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PROBABILISTIC FE-ANALYSIS OF COOLED HIGH PRESSURE TURBINE BLADES – PART B: PROBABILISTIC ANALYSIS

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Modern high pressure turbine (HPT) blade design stands out due to high-grade complexity comprising three-dimensional blade features, multi-passage cooling system (MPCS) and film cooling to allow for progressive thermodynamic process parameters. During the last decade, probabilistic design approaches became increasingly important in turbomachinery to incorporate uncertainties such as geometric variations caused by manufacturing scatter.

In Part B of this two-part paper, real geometry effects are considered within probabilistic finite element (FE) analysis that aims for sensitivity evaluation. The knowledge about the geometric variability is derived based on a blade population of more than 400 individuals by means of parametric models and the subsequent statistical analysis that are shown in part A. This allows for sensitivity analysis and robustness evaluation taking the variability of the airfoil, endwalls at hub and shroud, wedge surfaces and the MPCS into account.

Within this scope, the probabilisitic method – Monte-Carlo Simulation (MCS) using extended Latin Hypercube Sampling (eLHS) technique – is presented firstly. Based on this, the fully automated process chain involving CAD model creation, FE mesh morphing, FE analysis and post-processing is passed through. Here, the mesh morphing process is presented involving a discussion of mesh quality. Subsequently, the FE model that involves thermal, stress and creep analysis is described briefly.

Finally the results of the probabilistic simulation are evaluated in terms of sensitivities and robustness. For this purpose, regions of interest (RoI) are determined, wherein the statistical analysis is conducted. A remarkable influence of the considered geometric uncertainties onto mechanical output quantities is observed which motivates to incorporate these in modern design strategies or robust optimization.

Keywords: Probabilistic analysis, FE analysis, uncertainty quantification, manufacturing variation, real geometry effects