CORROSION FATIGUE OF Cr-Ni-Ti STEEL

T.Liptáková*, O. Bokůvka*, P.Palček*, M.Pražák**

Authors of this paper investigate the influence of corrosion inhibitors on corrosion fatigue properties of Cr-Ni-Ti stainless steel used for construction of steam turbine. The inhibitor (NO_3^-) was aplied in different concentration in a very aggressive (Cl^-) solution at normal temperature and simultaneous working at cyclic loading. The results are discussed from point of view of inhibitors effect and synergic effect of environment and cyclic loading.

INTRODUCTION

Many authors (1-8) dealt with processes of corrosion fatigue in water environments with different agressivity but no mechanism can explain them satisfactory since corrosion fatigue is affected by many internal and external factors.

Authors of this paper investigate the infulence of corrosion fatigue on the properties of a Cr-Ni-Ti stainless steel. It is known that this austenitic stainless steel with passivating ability suffers pitting corrosion in water solutions containing Cl^- ions. The corrosion atack affects their fatigue properties unfavourable and the presence of the created pits lowers the materials endurance. They act not only as the stress concentrators but enhance amount of plastic deformation

* Technical University of Transport and Communication, Žilina, CSFR
** National Research Institute for Protection of Materials, Prague, CSFR

places and diminish active diameter of details too (3, 4). One of the possibilities of stainless steels protection can be the use of corrosion inhibitors (NO_3^-, PO_4^{3-}, CrO_4^{2-}, SO_4^{2-}) against pitting corrosion.

Nitrate ions are considered to be adsorption inhibitors and they adsorb faster on the metal surface than aggressive ions. Very important is information on their mutual proportion which can be expressed as (10):

$$Epc = A + B.\log \frac{[I]}{[Cl^-]} \quad \ldots\ldots\ldots\ldots\ldots (1)$$

The certain chloride and other ions concentration is considered to be critical with regard on possibility of pitting corrosion origine. The experimental measurements showed synergy dependence at combination of chloride with more aggressive ions and the higher chloride effect with increasing temperature. The critical ion concentration for Cr-Ni austenitic steels can be expressed by equation (10):

$$Ipc = \frac{[Cl^-] .2.0\exp [0.05.(t-25)] .(1+100 [H_2S])}{4. [NO_3^-] + 0.18. [SO_4^{2-}] +1.5 [OH^-]} \quad \ldots (2)$$

In the case when Ipc 1 pitting corrosion occurs, if Ipc 1 the tendency to corrosion rapidly decreases. The critical conditions have been valided for static state, the correct metal surface treatment (11).

EXPERIMENTS

The tested specimens were made from stainless steel ČSN 41 7246; chemical composition in weight percent is: C-max.0.12; Mn-max.2.0; Si-max.1.0; Cr-17÷20; Ni-8÷11; Ti-5x(%C-0.03), P-max.0.045; S-max.0.03. The shape and dimensions of the specimen are shown in Figure 1.

The specimens surface of the wet area was ground and polished. Five variations of the test conditions were used to search the corrosion fatigue properties and inhibition effects: A-cyclic loading in distilled water; B-cyclic loading in a water solution (10 g $FeCl_3$ +10 g NaCl in 1 dm^3 of distilled water; C-cyclic loading in the solution of 2 g $NaNO_3$/1 dm^3 of sol. B (undercritical amount of inhibitor); D-cyclic loading in the solution of 10 g $NaNO_3$/1 dm^3 of sol. B (overcritical amount of inhibitor); E-the specimens were precorroded in the solution B without loading during 820 000 cycles. After this programme the same specimens were passivated in a 20 % solution of HNO_3 and than cyclic loaded in distilled water.

All the tested specimens were cyclic loaded by the rotating bending at the temperature of 23±2 °C, the frequency 40 Hz (2400 rpm), fatigue test device Rotoflex UBM. The loading of 80 N (σ_o =188,7 MPa) was first estimated experimentally in distilled water. Later the number od cycles in the environments A-E was measured at this loading. Corrosive solutions were regularly renewed to ensure reproducibility of results. The fracture areas and surface of the testing specimens were evaluated by S.E.M. (Tesla BS 350).

