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INVESTIGATIONS OF LOSSES AT THE INLET TO THE SHROUDED BLADE ROTOR

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The main flow in turbomachinery is accompanied by leakages through structural gaps between rotational and stationary elements. The most obvious effect of leakages is a reduction of the mass flow rate through the blade passage and, in consequence, a decrease in the energy transfer between the fluid and blades. The object of this study is a leakage over shrouded rotor blades of the axial turbine. In this case, the fluid is removed from the main flow path in front of the rotor blades and directed to the channel over the shroud. It undergoes numerous changes in the flow direction, contraction and expansion processes in labyrinth sealing elements and, finally, returns to the main passage downstream of the rotor blades. All these phenomena are responsible for fluid energy dissipation in a turbine stage as well as in subsequent stages to some extent. An appropriate design of the labyrinth sealing assures the minimization of the leakage mass flow rate and leads to minimization of energy dissipation.

Mixing of the leakage with the main flow at the rotor outlet is widely recognized as the most serious dissipative process due to a significant difference in the velocity values and the flow directions of these two streams (Denton, 1993). During the recent years a great effort has been devoted to experimental investigations of the mixing zone downstream of the rotor blade and methods of loss reduction in this region (Pfau et al., 2001; Pfau et al., 2007; Rosic and Denton 2008).

Dissipative processes at the entrance to the labyrinth sealing are not so intensive (Denton, 1993) and probably therefore, investigations of the flow at the entrance to the labyrinth sealing over the rotor shroud are limited (Pfau et al., 2007). What is obvious, uniform removal of a part of the boundary layer in front of the rotor can lead to improvement of the flow structure in the blade passage and can reduce the secondary flow intensity (Gundlach 2008). Unfortunately, the labyrinth channel entrance is located just upstream of the rotor, thus, the backward influence of the rotor blades is very important.

The pressure and velocity distributions change in this clearance in the circumferential direction. In the case of a wide clearance, the fluid enters the gap (Pfau et al., 2007) in front of the leading edge and at the pressure side of the blade. However, in front of the blade suction side, a part of this flow returns to the main passage. This reverse flow changes inflow conditions of the rotor and has a significant influence on the loss generation in its blade passages by means of the secondary flow intensification.

The flow behavior in the gap depends on its width (Sobczak et al., 2011). The amount of the reverse flow decreases with the gap width. For wide gaps, reverse flow regions which spread over the whole gap width appear, whereas for narrow gaps, the fluid enters the labyrinth cavity only. In such a case even though the boundary layer suction is not perfectly uniform, the secondary flow reduction can be observed. Thus, it can reduce a negative effect of the shroud flow to some degree (Gundlach 2008).

An impact of the gap width at the entrance to the labyrinth sealing on the axial turbine rotor performance is presented in this paper. A series of numerical simulations were carried out for a wide range of gap widths and for various labyrinth sealing clearances.

A progress in the computational power and Computational Fluid Dynamics methods allows one to investigate leakage processes numerically with various levels of precision. A few years ago the main flow and the side flow were considered separately. The leakage mass flow rate and parameter changes were usually determined on the basis of empirical data or a simplified numerical method. The influence of the side flow on the main flow in turbine simulations were taken into account by means of removal and delivery (sink-source) of the appropriate mass flow of the leakage (Chodkiewicz et al., 2005; Hunter and Orkwis 2000; Lampart, 2006). Unfortunately, this approach neglects the parameter variation at the entrance and the exit from the labyrinth sealing and decreases the approximation quality. Detailed numerical investigations of the loss mechanism require solutions of the full object, i.e., the main flow channel and the side flow gaps. In such a case, they represent adequately the reality (Rosic et al., 2006; Rosic and Denton 2008). Therefore, in the current study, such a procedure is applied.

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References

Chodkiewicz R., Sobczak K., Borzęcki T., (2005): *Secondary Flow Control in an Axial Turbine Stage,* CMP-Turbomachinery, Vol. 128 (1), pp. 123-130

Denton J. D., (1993): *Loss Mechanisms in Turbomachines*, ASME Journal of Turbomachinery, Vol. 115, pp. 621-650

Gundlach W., (2008): *Podstawy maszyn przepływowych i ich systemów energetycznych*, WNT, Warszawa, (in Polish)

Hunter S. D., Orkwis P. O., (2000): *Endwall Cavity Flow Effects on Gaspath Aerodynamics in an Axial Flow Turbine*, Part II. ASME Paper No. 200-Gt-513

Lampart P., (2006): *Tip Leakage Flows in Turbines,* Task Quarterly, Vol. 10, pp. 139-175

Pfau A., Kalfas A. I., Abhari R. S., (2007): *Making Use of Labyrinth Interaction Flow*, ASME Journal of Turbomachinery, Vol. 129, pp. 164-174

Pfau A., Treiber M., Sell M., Gyarmathy G., (2001): *Flow Interaction from the Exit Cavity of an Axial Turbine Blade Row Labyrinth Seal*, ASME Journal of Turbomachinery, Vol. 123, pp. 342-352

Rosic B., Denton J. D., (2008): *Control of Shroud Leakage Loss by Reducing Circumferential Mixing*, ASME Journal of Turbomachinery, Vol. 130, pp. 1-7

Rosic B., Denton J. D., Pullan G., (2006): *The Importance of Shroud Leakage Modeling in Multistage Turbine Flow Calculations*, ASME Journal of Turbomachinery, Vol. 128, pp. 699-707

Sobczak K., Chodkiewicz R, Kryłłowicz W., (2011): *Sterowania rozwojem przepływów wtórnych w obszarze wierzchołka łopatki wirnika stopni turbinowych*, Report of the project N502 4538 33, Łódź, (in Polish)