Effects of Tip Clearance Size on Active Control of Turbine Tip Clearance Flow Using Ring-type DBD Plasma Actuators

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Long Abstract

Introduction

The application of dielectric barrier discharge (DBD) plasma actuators has been developed from fundamental studies to a wide range of applications [1]; among these, major targets are separation control and drag reduction. Tip leakage flow through the small gap between the blade tip and the casing wall in turbomachinery reduces the aerodynamic performance of the blade [2]. Ring-type DBD plasma actuators have been developed to facilitate active control of the tip leakage flow of a turbine rotor [3]. Figures 1 shows the ring-type plasma actuator for tip clearance flow reduction in an axial-flow turbine rotor. Metallic wires coated with insulation material, to which high voltages are applied, are mounted in a ring-shaped insulator embedded in the casing (tip endwall). All of the conductive materials, such as the turbine blades, drive shaft, and casing wall, are connected to the ground for safety. When high voltages at high frequencies are applied to the metallic wires, the tip of the turbine rotor takes on the role of a ground electrode, and glow discharge plasma is formed between the metal wire in the casing wall and the tip of the turbine blades.

1. Experimental Methods

Figure 2 shows the test section of a low-speed, open-circuit, blower-type system. A metallic flat plate was installed in the test section of the wind tunnel with a tip clearance width at the bottom end. A string-type plasma actuator array was attached to the acrylic bottom endwall as a two-dimensional model of a ring-type plasma actuator. The plasma actuator array was excited with quasi-rectangular waveform from a power supply. Particle image velocimetry (PIV) was used to obtain two-dimensional velocity field near the plate tip regions.

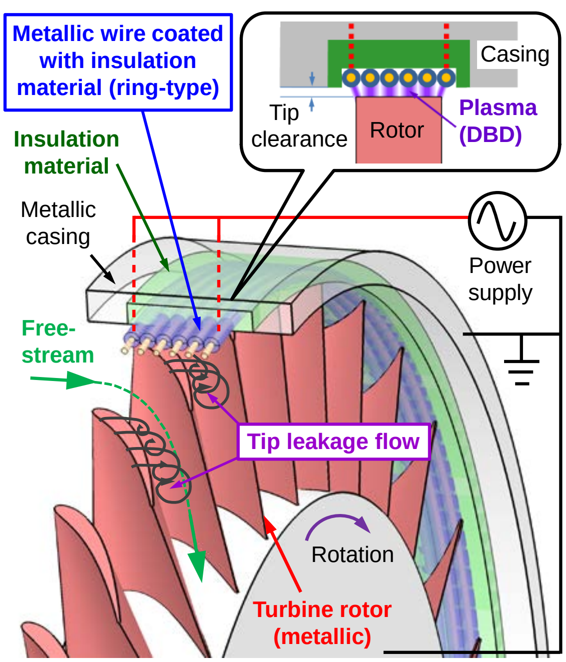


Figure 1. Ring-type DBD plasma actuator

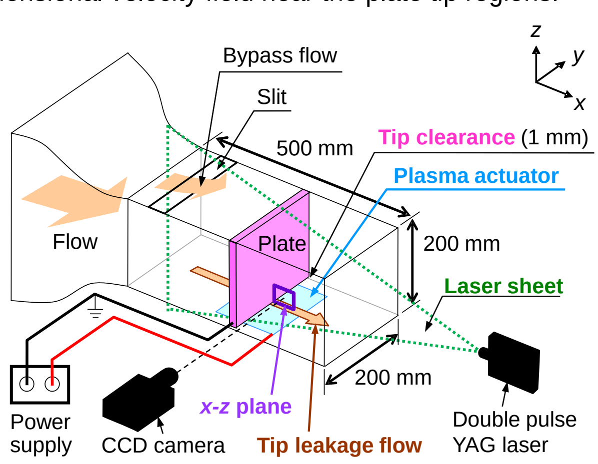
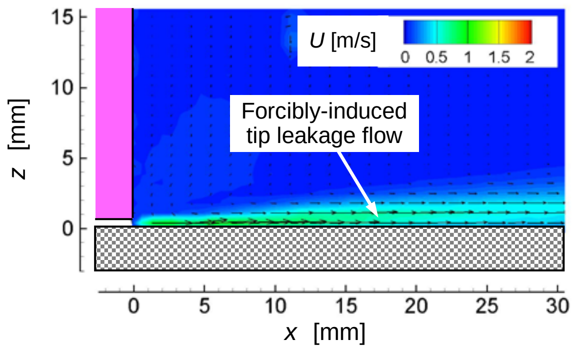
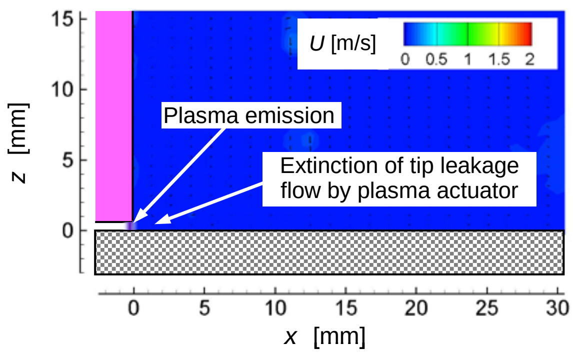


