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COMPREHENSIVE GEOMETRIC DESCRIPTION OF MANUFACTURING SCATTER OF HIGH PRESSURE TURBINE NOZZLE GUIDE VANES FOR PROBABILISTIC CFD ANALYSIS

Paul Voigt, Lars Högner, Barbara Fiedler,
Matthias Voigt, Ronald Mailach
Technische Universität Dresden
Institute of Fluid Mechanics
Chair of Turbomachinery and Flight Propulsion
D-01062 Dresden, Germany
Email: paul.voigt@tu-dresden.de

Marcus Meyer
Rolls-Royce Deutschland Ltd & Co KG
CFD Methods
D-15827 Blankenfelde-Mahlow, Germany
Email: marcus.meyer@rolls-royce.com

Alkin Nasuf
GWT-TUD GmbH
D-01307 Dresden, Germany

The increasing demands on jet engines require progressive thermodynamic process parameters, which typically leads to stronger loadings and accordingly to designs with high complexity. State of the art high pressure turbine (HPT) nozzle guide vane (NGV) design involves vane profiles with three-dimensional features including a high amount of film cooling and profiled endwalls (PEW).

Typically, the throat area which governs the engine's capacity is defined in the HPT NGV. Hence, geometric variations due to manufacturing scatter of the HPT NGV's passage can affect relevant aerodynamic quantities and the entire engine behavior. Within the traditional deterministic design approach, the influences of those geometric variations are covered by conservative assumptions and engineering experiences. This paper addresses the consideration of variability due to manufacturing of HPT NGVs through probabilistic CFD investigations.

In order to establish a statistical database, 80 HPT NGVs are digitized with an optical 3D scanning system to record the outer geometric variability. The vane profiles are parametrized by a section based approach. For this purpose, traditional profile theory is combined with a novel method that enables the description of NGV profile variability taking the particular leading edge (LE) shape into account. Furthermore, the geometric variability of PEWs is incorporated by means of principle component analysis (PCA).

On this basis, a probabilistic system assessment including a sensitivity analysis in terms of capacity and total pressure loss is realized. Sampling-based methods are applied in order to conduct a variety of 3D CFD simulations for a typical population of profile and endwall geometries. This probabilistic investigation using realistic input parameter distributions and correlations contributes to a robust NGV design in terms of relevant aerodynamic quantities.

Keywords: nozzle guide vane, manufacturing variation parametrization, Monte Carlo simulation, probabilistic CFD analysis