

## The Susceptibility of Austenitic Stainless Steel to Stress Corrosion Cracking in Sodium Chloride

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**Abstract:** - The stress corrosion cracking (SCC) behavior of type 304 austenitic stainless steel in Sodium Chloride (NaCl) was investigated. This was done by exposing the entire specimen to the corrosives (NaCl) at concentrations of 0.3M, 0.5M, 0.7M, and 1M. After every seven days one specimen from each of these corrosives was removed and loaded on a tensometer until fracture. Percentage elongation and percentage reduction in cross sectional area were used to investigate the SCC behavior of the steel.

**Keywords:** - SCC, Sodium Chloride, Austenitic Stainless

### I. INTRODUCTION

Stress-corrosion cracking relates to the environmental degradation of the mechanical Integrity of structural components. Stress-corrosion failures are well known in a variety of industries such as aircraft, petrochemical and underground pipeline transmission systems (Ashby and Jones, 1980).

Stress corrosion cracking (SSC) is the process of brittle crack growth in a normally ductile material exposed to conjoint corrosion and straining of a metal due to residual or applied stresses. In order for a component to undergo SCC a combination of three factors must be in place, a susceptible material, a corrosive environment and an appropriate level of tensile stress (Pipe Line research council, 2006).

An environment having the presence of dissolved elements such as chlorides, carbon dioxide, hydrogen sulphide and oxygen are termed aggressive. In such an environment steel is at high risk from corrosion. Some examples of such environments where processing facilities are found are water and wastewater treatment plants, pulp paper mills, chemical plants, refineries, seawater and brackish water (<http://www.outokumpu.com/46874.epibrw>).

#### 1.2 Significance of study

The evaluation of the susceptibility to cracking is a basic requirement for safe and economical design of many types of equipment since no one corrosive environment causes stress corrosion in all alloys, and most alloys are subject to attack in only a few specific corrosives. The information that will be obtained from this research is expected to be useful for the process chemical industries, petrochemicals and the water engineer.

### II. MATERIALS AND METHODS

#### 2.0 Materials

The material used in this study is a 5mm diameter 304 austenitic stainless steel. The chemical composition and mechanical properties as supplied by the manufacturer are shown in Table 1.0 and 2.0. The tensile specimen were prepared from this material using the lathe machine as shown in Figure 1.0. They were machined from round bars to the required specifications. They were then washed and degreased with acetone. The entire procedure was carried out according to (ASTM, 1989/1990).

Table 1.0 Composition of 304 austenitic stainless steel (wt%)

Element	C	S	Ni	Si	Mo	Mn	Cr	Fe
Wt%	0.06	0.005	8.03	0.45	0.03	1.40	18.95	Bal

Table 2.0 Mechanical properties of Type 304 Austenitic stainless steel at room temperature.(www.aksteel.com)

	UTS Ksi(MPa)	0.2%YS Ksi(MPa)	Elongation %in 2”(50.8mm)	Hardness Rockwell
Type 304	90(621)	42(290)	55	B82

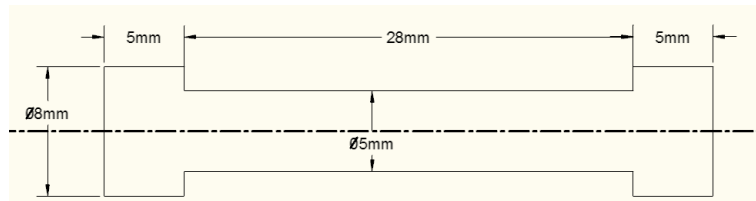


Figure 1.0 Tensile test specimen

2.1 Experimental procedure

All the specimen were immersed at the same time in the experimental media which were sulphuric acid(H<sub>2</sub>SO<sub>4</sub>) and sodium chloride(NaCl)at concentrations of 0.3M,0.5M,0.7M,1M. A specimen was removed from each of these acids after every seven days and the constant extension rate tensile test (CERT) was performed with a tensometer at a strain rate of 0.003cm/sec. As straining continued, the load extension curves were plotted by intermittently depressing the pin against the rotating drum which bore the graph paper. This operation continued until the specimen fractured. The time to fracture was measured with the aid of a stop watch and the percentage reduction in area of each test piece was recorded. This test was carried out according to the methods of (Le and Ghali,1993),(Rondelliet al,1997) and (Yawas,2005).

