Three-Dimensional Flow of a Turbine Nozzle at Low Reynolds Numbers (Effect of Turbulence Intensity on Loss and Flow Mechanisms)

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1. Introduction

Blade Reynolds numbers for the turbine stage of small-sized gas turbine engines can drop below 10^5. At these low Reynolds number conditions, the boundary layer is dominated by laminar flow and is susceptible to flow separation, which is associated with increased loss and reduced performance. Freestream turbulence intensity is considered to be one of the important parameters in determining the aerodynamic characteristics of turbine cascades, because this turbulence is particularly high in gas turbines.

In this research, aerodynamic measurements were conducted to evaluate the performance of an axial-flow turbine nozzle, with a focus on the influence of freestream turbulence intensity at low Reynolds numbers.

2. Experimental Method

The inlet flow condition was measured using a 3-hole pressure probe. The wake traverse was carried out at 15.6% chord downstream of the trailing edge using a miniature 5-hole pressure probe and a single element hot-wire anemometry. The turbulence intensity was varied between 0.5% and 8.9% by modifying turbulence generation sheet settings.

3. Results and conclusions

Figures 1 (a) to (c) present the distributions of the total pressure loss at the nozzle exit at three freestream turbulence intensities. Increased separation on the suction surface and decreased secondary vortices near the endwalls were observed at higher turbulence intensity. Instantaneous velocity signals proved the transformation of the flow mechanisms in separation zone.

Figure 2 shows the effect of the turbulence intensity on the passage mass-averaged losses. The turbulence intensity was found to have had negligible effect on overall total pressure loss. Since the increase in profile loss (separation) and the decrease in net secondary loss (secondary vortices) offset each other, the net overall loss remained almost constant.

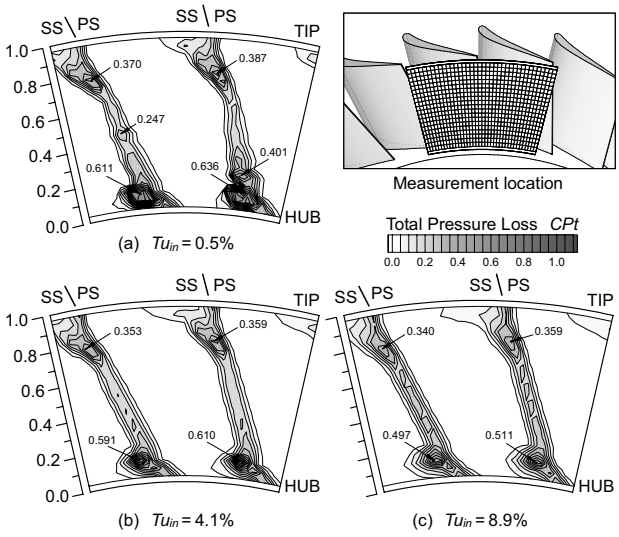

Fig. 1 Measurement location and distributions of total pressure loss at nozzle exit (exit Reynolds number, Re_{out} = 13.6 x 10^4)

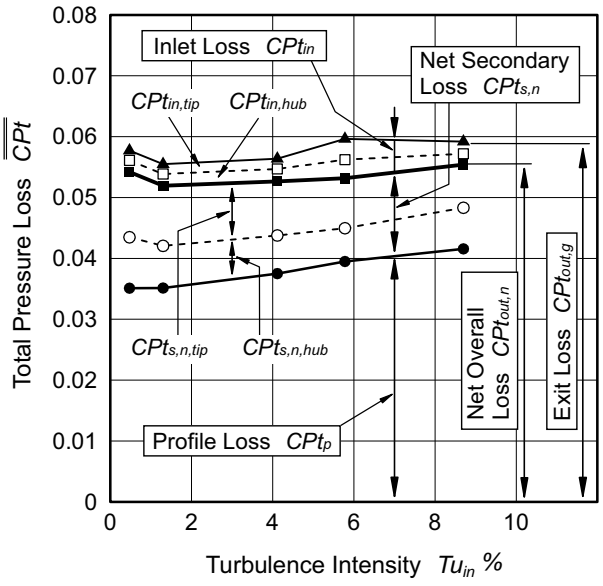

Fig. 2 Effect of turbulence intensity on losses

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