Three-Dimensional Flow of a Turbine Nozzle at Low Reynolds Numbers (Effect of Reynolds Number 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. In this study, detailed experiments under low Reynolds number conditions, Re_{out} = 4.5×10^4 ~ 27.1×10^4, have been conducted to evaluate the performance of an annular nozzle of axial-flow turbine.

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 measurement location at the nozzle exit is shown in Fig.1 (a).

3. Results and conclusions

Figures 1 (b) to (d) present the distributions of the total pressure loss at the nozzle exit at three Reynolds numbers. The total pressure loss at the trailing edge increased as the Reynolds number decreased, due to the growth of the boundary layer thickness on the nozzle surface, and due to the increase in the separation zone on the suction surface (indicated by "SS"). The regions of high total pressure loss spread near the hub and tip endwalls of the suction surface because passage vortices swept up the inlet endwall boundary layer fluid on the suction surface.

Figure 2 shows the effect of the Reynolds number on the passage mass-averaged losses. The net overall loss at Re_{out} = 4.5×10^4 (0.0770) was 1.8 times larger than that at Re_{out} = 27.1×10^4 (0.0424).

The Reynolds number had a significant effect on the total pressure loss and the aerodynamic mechanisms of the turbine nozzle at low Reynolds numbers. The total pressure loss and turbulence intensity increased rapidly and the nozzle exit flow velocity and flow angle decreased as the Reynolds number decreased.

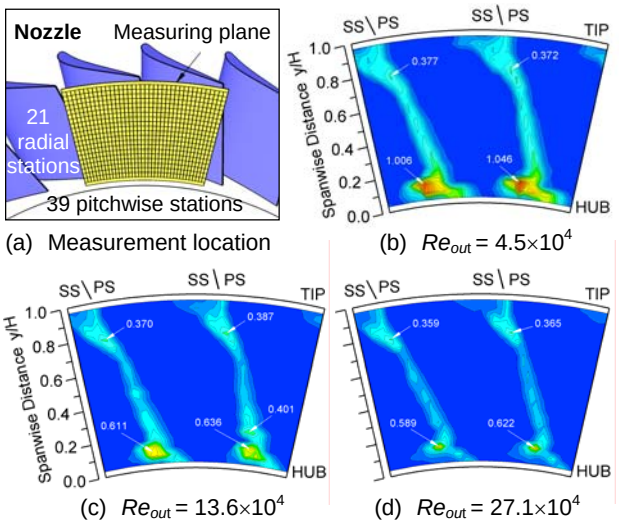

Fig. 1 Measurement location and distributions of total pressure loss at nozzle exit

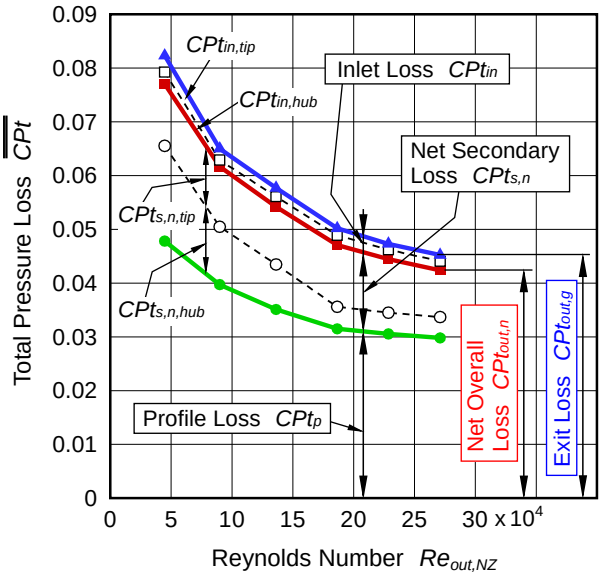

Fig. 2 Effect of Reynolds number on losses

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