COMPUTATIONAL MECHANICS 2018
34th conference with international participation
Srní
October 31 - November 2, 2018

Prediction of hub-seal effect on efficiency drop in axial turbine stage

P. Straka [a]

[a] Czech aerospace research centre, Beranových 130, 199 05 Prague, Czech Republic

In axial turbine stages the secondary flows have an important impact on the drop of the stage efficiency. Significant sources of the secondary flows are shroud- and hub-seals [1,2]. This paper deals with numerical simulation of the hub-seal leakage flow effect on the axial turbine stage efficiency drop. Simulation was done using in-house numerical software [3] based on solution of RANS equation closed with $k - \omega$ turbulence model.

Fig. 1 shows scheme of the computational domain containing stator and rotor blades and simplified hub-seal with two seal-fins and with separated inlet boundary. The mass flow rate through the hub-seal is controlled with the size of the radial clearance c_{rad} in range 0.1 – 1.5 mm. The isentropic outlet Mach number is $M_{is,out}$ = 0.24, the isentropic outlet Reynolds number is $Re_{is,out} \approx 5.1\times10^6$, rotational speed of the rotor blade is 3810 RPM. Two axial clearances c_{ax} = 5 and 10 mm are tested.

Fig. 2 shows streamlines in meridian plane inside the hub-seal colored by normalized mass-flux density $\dot{m}/\dot{m}_{nom}$, where $\dot{m} = \rho(u_{ax}^2 + u_{rad}^2)^{0.5}$, ρ is the density, u_{ax} and u_{rad} are axial and radial velocity vector components and $\dot{m}_{nom}$ is nominal value. Fig. 3a documents an ele-

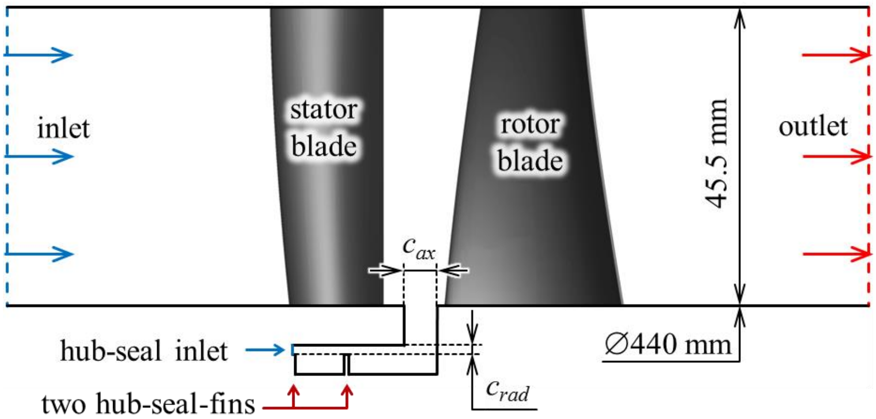

Fig. 1. Scheme of the axial turbine stage with the hub-seal

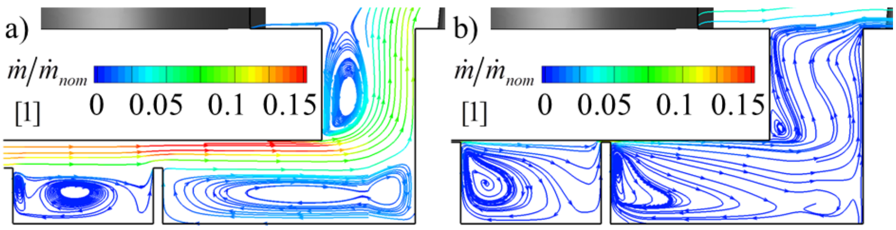

Fig. 2. Projection of streamlines to the meridian plane in the hub-seal region; the streamlines are colored by normalized mass-flux density; radial clearance: a) c_{rad} = 1.5 mm, b) c_{rad} = 0.1 mm

vation effect of the rotor blade on the stream from the hub-seal. The normalized efficiency drop dependency on the mass flow rate through the hub-seal is shown in fig. 3b. In fig. 3b there is $\Theta = q_{seal} / q_{tot}$, q_{seal} is mass-flux through the hub-seal and q_{tot} is total mass-flux through the outlet boundary. The normalized efficiency drop is defined as $\hat{\eta}_{TT} = (\eta_{TT} - \eta_{\min}) / (\eta_{\max} - \eta_{\min})$, where $\eta_{TT} = (T_{Tin} - T_T) / (T_{Tin} - T_{Tis})$, T_{Tin} is the total inlet temperature, T_T is local total temperature, T_{Tis} is local isentropic total temperature, $\eta_{\min}$ and $\eta_{\max}$ are chosen minimal and maximal values for normalization. Fig. 4 compares distribution of the normalized efficiency drop in axial section behind the rotor blades for radial clearance c_{rad} = 0.1 and 1.5 mm.

