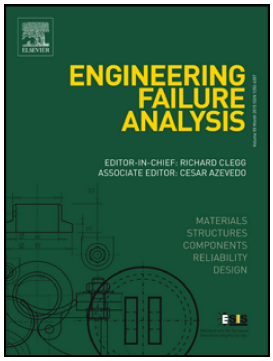

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Residual lifetime assessment of thermal power plant superheater header

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Abstract

The safe operation of thermal power plants (TPPs) is largely determined by the reliability of main components of steam systems of power units, to which belong the headers of boiler superheaters. The aim of this study is to estimate the residual lifetime of superheater header starting from the initial defect size and up to the maximum allowable one. The above-mentioned lifetime is affected by the fluctuations of temperature under steady mode of operation of TPP superheater header. Superheaters headers operate in a steamy environment under the pressure of 15.5 MPa at temperature of 545 ºC. The header is a thick-walled cylinder made of 12Cr1MoV steel with a length of 2314 mm, outer diameter of 325 mm and thickness of 50 mm.

To estimate the residual lifetime of the header, the steam temperature in header was measured and digitized. The temperature range of the header under quasi-stable operational mode was divided into three classes: (1) $\Delta t < 10$ ºC; (2) 10 ºC $< \Delta t <$ 30 ºC; (3) $\Delta t >$ 30 ºC. The local minima and maxima were determined based on the obtained steam temperature history.

The residual durability was evaluated taking into account the effect of thermo-mechanical stresses and also the stresses caused by internal steam pressure.

The stress intensity factors (SIFs) at the crack tip in the ligament between the holes of superheater collector were estimated by FEM. The SIF of mode I (K_I) were determined along the fronts of modelled semi-elliptical cracks. The SIF correction function at the midpoint of the semi-elliptical crack front in the ligament between holes of the superheater header versus the crack depth and the temperature difference between the external and internal surfaces under a constant internal pressure of steam was obtained.

Based on the analysis of header defects, the proposed front shape was taken in the form of the semi-ellipse. The crack growth at 500 ° C was modelled by Paris and NASGRO equations.

With the increase of temperature difference between the external and internal header surfaces from 10 ºC to 50 ºC, the number of cycles, that is necessary for the crack to reach 35 mm in depth, decreases approximately in 25 times. It was calculated, that the average value of temperature fluctuations is 15ºC for the Class 1, and is 46.2 ºC for the Class 2. The lifetime of header can be extended due to the decrease of fluctuations of temperature range and their frequency.

Keywords: Stress intensity factors; finite element analysis; fatigue crack growth; life assessment; fatigue.

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