Flow Visualization for the Endwall Region of a First-Stage Vane with an Entrance Step

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ABSTRACT

Due to its much shorter starting time than that of a steam turbine, a gas turbine is frequently used to provide additional electricity during daily pick-load period. For such a varying load gas turbine, damage of the first stage vanes is found to happen much earlier than the expected lifetime. The reason for the damage is not fully understood yet. Many researchers have pointed out that the flow near the endwall of a vane is three-dimensional and complicated, including secondary flows such as horseshoe vortices, passage vortex, wall vortex, and corner vortex, and the interaction of these vortices. The formation of these vortices, however, is intimately tied to the development of the upstream boundary layer along the endwall. A design that fully ignores the possibility of the occurrence of an entrance step is obviously not appropriate. Experiments were conducted in this work to investigate the three-dimensional flow field near the endwall region of a first stage guide vane of a gas turbine. Multiple smoke wires together with a laser light sheet were used to visualize the flow structure in that region for the cases with and without an entrance step condition. Results show that the observed flow structure for the case with a smooth entrance condition (i.e., no entrance step) agrees with the existing literature. With either a backward or a forward-facing entrance step, flow reattachment occurs on the endwall after the step. The distance of the reattachment point from the step and, thus, the size of the recirculation bubble increase from the pressure side to the suction side. The combined effects of the reattachment in the main flow direction and the cross-stream pressure gradients result in mixing of fluid in the recirculation zone as well as premature formation of the passage vortex system. As a result of this, the passage vortex near the trailing edge of the suction surface has a remarkable increase in its size.

Keywords : guide vane, endwall region, entrance step, multiple-smoke wires, three-dimensional flow field

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