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ScienceDirect

Procedia Engineering 213 (2018) 581–588

Procedia Engineering

www.elsevier.com/locate/procedia

7th International Conference on Fatigue Design, Fatigue Design 2017, 29-30 November 2017, Senlis, France

The Effect of Mean Stress on Corrosion Fatigue Life

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Abstract

An experimental investigation of the effect of mean stress on the fatigue life and corrosion fatigue life of cylindrical specimens is presented. Force controlled constant amplitude axial fatigue tests in the regime of 10^5 to 10^7 cycles were conducted for two different environments: in air (without corrosion) and in-situ in a corrosive environment, 0.824% $NaCl$ aqueous solution flow. The test results are assessed with respect to various standard models of mean stress influence on fatigue. The reduction in material fatigue strength due to the corrosion environment is evaluated and the results obtained show that in a low salinity aqueous corrosive solution, the fatigue strength at $4x10^6$ is reduced of a factor of 2 compared to no corrosion tests.

Peer-review under responsibility of the scientific committee of the 7th International Conference on Fatigue Design.

Keywords: Corrosion fatigue; mean stress; fatigue strenght; high cycles fatigue.

1. Introduction

Corrosion fatigue failure is relevant many industrial fields, including the mining industry, where pump components are design to operate under cyclic loading in corrosive environments. The effect of mean stress in such components is of high importance in the design process, as it can significantly influence fatigue strength. Low carbon steel is widely used in the mining industry because its cost and mechanical properties. The main problem with this material is that is affected by environmental conditions and is susceptible to corrosion.

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1877-7058
Peer-review under responsibility of the scientific committee of the 7th International Conference on Fatigue Design.
10.1016/j.proeng.2018.02.053

Many studies have been conducted to understand how corrosive environments affect fatigue life of steel [1] and how the corrosion fatigue strength of the material decreases. Usually, sea water conditions are tested and many data are available in literature relevant to this condition. However, other corrosive environments have received less attention in research and, consequently, less data are available. This study considers corrosion fatigue behavior in a fresh water environment.

The effect of mean stress on fatigue life is a long established research topic. Several models have been proposed to describe its effects of the on the fatigue limit and more generally on material fatigue strength [2-6]. Several comparison of these different methods have been done to understand which of them better predicted the material behavior and many materials, including low alloy steel, have been compared [7,8]. However, the effect of corrosion has not been taken in account in these models. Recently some workers have studied the effect of mean stress on crack propagation in corrosive environment but in these investigations the stress-life approach is not considered. This study aims to understand if mean stress models developed and validated from data for a non-corrosive environment, can fit with low carbon steel experimental data obtained in a fresh water corrosive environment.

2. Material and testing condition

2.1. Material description

The material investigated is a low carbon forged steel (S355J2G3+N). It is a popular type of structural steel, used in a variety of industrial application where both static loading conditions and dynamic loading conditions occur. Its chemical composition and mechanical properties under quasi-static monotonic tension are shown in Table 1 and Table 2.

Table 1.
Chemical composition of S355 (%)

C	Mn	Si	P	S	Cr	Ni	Mo	Al
0.2	1.32	0.34	0.009	0.002	0.01	0.03	0.01	0.042

Table 2.
Mechanical Properties

Young's Module [MPa]	Yield Stress [MPa]	Ultimate Stress [MPa]	Elongation [%]
172	258	500	35.6

2.2. Specimens and testing condition

Fatigue test were carried out in air at room temperature and in 0.842% $NaCl$ corrosive aqueous solution. Both fatigue test in air and in corrosive solution were performed using 6 mm diameter cylindrical specimens, as shown in Figure 1. The specimen geometry was designed according to ASTM E466-07 [9]. The roughness of the gauge length surface was evaluated for each specimen through the arithmetic mean of four different measurements. Values were between Ra=0.095 micron and Ra=0.130 micron.

An environment chamber for corrosion fatigue tests compatible with a servo-hydraulic testing machine was designed and manufactured. The chamber allows a continuous flow of aqueous corrosive environment during the application of dynamic loads. The chamber encases the test specimen so as to allow the corrosion of its central part during the fatigue test, as shown in Figure 2.