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NUMERYCZNA OCENA ZJAWISK CIEPLNO-PRZEPŁYWOWYCH W WYBRANYCH WĘZŁACH STOPNIA TURBINY GAZOWEJ

Praca doktorska

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Abstract

Numerical investigation of fluid flow and heat transfer phenomena in selected parts of the gas turbine stage

The work includes issues related to the fluid flow and heat transfer in selected fragments of the flow path of the gas turbine. Its main objective was to optimize the geometrical configuration of the tip seal of the counter-rotating LP turbine of the open rotor aero-engine. Second aim was to perform Conjugate Heat Transfer (CHT) analysis of the seal and rotating cavity above the seal.

At the beginning the basic concepts related to the seals in the moving parts of the turbine and heat transfer problems in rotating cavities have been characterized. Then the aim and scope of the work are presented.

Chapter four describes the preparation of a computational model for the optimization. The geometrical area and its simplification are presented. The simplification was needed to conduct an efficient optimization process carried out on the basis of numerical calculations, which were performed using ANSYS CFX solver. Much attention was also devoted to the preparation of mesh. This section contains definition of boundary conditions, the calculation model and discusses the parameters taken into account during optimization.

In the fifth chapter the results of the optimization are presented, which are preceded by a description of the optimization methods as well as tools used to obtain these results. The first part discusses the optimization carried out using commercial tools included in the ANSYS Workbench environment, like a Goal Driven optimization. Optimization was performed in two ways, first all ten geometrical parameters were optimized at the same time, in the second way parameters were divided into three groups, where parameters connected with the seal teeth were optimized first, then the inlet part of the seal was optimized and at the end the outlet part. The second part of this chapter discusses the optimization using the in-house optimization code, based on evolutionary algorithm.

The best result was obtained with the use of Goal Driven Optimization performed in three steps, which became the basis for further calculations. At the end of the fifth chapter the sensitivity analysis are presented. It was carried out as a global analysis, showing the overall impact of individual parameters on the objective function and the local analysis, for the best solution, which

shows how result can change when any of the parameters varies. In the global analysis the most important parameters were: the position of the left tooth, the angle of the left platform and the gap width at the outlet of the seal. In case of local analysis the most important parameters were: the right fin position and angle of the fin, the width of the seal inlet gap and the angle of the platform at the seal inlet.

Sixth chapter discusses the analyses of the optimized seal. It presents the verification of results obtained during the optimization, which was made on the extended geometrical model and on finer mesh. The verification confirmed the quality of the result obtained during the optimization. Results of an extended analyses of the seal were also presented, where the flow parameters like: the static pressure, static entropy, velocity and kinetic turbulence energy were considered. The extended analyses of the seal include also calculations for varied pressure at the outlet of the domain and for three times higher pressure level in the whole domain. In addition, there are discussed calculations for reduced tip clearance, which showed, among others the large potential to reduce the leakage by decreasing this parameter.

In the following part of the thesis the analyses of rotating chambers are presented, which were carried out on the basis of examples taken from the literature. The aim was to verify the calculation model and approach to modelling flow and heat transfer in a rotating chamber. The target chamber, separated from the seal was also analyzed, in order to assess proceeded phenomena and to select the size of computational domain.

The eighth chapter discusses the CHT analysis of the seal and the rotating cavity located above the seal, whose aim was to assess the conditions of the heat transfer across the seal. The geometric model and boundary conditions are presented. The analysis shows the key parameters associated with the heat transfer like: temperature distributions in the considered area, the velocity distribution in the chamber and the distribution of Nusselt number on the surface of the chamber.

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