Figure 2. Measurement system for flat plate with tip clearance



(a) No control

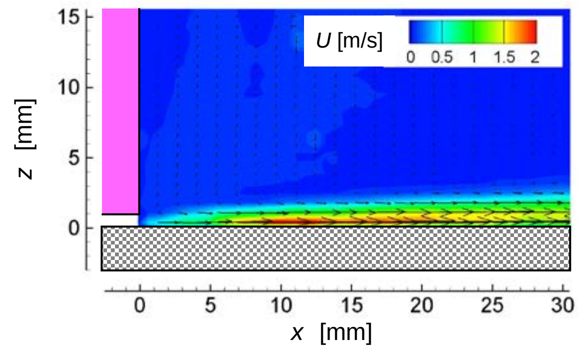


(b) Flow control ($V_{p\text{-}p} = 10$ kV, $f_p = 10$ kHz)

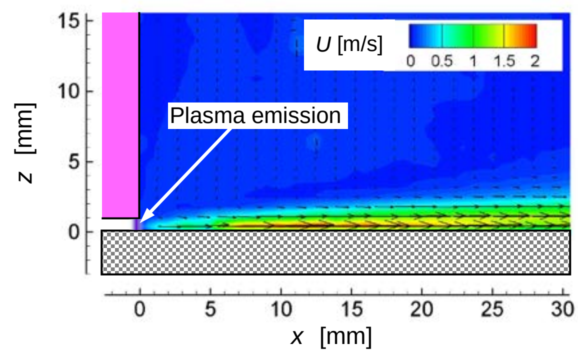
Figure 3. Time-averaged velocity distributions near tip clearance exit of flat plate (tip clearance size: 0.6 mm)

2. Results

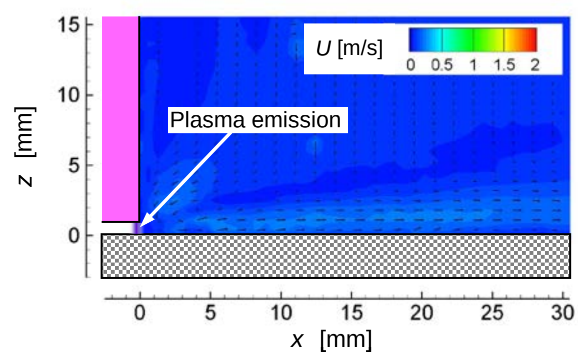
Figures 3 and 4 show the time-averaged velocity distributions near the tip of the flat plate. The tip clearance size is 0.6 mm (Fig. 3) and 1.0 mm (Fig. 4), respectively. As shown in Fig. 3(a) and Fig. 4(a), tip leakage flow is forcibly induced through the operation of the wind tunnel. The tip leakage flow is dissipated by the plasma actuator, as shown in Fig. 3(a) and Fig. 4(c). The larger tip clearance size requires the higher applied voltage in order to reduce the tip leakage flow.



(a) No control



(b) Flow control ($V_{p\text{-}p} = 10$ kV, $f_p = 10$ kHz)



(c) Flow control ($V_{p\text{-}p} = 12$ kV, $f_p = 10$ kHz)

Figure 4. Time-averaged velocity distributions near tip clearance exit of flat plate (tip clearance size: 1.0 mm)

Acknowledgments

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References

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