FLOW FIELD CHARACTERIZATION IN HIGH-ASPECT-RATIO SINGLE-SIDED RIBBED MULTI-PASS TURBINE BLADE COOLING CHANNELS USING PARTICLE IMAGE VELOCIMETRY

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ABSTRACT

The continuous increase in turbine inlet temperatures has placed growing demands on the performance of internal cooling systems used in modern gas turbine blades. Among the various cooling concepts employed in industrial gas turbines, rib-roughened multi-pass channels remain one of the most widely adopted solutions due to their ability to enhance heat transfer through flow disruption and turbulence generation. The resulting flow field is governed by a complex interaction between rib-induced secondary motions, passage geometry, and flow turning within successive bend sections. Although numerous studies have reported global pressure-loss and heat-transfer characteristics for ribbed cooling channels, comparatively few investigations have provided detailed velocity-field measurements capable of revealing the underlying flow mechanisms, particularly for high-aspect-ratio multi-pass geometries representative of modern wall-integrated cooling concepts.

The present work aims to experimentally characterize the flow field within a three-pass rectangular cooling channel using planar particle image velocimetry (PIV). The investigated geometry consists of three passages connected by two 180° turning sections and incorporates single-sided rib turbulators together with bend guide vanes. The configuration is representative of internal cooling passages encountered in advanced turbine blade designs, where geometric constraints frequently lead to elongated channel cross-sections and complex turning flows.

The study systematically investigates the influence of three key design parameters on the internal flow structure. Three channel aspect ratios, AR = 3.7, 5.0, and 7.5, are examined together with three rib topologies, namely V-ribs, W-ribs, and staggered V-ribs. In addition, guide vanes with 180°, 135°, and 90° spans are considered to assess their influence on flow turning and redistribution within the bend regions. Measurements are performed on the horizontal mid-plane of the channel ($z/D_h = 0.5$), providing spatially resolved velocity information throughout the passages and turning sections.

The PIV measurements will be used to obtain mean velocity fields, velocity fluctuations, turbulence statistics, and recirculation patterns across the investigated configurations. Particular attention will be given to flow acceleration, separation, reattachment, and redistribution phenomena induced by ribs and bends, as well as the interaction between passage aspect ratio and guide-vane design. The resulting dataset will provide detailed insight into the development of the flow through successive passages and turning sections and help explain previously observed thermal-hydraulic performance trends in similar cooling geometries.

Beyond improving the physical understanding of ribbed cooling flows, the measurements will establish a high-quality experimental database for the validation of computational fluid dynamics simulations and future investigations of flow-driven thermal-hydraulic performance in ribbed cooling channels. The work is expected to contribute new experimental evidence regarding the influence of rib topology, channel aspect ratio, and bend-vane geometry on the flow behavior of high-aspect-ratio turbine blade cooling channels operating under engine-relevant conditions.

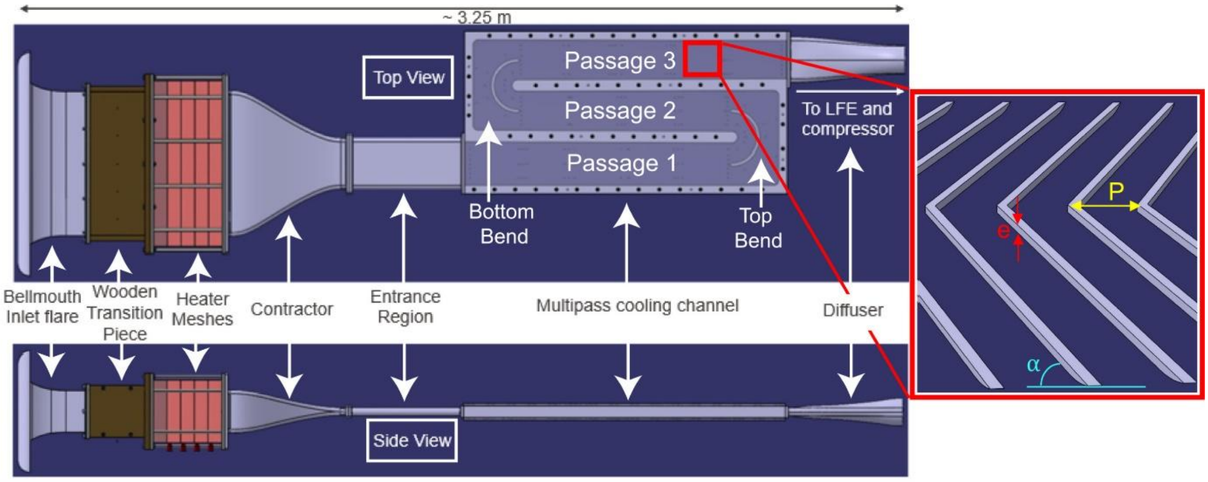

Figure 1: Schematic of the experimental facility and three-pass cooling-channel test section. The flow enters through the contraction, passes through three ribbed passages connected by two 180° turns, and exits through the diffuser. The inset illustrates the rib geometry definitions used throughout the study.