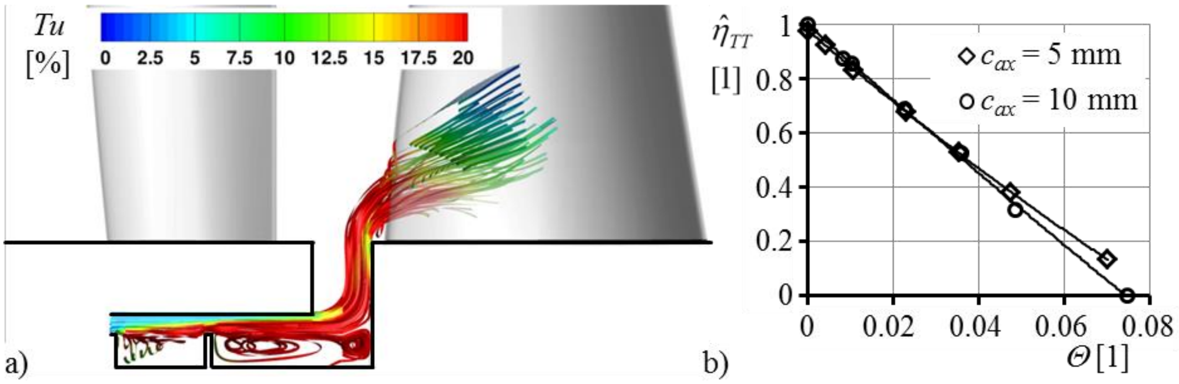

Fig. 3. a) detail of the streamlines (colored by local turbulence intensity) from the outflow-slot of the hub-seal; b) dependency of the normalized efficiency on the hub-seal mass-flux to total mass-flux ratio

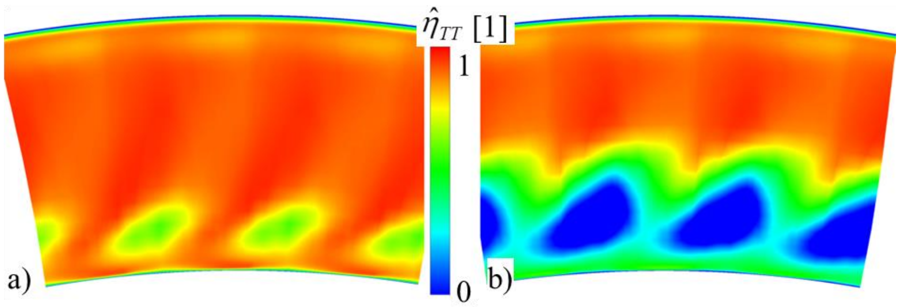

Fig. 4. Distribution of the normalized efficiency in axial section behind the rotor blades; radial clearance: a) c_{rad} = 0.1 mm, b) c_{rad} = 1.5 mm

Presented results demonstrate significant impact of the hub-seal leakage flow on the efficiency drop of the axial turbine stage. We can see that in case of higher mass flow rate through the hub-seal the seal leakage flow is able to send down the efficiency in lower half of the blade span.

Acknowledgements

This work has been supported by the project TH02020086 of the Technology Agency of the Czech Republic.

References

[1] Straka, P., Numerical study of shaft-seal parameters for various geometry configuration and operating regimes, EPJ Web of Conferences 180, 02100 (2018).
[2] Straka, P., Pelant, J., Numerical simulation of flow through a simplified model of the shaft-seal, Proceeding Conference Engineering Mechanics 2018, Svratka, 2018, pp. 821-824.
[3] Straka, P., Software for calculation of turbulent unsteady flow using the nonlinear turbulence model, Report VZLÚ R-6381, 2016. (in Czech)