AN APPROACH FOR DIGITALIZED OIL-FLOW VISUALIZATION IN THE LARGE SCALE TURBINE RIG (LSTR)

Jeannette Kruppa
Johannes Eitenmüller
Dominik Ade
Sebastian Leichtfuß
H.-P. Schiffer

Technical University of Darmstadt
Institute of Gas Turbines and Aerospace Propulsion
Otto-Berndt-Str. 2
64287 Darmstadt, Germany
E-Mail: lstr@glr.tu-darmstadt.de

ABSTRACT

Rotor-Stator-Interaction has a crucial impact on the efficiency of jet engines and gas turbines. Numerical investigations to resolve and understand effects of the Rotor-Stator-Interaction are time consuming and affected by model errors. Experimental validation is a key aspect to identify uncertainties of these numerical models and therefore contribute to the development of optimized rotor blades and stator vanes.

For this purpose, flow visualization with oil paint has been conducted on the second nozzle guide vane of the Large Scale Turbine Rig of the Technical University of Darmstadt. The LSTR is a 1.5-stage, low-speed high pressure turbine test rig. The test rig is cold-operated at near atmospheric conditions. The flow visualization data has been acquired for axial turbine inflow at the test rigs design point. For a direct comparison of numerical and experimental results an experimental approach for the conduction of a digitalized oil-flow visualization is presented within this paper.

INTRODUCTION

Current approaches for the optimization of components of high pressure turbines mainly focus on the aerothermal optimization of either rotor blades or stator vanes. Interaction mechanisms between the rotating and non-rotating components are investigated for the result of the numerical optimization in a subsequent step of the design process. Experimental data is crucial for the validation within the numerical design process in order to identify uncertainties of numerical models.

Oil paint has often been used for flow visualizations. Until today the documentation and evaluation has mostly been done based on the two-dimensional pictures. The qualitative comparison between the pictures or with Computational Fluid Dynamics (CFD) results only gave a rough impression of the flow structures and deviations. To improve the handling and the evaluation, the procedure has now been digitalized. Therewith it has been investigated how to transform the 2D pictures of the oil-flow visualization to a 3D object. This improves the evaluation of the now deskewed 3D flow visualization. Furthermore, they can be directly compared to each other or to CFD results.

RESULTS AND DISCUSSION

The 3D transformation is done according to the pattern in fig. 1. It can be distinguished between three parts: calibration, transformation and visualization.

The calibration procedure requires pictures from a calibration blade as well as the digital version of it, the so called virtual points. The calibration blade is geometrically identical to the probed NGV2 vanes. Additionally, a matt painted surface and drill holes were added. The holes were filled with gypsum to increase the contrast between the holes, that are going to be marker points, and the surface of the blade. The diameter of the drill holes was optimized to get the best detection with the MATLAB algorithm. The marker detection correlates the points on the calibration blade from the picture with the virtual points. The calibration determines the transformation from picture to real world coordinates, which is used to lay the oil paint pictures on a digital blade surface that was created in Siemens NX as a FEM mesh. The fineness of the FEM mesh is preset from the resolution of the taken pictures from the oil paint vane. The final step is the visualization.

For the creation of the oil paint pictures pre-investigations for the composition of the oil paint were made. The components of the oil paint were liquid paraffin oil, poppy seed oil and either titanium dioxide or oil paint as color. In the pre-heated rig the duration until reaching the operating point is about six minutes. In this time the oil paint should not dry. Therefore, additional pre-investigations have been conducted to account for the drying of the oil paint within the test rig. Variations of measurement time have been conducted to further optimize the oil paint composition for the final measurements. For the creation of the oil paint pictures two NGV2 vanes of the LSTR were prepared at a time and inserted in the already warmed up rig. The new features upgrade the oil-flow visualization to a modern standard and improve experimental investigations as well as validation of CFD results.

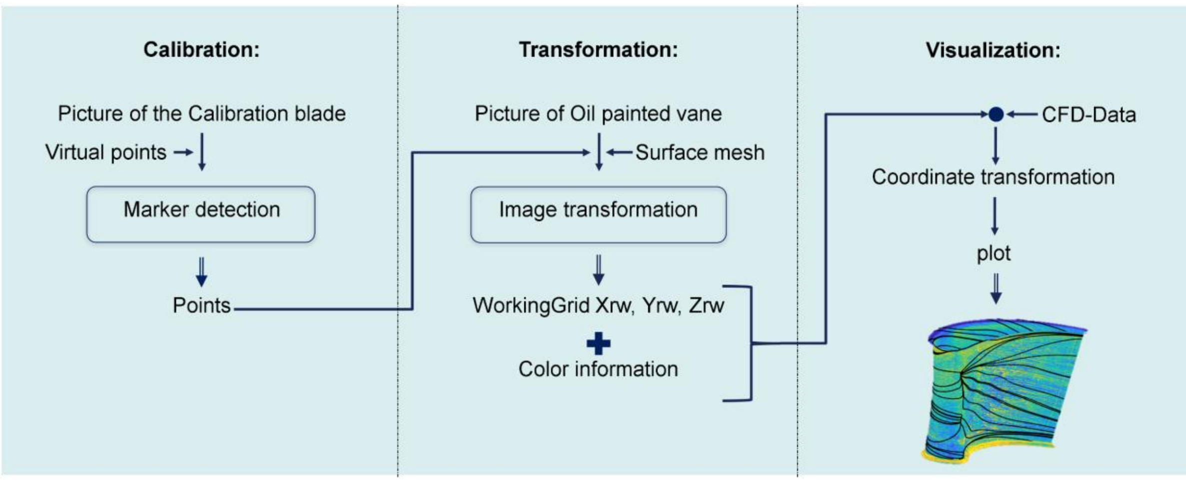

Figure 1. Approach for digitalized oil paint flow visualization