Characterisation of the Uncertainties of the Operating Conditions in Turbomachinery Design

by

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Abstract

In computational engineering design the robust analysis comprises a prerequisite towards the successful development of future gas turbines. However, reliable determination of the statistical characteristics of variation of the operating conditions in a turbomachine is crucial. Initially, the variability of the physical operating conditions along the operating line on the compressor map can be developed with the assistance of a throughflow analysis tool. The probability density functions of the variability of the pressure profiles, mass flow, input angles, etc. of each individual stage of the compressor can be extracted and processed accordingly for 3D aerodynamic shape robust design at a later stage of the whole design operation. In this way, flexibility in detailed design is developed leading to innovative and creative thinking in modern turbomachinery design, but at the same time the intelligence and level of robust design is improved, and hence the quality of the designed product. For a particular compression system of a turbo-shaft engine all the details can be extracted, along the whole operating line, covering all the possible scenarios of individual operating conditions of each component. With this methodology the appropriate information is developed for robust analysis at the preliminary or detailed design phases of a compression system.

The objective of this work is to define a sequence of processes that need to be performed before the execution of the robust analysis for the detailed aerodynamic, or any other discipline, design optimisation of a particular stage of the gas turbine. The proposed technique comprises a number of computational tools, which can be used individually either to evaluate the performance of a turboshaft and improve the design

in the preliminary stage of the whole design process, or perform statistical and probabilistic analyses for any type of random fields and uncertainty propagation.

In the illustrative case study that is presented here we only consider the random field of the inlet total pressure of the second stator of the particular compressor. This leads to the consideration of three uncertainties, representing the first three most energetic components of this random field. However, the technique can easily be expanded to the consideration of the variation of additional inlet conditions, as well as downstream conditions. In extend, we can design the particular stage of interest in such a way in order to produce smoother downstream conditions for the subsequent stages of the compressor (i.e. minimise the standard deviation of velocity profiles). As a result, we can develop a potentially dynamic robust behaviour of the whole system, and hence the detailed aerodynamic design of the following stages will fit in a generic robust envelope within the compression system of the gas turbine engine.