FATIGUE CRACK GROWTH IN STEEL IN AIR AND SEA WATER UNDER CONSTANT AMPLITUDE AND RANDOM LOADING

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INTRODUCTION

Fatigue crack propagation data has been accumulated, in recent years, in ever increasing amounts for various materials. However, much of the data comes from tests that are carried out at relatively high stress amplitudes giving crack propagation rates that correspond to short fatigue lives. In addition, most of the published data is obtained at constant amplitude loading which is quite different from the type of loading experienced by actual structures in service conditions. In fixed offshore structures, which have a design life of 30-50 years, most of the fatigue damage is caused by low to medium stress amplitudes \(10^8 \leq N_f \leq 10^{12}\). Very little data is available for this life range and there is a 3-4 log cycle spread between the various S-N design curves [2], [5].

The lack of design data in the high-cycle part of the S-N curve, for steels in sea water is due to the fact that reliable corrosion fatigue results can only be obtained from tests that are carried out at the same frequencies as those experienced by the actual structure. This, however, imposes severe limitations on the amount of data that can be generated because of the long testing times involved. Typical North Sea waves have a frequency of approximately 0.17 Hz. Nineteen years would be required to obtain one data point on the S-N curve at \(10^8\) cycles! For welded structures, the dominant part of the fatigue life is spent in propagating a crack-like defect to the critical crack size. In this case it is possible to compute the life, \(N\), by integration of crack growth relations of the form

\[
\frac{da}{dN} = f(\Delta K)
\]

In particular, Paris' equation

\[
\frac{da}{dN} = C(\Delta K)^m
\]

where \(C\) and \(m\) are material constants, is often used to predict life.

The purpose of the present investigation was to establish fatigue crack growth data for a type of steel, in a corrosion environment, that is a candidate material for offshore structures. The effect of irregularly varying stress amplitudes was also studied.

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MATERIAL AND TEST CONDITIONS

The test pieces were made from a medium strength carbon steel, details of which are given in Table 1.

Single Edge Notch (SEN) specimens, with a cross section of 15 mm by 60 mm, Schenk electrohydraulic closed-loop fatigue machine. A machined notch, give a slot at the root of the notch that was approximately 2 mm deep and 3 mm wide, was sharpened by electroerosive machining to 0.25 mm wide. The notch was further sharpened by fatigue loading in air in air were also carried out at 20 Hz.

Due to limitations imposed by the random noise generator/narrow band filter set, all tests in sea water were carried out at 6.5 Hz. The random loading The test section of the specimen was surrounded by a plexiglass test were performed with a mean stress level of 240 MPa.

The crack lengths were measured visually with a 60 power microscope mounted on a micrometer screw. Crack length measurements were also made with a curves. The agreement between results obtained by the two methods was excellent.

EXPERIMENTAL RESULTS

The recorded a vs. \( \Delta K \) data was transformed into \( da/dN \) vs. \( \Delta K \) data by two different methods. The 'manual method' involved fitting a curve to the other method consisted of fitting a second order polynomial to five squares regression. The results of the two methods are compared in Figure comparison.

DISCUSSION

The data given in Figure 2 seems to confirm Barson's test results [4].

There is no large difference in crack propagation rates obtained from tests with constant amplitude loading and from those with variable amplitude loading in air (at least for \( da/dN > 10^{-3} \)). A similar conclusion can be based on the data obtained from tests in sea water. The results thus confirm that the average fatigue can be described by one equation with \( da/dN \) as a function of \( \Delta K_{rms} \), as in the low values of \( da/dN \), and no threshold is apparent in the sea water test results.
Figure 1: Crack propagation rate as a function of stress intensity range.

Figure 2: Crack propagation rate as a function of stress intensity range.

- Manual curve fitting
- 5 point polynomial curve fitting

Constant amplitude at 20 Hz in air