Effects of Duty Ratio on Tip Leakage Flow Control of Gas Turbine Rotor Blades Using Ring-type DBD Plasma Actuators

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Tip leakage flow through the small gap between the rotor blade tip and the casing endwall in a gas turbine reduces the aerodynamic performance of the blade. "Ring-type" dielectric barrier discharge (DBD) plasma actuators have been developed to facilitate active control of the tip leakage flow of a turbine rotor.

Figure 1 shows a comparison of conventional "sheet-type" and newly developed "string-type" DBD plasma actuators. A conventional "sheet-type" DBD plasma actuator consists of a dielectric layer sandwiched between exposed and encapsulated electrodes. A "string-type" DBD plasma actuator (patent US20150267727A1) consists of a stringy metallic wire coated with insulating material, instead of a flat encapsulated electrode [1]. When the wires are attached to a metallic material, the exposed electrode is unnecessary because the conductive surface itself is utilized as the exposed electrode. If elastic materials such as silicone resin and polytetrafluoroethylene (PTFE) are utilized as wire insulation materials, it is possible to attach wires flexibly to two- or three-dimensional surfaces of various fluid machines.

Figures 2 shows the newly developed "ring-type" plasma actuator (patent US20170326989A1) for tip clearance flow reduction in a gas turbine rotor [2]. Metallic wires coated with insulation material, to which high voltages are applied, are mounted in a ring-shaped insulator embedded in the casing endwall. All of the conductive materials, such as the turbine rotor blades, drive shaft, and casing wall, are connected to the ground for electric 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. Glow discharge plasma is formed between the metal wire in the casing wall and the tip of the turbine rotor blades, and blocks the leakage flow through the tip clearance.

Figure 3(a) shows the measurement system for flat plate experiments, which is a fundamental 2-dimensional model of the ring-type plasma actuators. Figure 3(b) shows the effects of duty ratio on absolute velocity distributions of the leakage flow at the exit of the flat plate tip. Tip leakage flow is gradually reduced as the duty ratio of the plasma actuator operation is increased.

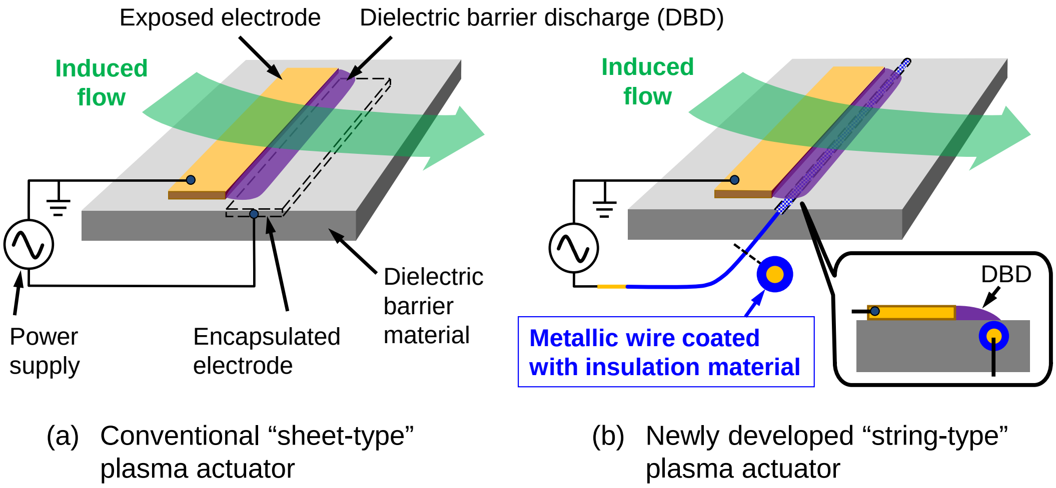


Figure 1: Comparison of sheet-type and string-type plasma actuators.

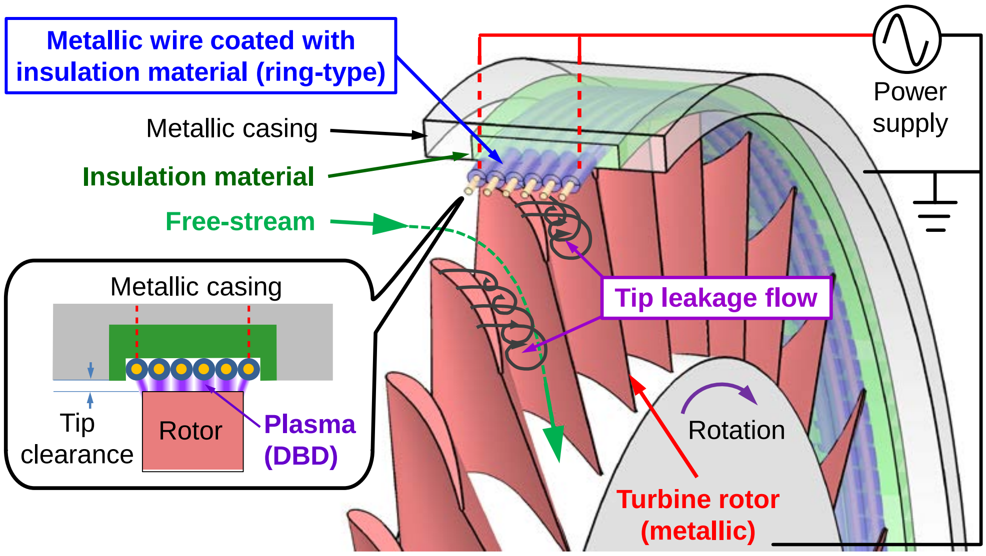
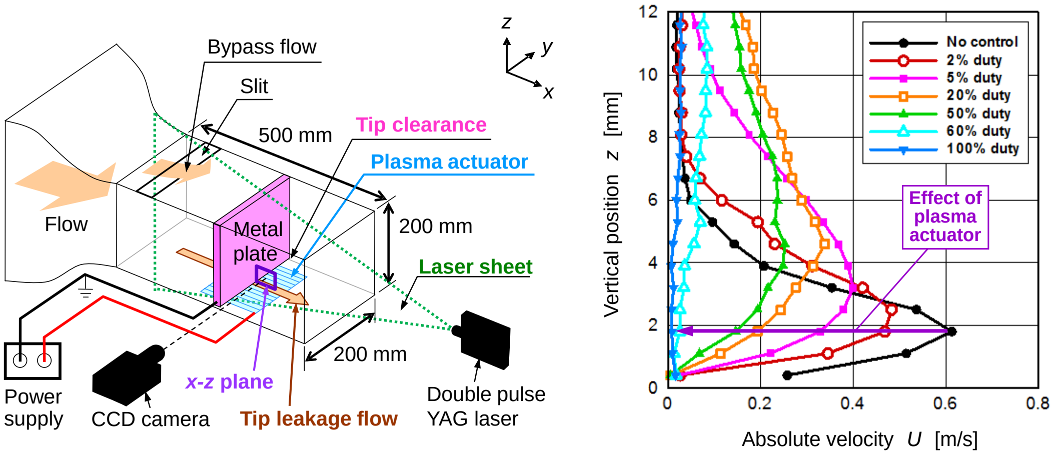


Figure 2: Ring-type plasma actuator.



(a) Measurement system for flat plate with tip clearance (2-D model of ring-type plasma actuator)

(b) Absolute velocity distributions at x = 35 mm, input voltage 14 $kV_{p\text{-}p}$, frequency 10 kHz, tip clearance 0.6 mm

Figure 3: Effects of duty ratio on fundamental flat plate experiments.

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References

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