RESULTS AND DISCUSSION

The results of the corrosion fatigue tests in different environments are in Figure 2. In the strong aggressive aggressive solution of chloride ions the deterioration of fatigue properties can be observed very expressively (the average number of cycles to failure is 435 775). The undercritical amount of inhibitor NO_3^- had already a positive influence on the fatigue charácteristics of the tested material (the number of cycles to failure 1 512 444). The overcritical content of the used inhibitor supressed the effect of the chloride ions and the result was comparable with that in distilled water. The influence of pitting corrosion on fatigue characteristics have confirmed the results of test on precorroded specimens an the fact that simultaneous effect of environment and mechanical loading is synergic.

The typical failure areas of the tested specimens are presented in Figure 3 and Figure 4. Detail of corrosion damaged place of specimens in solution C is shown in Figure 3. The case of crack propagation after cyclic loading from the bottom of passivated corrosion pit on precorroded specimen (E) can be seen in Figure 4. The general fatigue character of failure areas in distilled water and in solution of chloride ions were not substantialy different.

CONCLUSIONS

1. The chloride ions evoking pitting corrosion of stainless steel intensively reduce fatigue characteristics (the number of cycles to failure) which were followed at a simultaneous action of the aggressive environment and the dynamic stress.

2. The effect of NO_3^- as inhibitor was positive already at undercritical amounts-the number of cycles to failure increased. The overcritical amount of this one supressed the aggressivity of the chloride ions. Only the distilled water influence on fatigue properties was observed. The inhibitor presence has limited the density and magnitude of the pits.
3. The effect of the presence of the passivated pits (on precorroded samples of tested steel) exposed to dynamic stress in distilled water was evident but synergic cooperation of environment and cyclic loading was eliminated.

SYMBOLS USED

Epc = pitting potential

Ipc = pitting corrosion index

A = material constant

B = ion constant

[I] = inhibitors concentration

$[Cl^-]$ = chloride concentration

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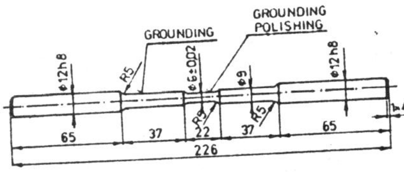

Figure 1 Shape and dimensions of the specimens

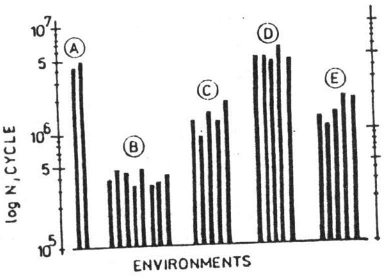

Figure 2 Number of cycles vs.different corrosion environments

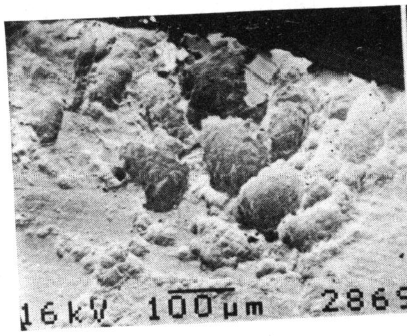

Figure 3 Fracture area, solution C

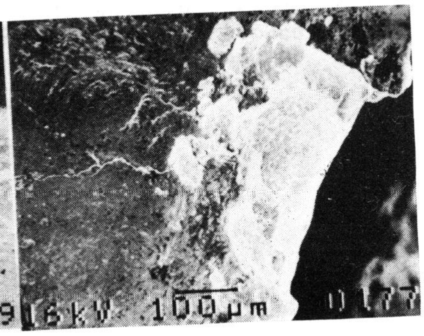

Figure 4 Fracture area, solution E,crack from pit