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

# MODELING TRANSITION FOR THE DESIGN OF MODERN AXIAL TURBOMACHINES

**Vincent Marciniak, Anton Weber, Edmund Kügeler**

German Aerospace Center (DLR), Institute of Propulsion Technology
Linder Höhe, 51147 Cologne, Germany
Vincent.Marcinak@dlr.de, Anton.Weber@dlr.de, Edmund.Kuegeler@dlr.de

**Key Words:** *Transition Modeling, Compressor, Turbine*

Nowadays, numerical simulations play an essential role in the design of turbomachines because of the complexity of the flow physics involved. Since the Reynolds number and pressure gradients vary greatly inside a turbomachine, transition can, in many cases, have a major influence on the components performance. Therefore, transition must be taken into account during the design phase of turbomachine parts.

Traditionally, low-pressure turbines, due to their low Reynolds number flows, are designed by usage of transition models. Here, the separation-induced and wake-induced transition modes are most likely to occur [7]. For compressors, transition has been so far considered only in exceptional cases. However, the prediction of transition in the front stages is important because it can significantly affect the matching between the stages and finally alter the workload.

Hence, turbomachinery designers need tools which could be used to achieve an accurate prediction of the laminar-turbulent transition. Many computational techniques are available to predict transition. Nevertheless, only the Reynolds Averaged Navier-Stokes (RANS) technique is able to be used in an industrial context, due to the relatively low computational resources required.

The aim of this paper is to present and compare state of the art transition prediction models on industrial relevant test cases. Different turbulence and transition models have been implemented in DLR's in-house turbomachinery specific CFD solver TRACE. The k-ω turbulence model of Wilcox [1] and the k-ω - SST turbulence model of Menter [2] are coupled with the $\gamma-Re_\theta$ transition model of Menter et al. [3]. Some correlations being part of the original transition model had not been released in the first publications. Therefore, in order to close the model, several correlation sets have been published by different authors -for instance [4]- and are implemented in TRACE. The transition model used is extended to simulate multistage turbomachinery components for steady as well as unsteady configurations including different types of outer air sealings. The paper is organized as follows:

First, different combinations of models are validated with the help of cascade measurements for low pressure turbine profiles as well as for compressor blades. Then, a modern two-stage low-pressure turbine [5] and a 4.5-stage transonic compressor (**Fig 1**) are computed at design and off design conditions [6]. In both cases, the computations are compared to experiments (**Fig 2**) and the different results are discussed. Finally, it demonstrates that different transition models implemented in TRACE can be used effectively for the design of turbomachines.

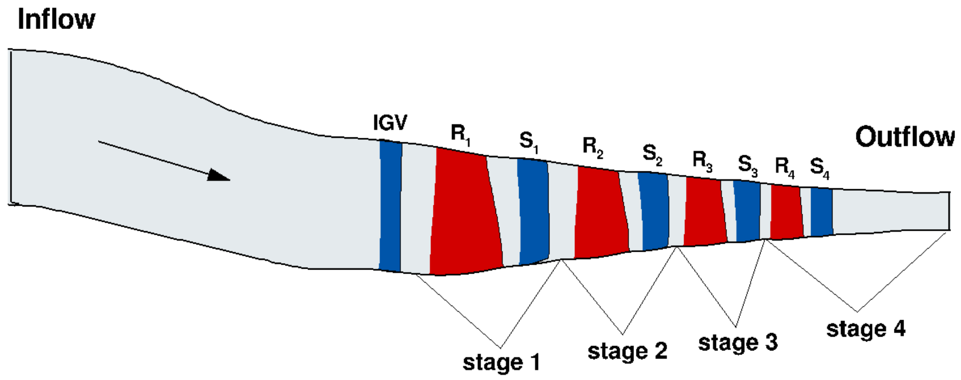


**Figure 1**: Rig 250 - Compressor rig setup

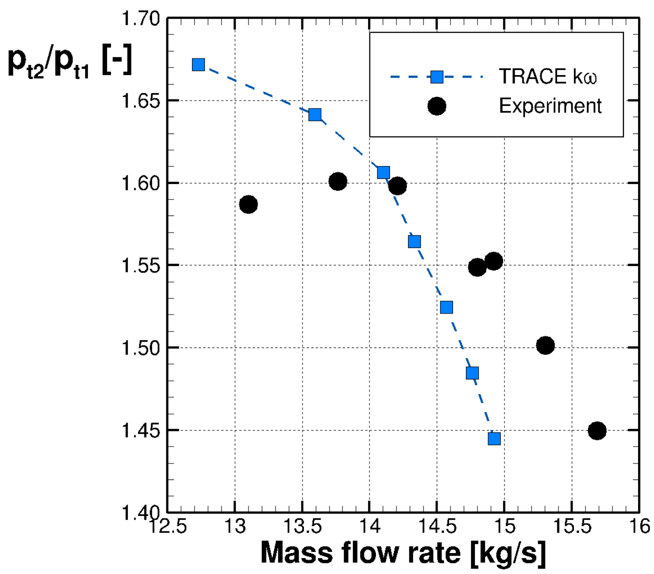


**Figure 2**: Rig 250 - Total pressure ratio for 60% RPM design

## REFERENCES

[1] D. C. Wilcox, "Turbulence Modeling for CFD, Third Edition "DCW Industries (2006)
[2] Menter, F. R., "Two-Equation Eddy-Viscosity Turbulence Models for Engineering Applications," AIAA Journal, Vol. 32, No. 8, August 1994, pp. 1598-1605
[3] F. R. Menter, R.B. Langtry, "Transition Modelling for General Purpose CFD Codes", Flow, Turbulence and Combustion, Vol. 77, pp. 277-303 (2006)
[4] P. Malan, K. Suluksna, E. Juntasaro, "Calibrating the $\gamma$–$Re_\theta$ Transition Model ", ERCOFTAC Bulletin, (September 2009)
[5] Martin Marx et al., "Unsteady Work Processes within a Low Pressure Turbine Vane Passage", ASME-GT2013-94234
[6] T. Röber, "Investigation of Unsteady Flow Effects in an Axial Compressor based on Whole Annulus Computations", ASME-GT2010-23522
[7] R. E. Mayle, "The Role of Laminar-Turbulent Transition in Gas Turbine Engines", ASME-Journal of Turbomachinery V.113, 1991, pp 509-537.