Control of Vortex Formation in Axisymmetric Jet by DBD Plasma Disturbance

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Abstract The purpose of this study is to control large vortex structure in an axisymmetric jet. To provide the velocity disturbance to the large vortex structure, we applied a coaxial type plasma actuator to the disturbance source. The coaxial type plasma actuator was composed of two round shape electrodes and a dielectric. Various diameter of round shape electrodes of 30, 40 and 60mm were installed in the nozzle of the axisymmetric jet.
We investigated the vortex formation and the diffusion by flow visualization and hot-wire measurement. The maximum velocity of induced jet by the coaxial type plasma actuator reached to about 0.25m/s. In the case of electrode of 30mm, large vortex was generated near the nozzle exit. On the other hand, the electrode of 40mm diameter retarded the vortex formation. This result suggested that roll-up of large vortex was able to control by DBD plasma disturbance. The turbulent intensity measured by I-type hot-wire anemometer showed the maximum value enhanced by plasma disturbance.
Keywords: Axisymmetric jet, Vortex, Plasma actuator

1 Introduction

The jet flow and its large “roll-up vortex” structure are widely used in industrial applications, such as mixing, heating, cooling and combustion. In general, disturbances to enhance the turbulence characteristics of jet are provided acoustically or mechanically, for example, by a speaker and a mechanical flap. We focus on the DBD Plasma actuator as a disturbance sources. DBD Plasma actuator is a novel flow control device which consisted of two electrodes and a dielectric. For flow control, DBD plasma actuator has a lot of advantages such as quick response by electrically driven, light weight and easy installation with simple structure. Especially, the degree of free designability with electrode shape is suitable to set up on various location for fluid machinery. Here, a coaxial type plasma actuator, which consists of round shape electrodes, are able to induce azimuthal jet. Segawa et al. have developed the coaxial type electrode which they called it a doughnut shaped electrode and investigated flow properties of induced jet [1] . Miyagi et al. also studied the relationship between the diffusion of axisymmetric jet and the momentum changes which was excited by the round shape DBD plasma actuator [2]. Here we aaplied the coaxial type DBD plasma actuator as a velocity disturbance sources. The vortex fromation and the diffusion of axisymmetric jet was measured by flow visualization and hot-wire measurement.

2 Experimental setup

The experiment was conducted in the axisymmetric jet with round nozzle. Figure 1 shows the schematic diagram of axisymmetric jet setup. The radius of the round nozzle exit R_0 was 10 mm. The origin of coordinate system was set to the center of nozzle exit. The x-axis and r-axis were corresponded to the streamwise and the radial direction respectively. The time-mean velocity at nozzle exit was set to 1.5 m/s.

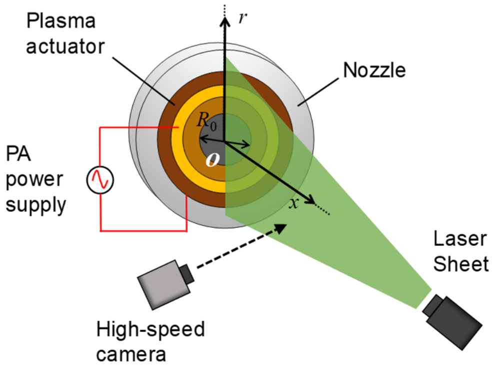

Fig. 1 Experimental setup of axisymmetric jet disturbed by coaxial type DBD plasma actuator

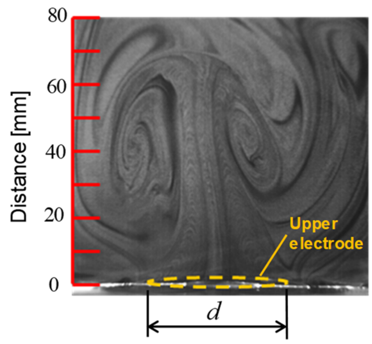

Fig. 2 Disturbance induced by coaxial type plasma actuator in the quiescent air (d = 60mm)

