Flow analysis of the turbine rotor tip seal on a highly rotary test rig

Authors: Szymański A., Dykas S., Wróblewski W.

Affiliation: Institute of Power Engineering and Turbomachinery,
Silesian University of Technology, Gliwice, Poland

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Summary:

Ever increasing requirements concerning the reduction in the emissions of pollutants into the atmosphere and soil necessitate a rise in the efficiency of power engineering machinery and equipment. Despite the fact that the efficiency value is limited, both manufacturers and scientists make strenuous efforts to improve it. One of the most important factors exerting an impact on turbomachinery efficiency is the type of sealing used in areas separating high and low pressure regions during the relative rotational motion. Sealing bears a 2-3% responsibility for a drop in the gas turbine efficiency. The lower the turbine power output capacity, the bigger the impact of the sealing. Beside state-of-the-art techniques of reducing leakages, such as film riding face seals, finger seals or brush seals, labyrinth seals remain the most common solution used in turbines. They are favoured for their low price, low maintenance costs, resistance to high temperatures and destruction resulting from rubbing (friction on the seal fin-shroud interface). This article presents a detailed CFD analysis of a highly rotary labyrinth tip seal. An impact of the rotor rotational speed and of the pressure ratio on the flow characteristics was observed. The characteristics were calculated for different pressure ratios. Moreover, the effect of roughness was discussed in each case. The calculation results are shown in the form of curves illustrating the mass flow. The conducted analyses show an essential impact of the rotor rotational motion and roughness on the mass flow through the sealing and on the aerodynamic friction factor. Moreover, the analysed profiles of the axial and circumferential velocities strongly depend on the wall roughness. The rotational motion also has a significant effect on the characteristics presented herein. For the rotor rotational speed in the range of 15000 – 24000 rpm, there is a substantial drop in the value of the discharge coefficient from 1 to 0.8 (rough rotor) or 0.87 (smooth rotor); this is accompanied by a rise in the friction factor value. The impact of the rotor rotational motion and roughness is higher for low pressure ratios. For supercritical values of the pressure ratio, the impact of roughness and rotational motion is slight. The conducted CFD analysis confirms the thesis that the discharge coefficient depends on the rotor rotational speed as well as the fact that the flow field is entirely symmetrical in the circumferential direction. For the geometry presented herein, in the case of smooth walls and at the rotational speed value of 24000 rpm, a drop by 12 % was observed in the mass flow. If increased roughness is taken into account, the mass flow – for the highest rotational speed – drops by 20.1% compared to the stationary case. This means that the surface quality affects the flow essentially and that it is possible to exert an impact on the flow characteristics using materials with appropriate porosity.

The optimum working configuration of the sealing can be selected from all those presented in the paper.