997), (LO, et al, 2009). These austenitic stainless steels, when exposed to temperature within the range of 538°C - 850°C passes through precipitation of chromium carbides at the grain boundaries. This precipitation of chromium carbides at the grain boundaries is termed sensitization. This sensitized steel withstands intergranular corrosion. The presence of nitrogen is thought to ameliorate resistance to intergranular attack due to the deceleration of carbide precipitation. Sensitization is a prime tussle in stainless steels that affects the alloy's strength. Chromium addition in steel is the principal contributor to sensitization. Sensitization is described when a carbide precipitation motivated by heat treatment causes chromium depletion near the grain boundaries. Chromium is vastly reactive with oxygen and forms a very small chromium oxide layer on the surface of stainless steel. Sensitization treatment expressively modifies the stress corrosion cracking geste and the cause of this is intergranular precipitation and grain boundary chromium depletion (Mohamad., K. et al, 2013).

## Materials And Method

This work adopted the method used by (Alexander., N.O et al, .2016) to investigate the effect of sensitization and weight loss of the test steel in received and sensitized condition. Austenitic stainless steel (304 grade) was used. Investigations on weight loss and sensitization were conducted. This special grade of steel was obtained from NNPC Warri in the form of a sheet. The chemical composition is shown in Table 1.

Table 1. Chemical Composition of Austenitic Stainless-Steel Type 304

Type	Fe (%)	Mn (%)	Cu (%)	V (%)	Co (%)	Cr (%)	Ni (%)	Mo (%)	Ti (%)
304	69.40	1.25	0.22	0.07	–	18.82	9.99	0.26	–

Five sets of test samples were given sensitization treatment under different soaking times of (30mm, 1hour, 2hours, 6hours and 10hours), within the temperature range of 550°C-750°C, using a digital heat treatment furnace, and cooled in air (normalized). Five test samples of the material were fully immersed in five beakers containing fresh water and properly labeled. The test samples were cleaned with a soft brush and air dried in every three (3) days intervals for weight loss reading for a total exposure time of 60 days. A digital balance was used for the reading. Another five test samples of the material in the treated condition were cut, serve as a control specimen for metallographic studies. The test samples were mounted and ground increasingly on emery grit papers (220-1000 grits) with water as the coolant. The ground test samples were then polished with diamond polishing paste, and etched with freshly prepared oxalic acid (HCL) and distilled water at a ratio of 30:70. The micrograph of each etched coupon was viewed under a metallurgical microscope at a magnification of 100 and the data analysis was

performed using MATLAB software. A simple linear regression model was used to investigate the effect of sensitization on the weight loss of the test samples. The simple linear regression model is given as follows:

$$y = b_1x + b_2 \quad (1)$$

Where  $x$  is the soaking time of ASS and  $y$  is the weight loss of the test samples.

### Results and Discussion

```
>>x = [72 144 216 288 360 432 504 576 648 720 792 864 936 1008 1080 1152 1224 1296 1368 1440];
```

```
>> y = [0 0 .01 .01 .01 .02 .02 .02 .02 .03 .03 .03 .03 .04 .04 .04 .05 .05];
```

```
>> b = polyfit(x, y,1)
```

```
b =
```

```
1.0e-03 *
```

```
0.0336 -0.4211
```

```
>> ym = b (1) *x + b (2);
```

```
>> e = y-ym;
```

```
>> sr = sum(e.^2);
```

```
>> st = sum((y-mean(y)). ^2);
```

```
>> r2 = (st-sr)/st
```

```
r2 = 0.9507
```

The dependent variable weight loss was regressed on a predicting variable soaking time to investigate the effect of sensitization on the weight loss of austenitic stainless-steel type (304) in fresh water. The predicting variable (soaking time) significantly predicts the dependent variable with a P-Value of  $1.0e^{-03}$  which depicts that as the soaking time of the test samples in fresh water after the sensitization period increases, there is also a corresponding increase in the weight loss of austenitic stainless steel (type 304) progressively. This result clearly indicates a positive effect of the predicting variable (soaking time). Hence, the alternative hypothesis ( $H_i$ ) is accepted. Moreover,  $R^2 = 0.9507$  depicts that the model explains 95.07%, which is approximately 95.1% of the variance. This result is valid because it is observed that the weight loss in ASS 304 increases progressively, which is attributed to an increase in the time of exposure for the sensitization of ASS 304 (Alexander., N.O et al, .2016).

