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The current status of new Czech corrosion fatigue evaluation proposal for WWER nuclear power plants

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Abstract

Presented paper introduces an innovative principle of fatigue life assessment suggested for WWER nuclear power plants. The subject of this work is to take into account the corrosion environment influence in actual methodology of low-cycle fatigue (LCF) assessment and prediction. The aim of this paper is to summarize the current status of the Czech proposal of corrosion fatigue assessment and prediction. The first project focused on base steel materials, which are used in primary circuit of WWER-440, started in 2010. The basic idea of Czech environmental fatigue correction factor has been introduced on international PVP conference in 2013. The new project linked to the previous one is focused on the additional area of welding joints. Theoretical base is completed by experimental verifications of proposed environmental correction factor. The subject of actually running theoretical-experimental program covers similar metal welds of austenitic stainless steel 08CH18N10T and results will be available in 2015. Moreover LCF tests in corrosion environment of dissimilar metal welds are under preparation. Experimental work is based on LCF strain-controlled tests in primary water environment of WWER-440.

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Keywords: low-cycle fatigue; environmental factor; austenitic stainless steel; welds; nuclear power plant

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1. Introduction

It is well known that initiation and growth rate of fatigue crack could very strongly depend on local environment. In general corrosion environment decreases the number of cycles to initiation and increases the crack growth rate. The measure of such influence is done on one side by corrosion environment aggressiveness and on the other side on corrosion resistance of material. In the frame of technical public, the influence of environment on fatigue life is not a new topic, but in the last two decades this phenomena is increasingly discussed in the area of nuclear energy.

The decrease of fatigue life due to primary water environment is generally realized by so called fatigue life environmental correction factor (F_{en}). Such correction factor was originally introduced in NUREG documents (2007), as results of large experimental program of Argonne National Laboratory-ANL (2011). The environmental correction factor F_{en} is defined as a ratio of fatigue life in air at reference temperature to fatigue life in water at operating temperature:

$$F_{en} = N_{air,\ RT} / N_{water} \tag{1}$$

Such way defined environmental correction factor can't be directly used for fatigue life assessment and prediction under operating conditions of WWER nuclear power plants. Reasons are lying on the side of different way of fatigue life assessment and prediction, which is used on the WWER power plants. Direct application of F_{en} values leads to unrealistic conservative results of estimated allowed number of cycles to fatigue crack initiation. Moreover, the ANL low-cycle fatigue (LCF) data in corrosion environment weren't measured for materials of primary circuit of WWER power plants.

Presented paper introduces an innovative principle of fatigue life assessment suggested for WWER power plants. The subject of this work is to take into account the corrosion environment influence in actual methodology of low-cycle fatigue assessment and prediction. The aim of this paper is to summarize the current status of the Czech proposal of corrosion fatigue assessment and prediction. Assessment procedures used for fatigue life evaluation are stated in NTD A.M.E. standard (2013). The purpose is to take into account the influence of primary water corrosion environment on fatigue life of components and piping for WWER power plants.

2. Czech alternative approach for WWER

Considering the Long Term Operations (LTOs) of WWER power plants, the modification of NUREG proposed F_{en} computation should be found and experimentally verified. The first project focused on base steel materials, which are used in primary circuit of WWER-440, started in 2010. The new actual project linked to the previous one is focused on the additional area of welding joints. The basic idea of Czech environmental fatigue correction factor was firstly suggested in 2010 by Vlcek (2010) and after three years later introduced on international PVP conference by the same author (2013). Decreasing of fatigue life has been observed when the synergic effect of next parameters and their critical values are met: (i) strain amplitude, (ii) strain rate, (iii) operating temperature, (iv) dissolved oxygen and (v) sulphur content (not for austenitic steels). The redefinition of environmental correction factor F_{PR} was introduced as a ratio of total strain amplitude in air at operating temperature condition to total strain amplitude in water at operating temperature condition, see Vlcek (2010):

$$F_{PR} = \varepsilon_{at\ air} / \varepsilon_{at\ water} \tag{2}$$

where $\varepsilon_{at\ air}$ is the total strain amplitude in air at operating temperature, $\varepsilon_{at\ water}$ is the total strain amplitude in water at the same operating temperature.

The whole idea of environmental factors is simply defined in Fig. 1. Brief summary of discussed factors is tabulated in Table 1. Information is completed by the references in which the definitions were introduced. In addition, the minimal values of environmental factors are shown for austenitic stainless steels together with year of publication.