2.3 Determination of results

To determine the percentage elongation and percentage reduction in cross sectional area the relations 1 and 2 below were used (Afolabieta,2007):

- The percentage elongation (%EF) of the samples was calculated using the relation

$$\%EF = \frac{L - L_0}{L_0} \times 100 \dots\dots\dots(7)$$

Where

*L* = Length after fracture and

*L<sub>0</sub>* = Initial Length

- The percentage reduction in area (%RA) is given by

$$\%RA = \frac{A_0 - A}{A_0} \times 100 \dots\dots\dots(8)$$

Where *A<sub>0</sub>* = Cross sectional area before deformation and

*A* = Cross sectional area after deformation

III. RESULTS

The results of this work are shown in figures 2.0 to 5.0

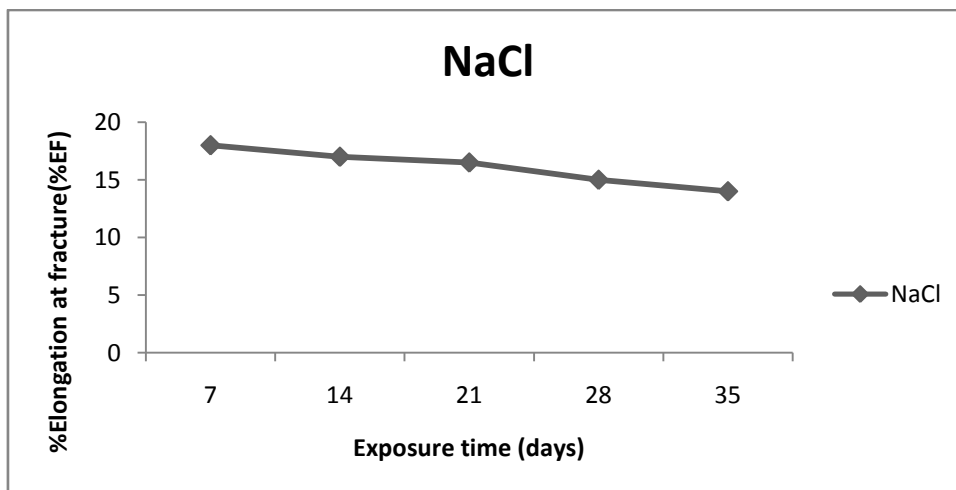


Figure 2.0.Variation of % Elongation to fracture against time for steel immersed in 1M NaCl

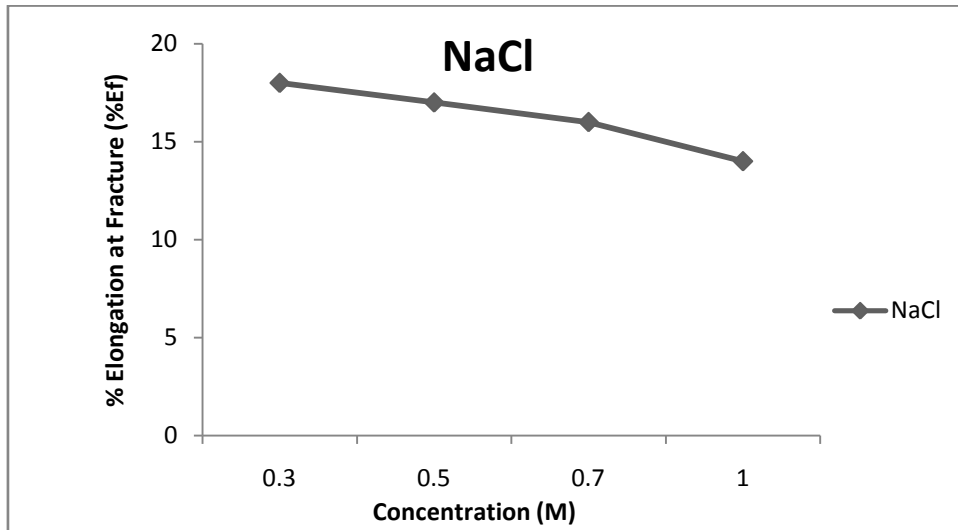


Figure 3.0 Variation of % Elongation to fracture against concentration for steel immersed in NaCl after exposure for 7 days