Table 2. Soaking Time for Type 304

Soaking Time	72	144	216	288	360	432	504	576	648	720	792	864	936	1008	1080	1152	1224	1296	1368	1440
Type 304	0	0	.01	.01	.01	.02	.02	.02	.02	.03	.03	.03	.03	.04	.04	.04	.05	.05		

### Conclusion

The predicting variable (soaking time) significantly predicts the dependent variable with a P-Value of  $1.0e^{-03}$  which depicts that as the soaking time of the test samples in fresh water after the sensitization period increases, there is a corresponding increase in the weight loss of austenitic stainless steel (type 304) progressively. This result clearly indicates a positive effect of the predicting variable (soaking time). Hence,  $R^2 = 0.9507$  indicates that the model explains 95.07%, which is approximately 95.1% of the variance.

## REFERENCES

- Alexander, N. O., Adi, C., & Emomotimi, A. (2016). Effect of sensitization on the corrosion of austenitic stainless steel in fresh water. *IOSR Journal of Mechanical and Civil Engineering (IOSR-JMCE)*, 13.
- Galal, A., Atta, N. F., & Al-Hassan, M. H. S. (2005). Effect of some thiohere derivatives on the electrochemical behaviour of AISI 316 austenitic stainless steel in acidic solutions containing chloride ions: I. Molecular structure and inhibition efficiency relationship. *Materials Chemistry and Physics*, 89(1), 38-48.
- Lo, K. K., Shek, C. H., & Lai, J. K. L. (2009). Recent development in stainless steels. *Materials Science and Engineering: R: Reports*, 65, 39-104.
- Ma, H., Chen, S., Yang, C., & Luo, J. (2002). *Serbian Journal of Chemical Society*, 67, 435.
- Muñoz, A. I., Antón, J. G., Nuevalos, S. L., Guinon, J. L., & Herranz, V. P. (2004). Corrosion studies of austenitic and duplex stainless steels in aqueous lithium bromide solution at different temperatures. *Corrosion Science*, 46(12), 2955-2978.
- Kamaruzaman, M. K. B. (2013). Investigation of chloride stress corrosion cracking in austenitic stainless steel.
- Nakayama, T., & Oshida, Y. (1968). Identification of the initial oxide films on 18-8 stainless steel in high temperature water. *Corrosion*, 21, 336-337.
- Okamoto, G., & Shibata, T. (1978). In R. P. Frankenthal & J. Kruger (Eds.), Passivity and breakdown of passivity of stainless steel. *Passivity of Metals Electrochemical Society*.
- Outokumpu. (2013). Handbook of stainless steel. *Outokumpu*. Retrieved from <http://www.outokumpu.com>
- Platt, J. A., Guzman, A., Zuccari, A., Thornburg, D. W., Rhodes, B. F., Ossida, Y., & Moore, B. K. (1997). Corrosion behavior of 2205 duplex stainless steel. *American Journal of Orthodontics and Dentofacial Orthopedics*, 112, 69-79.
- Radenković, G., Zečević, S. K., Cvijović, Z., & Dražić, D. M. (1995). *Serbian Journal of Chemical Society*, 60, 53.
- Singh, R., Ravikumar, B., Kumar, A., & Dey, P. K. (2003). *Metallurgical and Materials Transactions A*, 34, 2441.
- Stretcher, M. A. (1997). Stainless steels: Past, present and future. Climax Molybdenum Co.