ADVANCED THERMAL-FSI CONCEPTION AND APPLICATION IN DAMAGE ASSESSMENT OF STEAM TURBINE CAUSED BY A FLOOD WAVE

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1. Introduction

Development of Thermal-FSI (Fluid Structure Interactions) allowed to optimize process of steam turbines force cooling systems [3]. Those systems allow to shortening time of renovations and reparations, because natural cooling of steam turbine heated up to over 500 ^{o}C can take even a week. Insulation and casing can be removed not before temperature of the turbine body will drops below about 100 ^{o}C. Through detailed calculations of temperature distribution in the turbine body it is possible to estimate thermal elongations and stresses induced in the turbine elements. This helps to balance between fast cooling and negative influence on the turbine lifetime.

In this work authors propose to use this method to estimate destructions in the turbine body caused by irruption of water to the flow channels. This extremely situation leads to critical stresses induced by uneven thermal fields in metal elements, which cause material deformation and cracks.

Aim of the paper is estimate level of destruction of individual elements. This will help to answer the question which of elements need to be replaced, which can be used again and which ones need to be repaired.

Methodology of Thermal-FSI is about calculate flow of fluid using CFD (Computational Fluid Dynamics) and then uses those results, as a function of time, to calculate solid (structure) interaction. This method is so-called one-way coupling, which means that solid do not affects the flow. Full coupling, in which in each time step flow is interacting solid and solid affect the flow, is much more computing power and time consuming. Thermal-FSI describes energy transport and conversion within a thin layer occurring in a contact of solid and fluid material. In difference to the Momentum-FSI where the exchange of momentum between solid and fluid is the main phenomena, in the Thermal-FSI the equation of energy plays the main role in two-way (from solid to fluid and vice versa) energy transport [1,2,3,4,5,6,7].

2. Simulation of flood wave.

A water cooling is presented in the paper. In this case steam turbine is under high temperature reach to 390^{o}C. In a model flood wave load is given as a pressure inlet of air or water with temperature 20 ^{o}C and 12 kPa. In CFD solver is obtained field of temperature and then imported to CSD solver where stresses fields and strains fields are obtained.

The Chaboche model is used in simulation, which is fully dependent on temperature, where the yield function is shown below:

$$(1) \qquad f = J_{HMH}\left(\frac{1}{1-D}\boldsymbol{\sigma}' - \boldsymbol{\alpha}'\right) - k - R = 0$$

where R is the isotropic hardening, k is the yield stress, $\boldsymbol{\alpha}'$ is the kinematic hardening (the backstress), $\boldsymbol{\sigma}' = \boldsymbol{\sigma} - \frac{1}{3}\mathrm{tr}(\boldsymbol{\sigma})\mathbf{I}$ is the deviatoric stress, $J_{HMH}(\boldsymbol{\sigma}') \equiv \sqrt{\frac{2}{3}\sigma'_{ij}\,\sigma'_{ji}}$ is the equivalent stress from Huber-Mises-Hencky criterion, D is the damage coefficient .

$$(2) \qquad \boldsymbol{\alpha} = \sum_{k=1}^{N} \boldsymbol{\alpha}_k$$

In the literature it has been developed, depending on the type of load cycles versions with different amounts of N kinematic hardening stresses.

Lemaitre and Chaboche during the development of the model back to the Armstrong and Frederick metallurgical law which gave mathematical form:

$$\dot{\boldsymbol{\alpha}}_k = C_k(\theta)[a_k \dot{\boldsymbol{\varepsilon}}^{vp} + \dot{p}\boldsymbol{\alpha}_k](1-D)\,, \quad k = 2,3,4,..,N\,. \tag{3}$$

In equation above appears two constants: C_k and a_k, proper calibration of these constants is important to obtain correct results.

In figure 1 are shown temperatures at the beginning of simulation (left) and equivalent stresses (right). The model is axisymmetric.

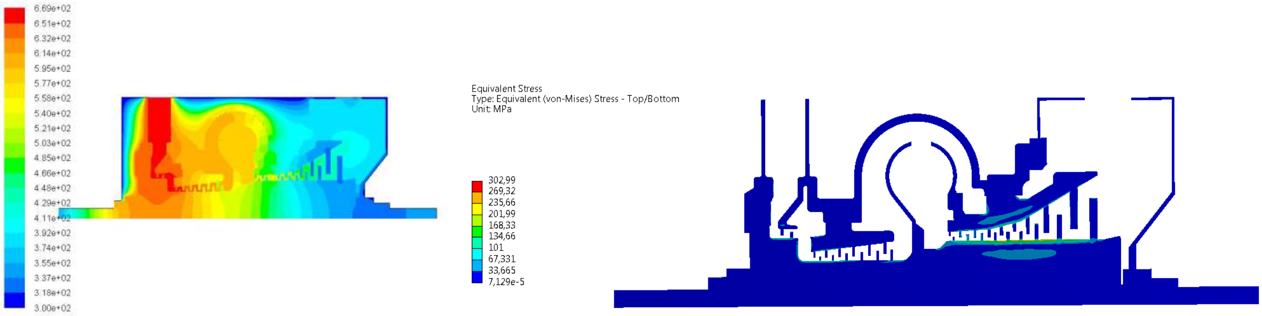

Figure 1. Temperatures at the beginning of simulation (left) and equivalent stresses (right).

3. Conclusions

Thermal-FSI is useful in the energy industry, particularly in issues related to steam turbines. The biggest values of stresses appear in turbine blades at notches.

Chaboche model can describe some behaviors of heat-resistant steels e.g.: Bauschinger effect, viscoplastic stresses in time of cyclic loading, stress relaxation, high-temperature creep and stress ratcheting.

4. References

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