FAILURE OF STAINLESS STEELS BY CORROSION-FATIGUE

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INTRODUCTION

Corrosion-fatigue is often met in work pieces used in conditions which do not appear very aggressive: in this respect, corrosion-fatigue is analogous to, and as pernicious as, pitting corrosion or stress-corrosion. One cannot help being struck by such close analogies, at least in appearance, which exist between corrosion-fatigue cracks and those of stress-corrosion, or again between corrosion-fatigue and pitting corrosion: these analogies have strongly attracted the attention of researchers who were interested in these various aspects [1], so that it seems impossible to study one of these three aspects in isolation, neglecting their analogies.

The aim of this study was to specify or determine the mechanisms leading to the failure of stainless steels by corrosion-fatigue in a chlorinated environment. In particular, it was proposed to define the respective roles of electrochemical corrosion phenomena and mechanical damage. This knowledge should allow a better choice of stainless steels to resist corrosion-fatigue to be made.

EXPERIMENTAL PROGRAMME

The tests were carried out to produce the S.N. curve in rotating-bending, and the rate of fatigue crack growth in air and in a corrosive medium.

The behaviour of the following stainless steels was studied:

- an austenitic stainless steel with molybdenum of the type AISI 316, quenched from 1100°C (steel A);
- a titanium stabilized austenitic steel of the type AISI 316, with titanium, quenched from 1100°C (steel B);
- an austenoferritic steel: C = 0.03, Ni = 0.2, Cr = 21.1, Mo = 2.4, Cu = 1.4, quenched from 1150°C (steel C);
- a ferritic steel with a high percentage of chromium: C = 0.001, Cr = 26.2, Mo = 1.0 quenched from 900°C (steel D).

It is well known that the nature of the corrosive medium can have a great effect on the kinetics of the corrosion-fatigue phenomena. It is also known that in the case of stainless steels, localized attacks on the

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stress-corrosion or pitting-corrosion type are characteristically produced to carry out these tests in a 35% aerated solution of sodium chloride. In some cases, to demonstrate the influence of the electrochemical processes during the test.

The rotating-bending tests and the fatigue crack growth experiments were carried out in an immersion cell. All the metallic parts, other than the samples, were protected against the effects of galvanic coupling.

The rotating-bending tests were carried out with 15 samples to produce the method of the comparison tests. The rotational speed of the samples was 3000 RPM.

The measurements of fatigue-crack growth were made on servo-hydraulic pulsating machines. For each of the steels, a curve was drawn given by stress intensity factor K as a function of the variation ΔK of the case, from 0.5 to 20 Hz.

RESULTS AND DISCUSSION OF THE TESTS

Rotating-Bending Tests

The results of the rotating-bending tests are given in Table 1. The value of endurance ratio σ/σ_UTS is shown beside each fatigue limit σ_f.

The results obtained in air show that the steels can be classified in: austenitic steel C: 0.61; austenitic steels A and B: 0.54.

The results obtained in the corrosive medium show that the classification austenitic steel C: 0.45; austenitic steels A and B: 0.41.

Fatigue Crack Growth Tests

The influence of the principal parameters studied can be assessed from the curves produced by the variation of fatigue crack growth rate da/dN as a function of the variation ΔK of the stress intensity factor.

The measurements made on the austenitic steels A and B show that, in this steel, at a frequency of 20 Hz, the corrosive solution has no influence on the crack growth rate. On the contrary, in the case of the austenitic-ferritic steel C, for high values of ΔK, an overall increase in the rate of fatigue crack growth is observed (Figure 4), and the lower the frequency, the greater is this increase.

An analogous result is found in the case of the ferritic steel D.

The increase in rate of fatigue crack growth can be explained by an acceleration of anodic dissolution under the effect of increasing stresses.

The current-potential curves of the various steels studied have been determined by means of quasi-potentiostatic tests with samples turning at the same speed as that of the fatigue samples. Figure 2 shows, for
CONCLUSIONS

From the tests carried out, a study of the initiation and propagation stages of the fatigue cracks in four stainless steels was possible.

The rotating-bending tests and the rate of fatigue crack growth produced resistance to fatigue: austenitic steels, austeno-ferritic steel, ferritic steel.

The following classification of the steels, in the order of increasing resistance to fatigue:

From the measurements of potential and the tests made under an imposed passivity of the metal seems likely to depend on the stress.

In a corrosive medium with a sufficiently low potential, the values for the rate of fatigue crack propagation is noticeably diminished.

The results overall show the importance of electrochemical phenomena in the mechanisms of corrosion-fatigue.

The capacity of the metal for dissolution and for passivation seems largely to be responsible for the behaviour of the metal is a corrosive medium. The loading conditions of the samples. It appears, moreover, that the rate of uncharged sample can correspond to a region where dissolution is still possible if the metal is under a high stress.

The result of these various findings is that, for stainless steels, the mechanism of stress-corrosion and corrosion-fatigue are similar. The formation of slip steps, and secondly by the phenomena of intrusions.

Any accident in the micromechanics of the surface of the metal favours these pitting, in such a way, the cracks are preferentially initiated on inclusions (oxides - sulphides...) or on carbides and carbonitrides. This [1, 3], existing between resistance to corrosion fatigue and resistance to pitting which are produced preferentially on inclusions.

The essential difference between mechanisms of corrosion-fatigue and stress-at lower levels of stress than are necessary to produce the slip bands which lead to the deterioration of the passive film in stress-corrosion.

REFERENCES

1. Proceedings of the International Conference on Corrosion-Fatigue, 1971, NACE.
3. WIEGAND, H., SPECKHARDT, H. and SPARN, H., Archiv für das Eisen-

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<th>Steel</th>
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<td></td>
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<tr>
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<tr>
<td>D</td>
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Figure 1 Evolution of Potential as a Function of Time in Open Circuit

Figure 2 Results of Quasi Potentiostatic Tests
Figure 3: Results of Rotating Bending Tests

Figure 4: Influence of Corrosive Solution on the Rate of Fatigue Crack Growth

AUSTENO - FERRITIC STEEL C