The diameter of round shape electrode *d* was varied in 30, 40 and 60mm. Driving conditions of the plasma actuator were the applied voltage of 3.0 kV and the frequency of 5.0 KHz. The burst frequency generated the plasma disturbance of 38Hz was chosen because the roll-up frequency of large vortex structure was observed in our axisymmetric jet setup. This is the “prefered frequency” is a natural frequency that an axisymetric jet was more enhanced by the velocity disturbance. Crow and Champagne generalized the prefered mode by experiments and instability analysis [3]. Duty ratio which was the time interval ratio of the plasma jet turned on and off was 50%.

3 Results

As the preliminary study, the coaxial type plasma actuator was driven in the quiescent air. Figure 2 shows the behavior of induced disturbance by the coaxial type plasma actuator. The induced jet collided each other at the center of round shape electrode, blowing to upward direction. The maximum jet velocity was about 0.25 m/s when the electrode diameter *d* was the smallest of 0.30 mm. The velocity of induced jet was increased when the diameter of electrode was small. It was founded that the jet velocity became almost constant of 0.05 m/s as the electrode diameter was getting larger than 40 mm. This is because the plasma induced jet decay at the center of co-axial type plasma electrode. Figure 3 shows the flow visualizations of axisymmetric jet by DBD plasma disturbance. At first, in the baseline case without disturbance, the roll-up position of the large vortex was about 6.7 x/R_0. However, in the case of small electrode of 30mm, the roll-up position came near to the nozzle exit. On the other hand, the electrode of 40mm disturbance suppressed the vortex formation. This result suggested that roll-up of large vortex was enhanced or suppressed by DBD plasma disturbance.

4 Conclusions

It was found that the velocity disturbance generated by coaxial type plasma actuator controlled large vortex formation in axisymmetric jet. The small diameter of the plasma electrode generated large velocity disturbance, enhancing the roll-up vortex. While the large electrode with small disturbance suppressed the formation of vortex. The turbulent intensity which was measured by I-type hot-wire anemometer showed the maximum value which was enhanced by plasma disturbance.

References

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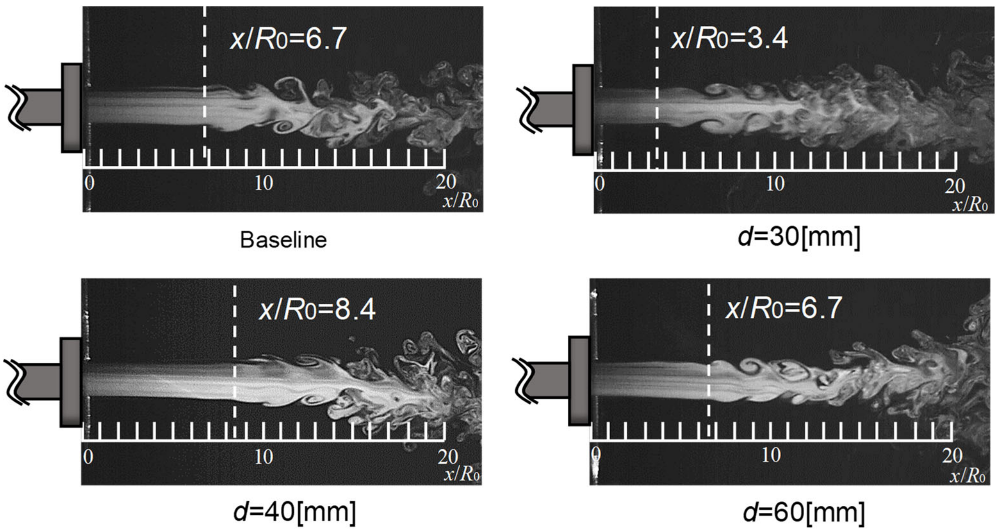

Fig. 3 Flow visualization of vortex formation in axisymmetric jet disturbed by plasma disturbance.