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Creep Analysis of High Pressure Steam Turbine Part

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Abstract. Steam turbines are complex rotating machines working at high pressure and high temperature levels. Their high-pressure parts, which are subjected to the highest steam parameters, are most affected by these conditions and may suffer from creep deformation. Permanent changes in geometry become visible in high-pressure turbine casings when they are disassembled after certain time in operation.

Introduction

The analysis was done to gain knowledge on possible geometry changes that may appear in inner high-pressure casings during their lifetime. Numerical simulations were performed in the ANSYS 14.5 software for different operating time intervals. The results were compared to actual displacements measured on a disassembled casing.

Analysis Setup

3D Model. For the purpose of the numerical study, the model design was simplified and considered as symmetrical with respect to the vertical plane. This decision led to a significantly shorter computing time. The mesh consisted of 400,000 tetrahedral elements. A frictional contact was set in the splitting plane of the casing where creep-induced geometry changes are observed. The bolts connecting the upper and lower half of the casing, which ensure tightness of the structure, are substituted with force boundary conditions. The force remains constant over the duration of creep time and it is considered as after relaxation.

Temperature Field. A temperature analysis was run as the first step of the calculation. Convection boundary conditions were applied with steam temperature and heat transfer coefficients set according to the operating mode of the turbine.

Static Structural Analysis. The temperature field obtained in the above step was used as a load in a static structural analysis, which was divided into multiple load steps with different sets of boundary conditions. In the exposition load step, these conditions were determined by the supports of the casing, external pressure, forces imparted by the splitting plane bolts and the temperature field. The load step following the exposition time included gravity load only, with splitting plane bolts and all other loads removed. Several additional load steps followed, which were useful for gaining insight in the behavior of the casing after reassembly.

Material Properties. To obtain correct creep response of the material, it is important not only to have boundary conditions corresponding to reality but also to define realistic material properties. The high pressure inner casing was a GX12CrMoVNbN9-1 steel casting for which the creep strain behavior was assumed to follow the Bailey-Norton equation, Eq. 1 [1]:

$$\varepsilon = B\,\sigma^{n}\,t^{m}, \qquad (1)$$

where B, n, m are temperature-dependent material parameters.

Results. Upon completion of the analysis, the displacements were evaluated at the splitting plane between the upper and bottom parts of the casing. The difference between the displacements detected on the real casing and the displacements obtained from the analysis varied from nearly zero to 38 %, the average difference being 21 %. One place with the highest difference 71 % was considered as irrelevant. Fig. 1 presents the calculated displacements after disassembly.

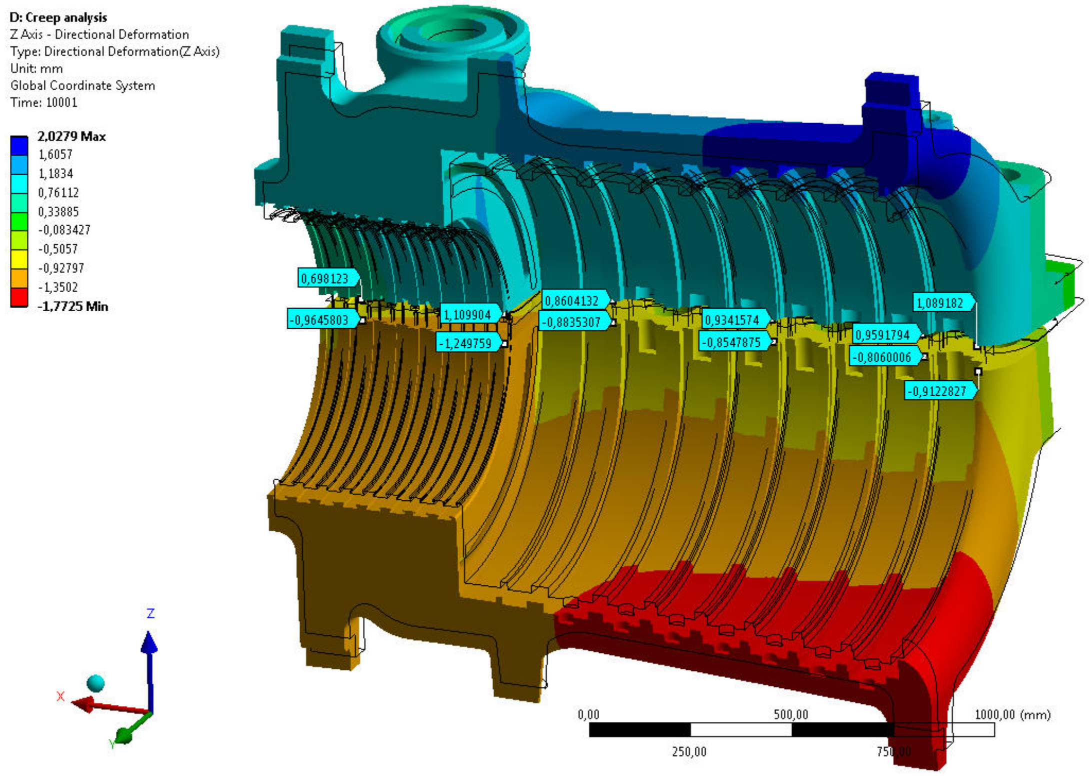

Fig. 1. The calculated displacements after disassembly.

Conclusion

The results of numerical simulations were compared to displacements detected on an actual turbine casing. The comparison proved that numerical simulations are useful for prediction of creep deformation. Casing design can be optimized on the basis of those simulations to reduce the geometry changes and ensure correct function of the casing over turbine life.

References

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