11th World Congress on Computational Mechanics (WCCM XI)
5th European Conference on Computational Mechanics (ECCM V)
6th European Conference on Computational Fluid Dynamics (ECFD VI)
July 20 - 25, 2014, Barcelona, Spain

Adaptive CFD-Enhanced Windage Modelling for Aero Engine Turbine Rotor-Stator Cavities

J. M. Rey Villazón[1] and A. Kühhorn[1]

[1] Chair of Structural Mechanics and Vehicle Vibrational Technology
Siemens-Halske-Ring 14, 03046 Cottbus, Germany
reyvilla@tu-cottbus.de
kuehhorn@tu-cottbus.de

Key Words: *Flows with heat transfer, Sensitivity Analysis, Internal Air System, CAE and finite element integrations, Cavity flows, Windage, Turbomachinery, Aero Engine.*

ABSTRACT

The rotating components in aero engines are highly stressed as a result of the centrifugal and thermal loads. The turbine discs are embedded in the secondary air system (SAS), see Figure 1 left, which is defined as the air flows that are not directly contributing to engine thrust. One of the main functions of the SAS is to ensure that the rotating components are surrounded by fluid conditions that optimize their life and integrity. This paper describes a novel approach to develop adaptive flow field modeling methods for the turbine preliminary design phase. The proposed techniques allow fast scaling of varying disc cavity flows and heat transfer effects, to be able to cope with changes in turbine topology.

The phenomenon known as rotor-stator drag or windage is defined as the power of the rotor moment acting on its environment. The power loss due to windage has a direct impact on the performance of the turbine and the overall efficiency of the engine. Additionally, windage increases the total temperature of the fluid in the cavities surrounding the turbine disc [1]. The method proposed in the paper is used to investigate the impact of the SAS design parameters on the windage power losses in the front cavities of a typical aero engine high pressure turbine (HPT).

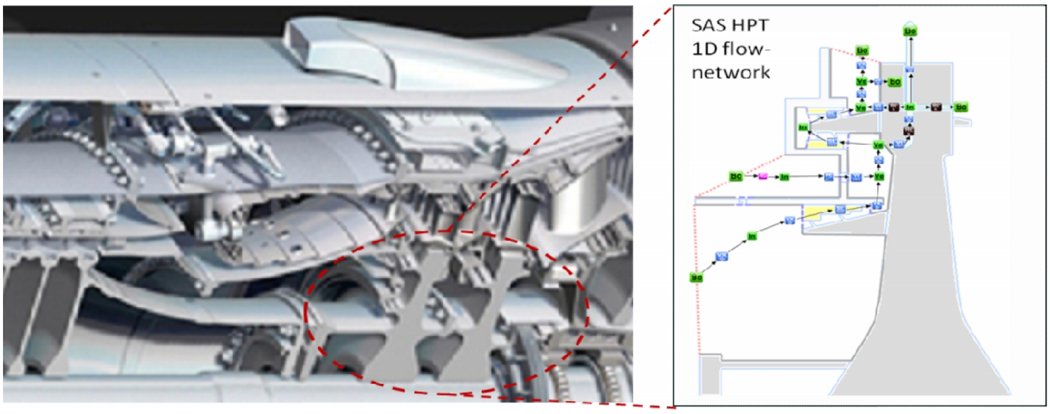

Figure 1: Aero engine 2-stage HPT cutaway (left) & 1D flow network of the HPT front SAS (right). Courtesy of Rolls-Royce Deutschland

A 1D flow network model is used to calculate the power losses of the HPT air feed system, see Figure 1 right. As proposed method in this paper, the 1D model is enhanced with local flow effects from 3D CFD investigations. To this effect, a parametric CFD automated process is set up to conduct sensitivity analysis of the flow field properties. The CFD solution is verified against the experimental cavity flow results from reference [2]. The automated CFD workflow is used to produce the windage correlations that will later be used to enhance the 1D flow network model. In order to validate the CFD-enhanced correlations, they are used as thermal boundary conditions for a HPT FE-model of an actual engine. The investigation results show that the temperature prediction from the CFD-enhanced method is closer to the engine experimental data than those from a traditional method, as presented in Figure 2.

As a conclusion, the comparison between the previous and the enhanced flow network models puts forward the relevance of the local flow field effects in the power losses of the disc cavities. Finally, a sensitivity study of the SAS design parameters is carried out using the CFD-enhanced 1D flow network. This study shows that the SAS design has a significant influence on the HPT overall power losses. Thus, accurately predicting the turbine discs thermal field and SAS power losses is essential to bid a competitive technology in the aero engine industry.

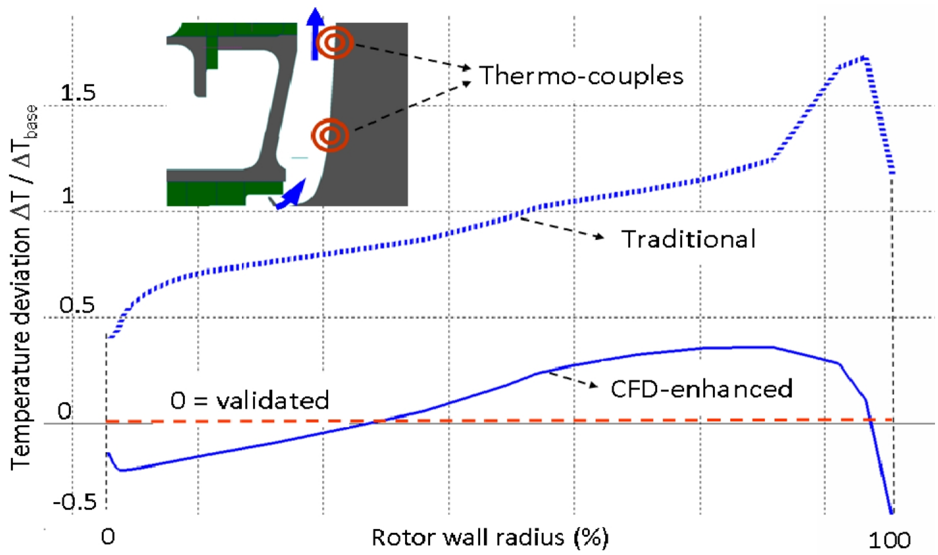

Figure 2: Normalized temperature deviation of CFD-enhanced and traditional FE-models to experimentally validated model, at design operating conditions

REFERENCES

[1] J. M. Owen and R. H. Rogers, Flow and Heat Transfer in Rotating-Disc-Systems – Volume 1: Rotor-Stator Systems. *England: University of Sussex, 1989*.

[2] J. Daily and R. Nece, Roughness and Chamber Dimension Effects on Induced Flow and Frictional Resistance of Enclosed Rotating Disks, *Massachusetts Institute of Technology, USA, 1958*.