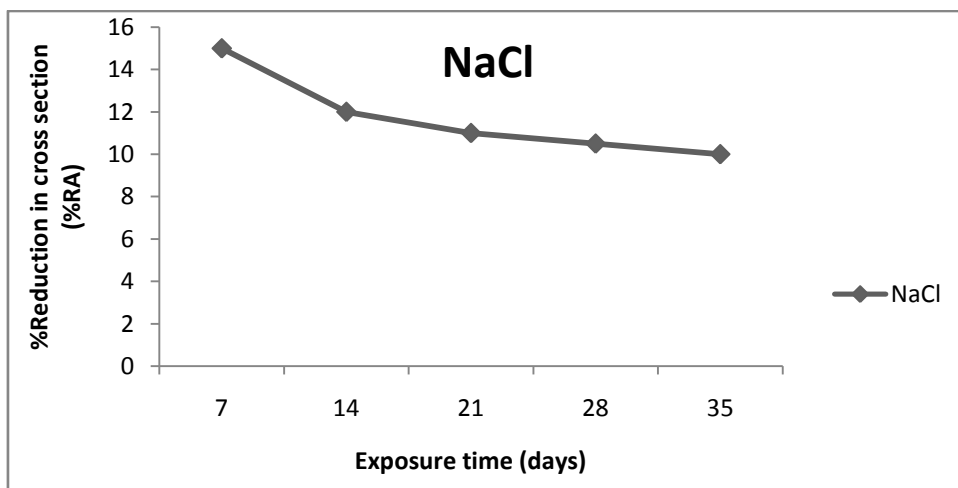


Figure 4.0 Variation of % Reduction in cross sectional area against time for steel immersed in 1M NaCl

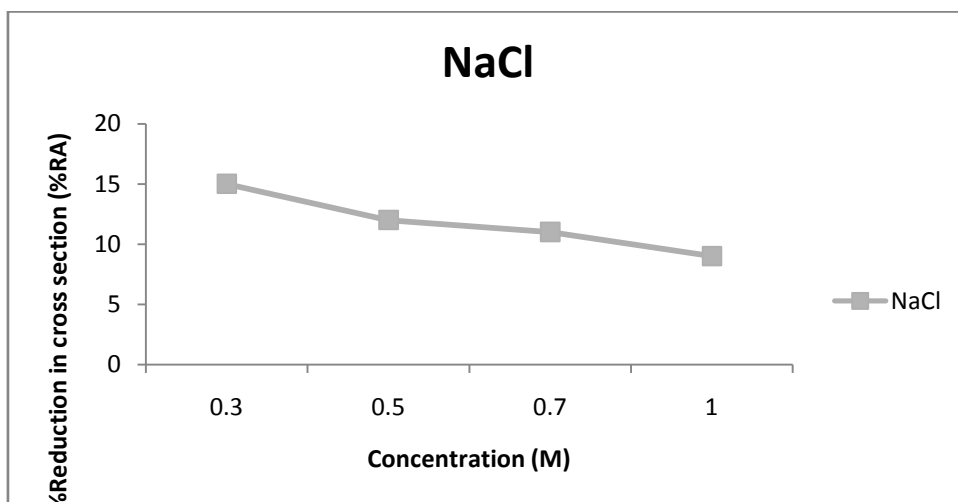


Figure 5.0 Variation of % Reduction in cross sectional area against concentration for steel immersed in NaCl after exposure for 7 days

#### IV. DISCUSSIONS

Figures 2.0,3.0,4.0 and 5.0 show the SCC behaviour of type 304 austenitic stainless steel in NaCl expressed in terms of percentage elongation to fracture and in terms of reduction in cross sectional area. These parameters were derived following the procedures of McIntyre and Dillion(1985) and Beaver and Koch (1994). From the Figures it can be observed that both the percentage elongation and reduction in cross sectional area decreased with increased exposure time and increased concentration, showing a high susceptibility to SCC. This higher susceptibility in NaCl could have been enhanced by the presence of chloride ions in the media. Consequently, the risk of cracking chlorides tends to be most severe for the austenitic steel. Owing to the low nickel and molybdenum contents austenitic stainless steel type 304 is highly susceptible to stress corrosion cracking in chloride solution([www.sandmeyersteel.com/300-series-austenitic.html](http://www.sandmeyersteel.com/300-series-austenitic.html)). High-alloyed austenitic stainless steels with such high contents of nickel above 10% and molybdenum above 2% will offer high resistance to SCC ([www.avestapolarit.com](http://www.avestapolarit.com)).

#### V. CONCLUSIONS

The following conclusions can be drawn on the studies undertaken on SSC of type 304 austenitic stainless steel in dilute H<sub>2</sub>SO<sub>4</sub> and NaCl.

- i. The ductility of Type 304 Austenitic stainless steel decreased with increased exposure time and concentration, an indication that it is susceptible to stress corrosion cracking in NaCl.
- ii. Chloride is a principal agent in environments causing stress corrosion cracking e.g sea water, oil and gas industries
- iii. The mechanism of SCC involves the conjoint action of the environment and the presence of a tensile stress.
- iv. High-alloyed austenitic stainless steels with such high contents of nickel above 10% and molybdenum above 2% will offer high resistance to SCC.

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