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Flexible DBD plasma actuator for energy saving application

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ABSTRACT

Flexible DBD plasma actuator was developed to save energy losses of a fuel cell, wind-turbine, solar panel and chemical reactor. DBD actuator requires flexibility to install on bending shape. Separation flow is generated easily on the sharp incline. The flexible DBD actuator was designed using the different dielectric barrier because the actuator performance is dependent on the dielectric constant. Ionic wind velocity was measured using a pitot-tube to evaluate the performance of flexible DBD actuator on dielectric surface. The optimal operating condition was investigated as changing the applied voltage amplitude, frequency and electrode distance.

1. INTRODUCTION

Many researchers are in progress in order for energy saving because fossil fuel was rising in oil costs. One of the methods is that the flow is controlled to improve energy efficiency. Airline, train and ship field are endeavored to reduce aerodynamic drag for improving energy efficiency as a changed model. Aerodynamic drag is generated on most of the transportation. Skin friction account for 40% of the aerodynamic drag and pressure drag accounts for 60% of aerodynamic drag. In ground vehicle case it is known that 50% of total energy is consumed to overcome drag and aircraft consumed 90% of total energy. Vortex generator installed for reduction of pressure drag is known as less than 10% of reduction drag (Richard M 2004). The above method was limited because of shape restrictions. So many researchers have investigated about active technologies.

One of DBD plasma actuator among active technologies is many attentions to many fields because DBD plasma actuator has many advantages. For example, heating energy is small due to low temperature plasma and also a flexible actuator is not additionally weighted compared to the current active technology. Moreover, the pressure drag as well as boundary layer can be controlled using the actuator. The

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maintenance is simple and it can be produced at low cost because structure is not complex.

Structure of flexible DBD actuator consists of two electrodes and a dielectric. Two electrodes are asymmetrically located on the dielectric and then plasma was generated on dielectric surface so that wind is generated by corona discharge. This wind is called "electric wind" or "ionic wind" (J. Pons 2005). The ionic wind was produced due to colliding electrons to gas molecules between the electrodes. Electric wind was found in 1709 by Hauksbee and was defined by Robins (MYRON 1961). It is defined as follows:

$$v_G = g \times \sqrt{\frac{i}{\rho b}} \qquad (1)$$

Reduction of drag is possible as high velocity of electric wind generates strong vortexes. Many researches have been conducted so as to improve performance of DBD plasma actuator. Exposed electrode diameter of DBD plasma actuator was investigated. A system in which AC and DC voltage were simultaneously applied was developed by Moreau et al. DBD actuator was analyzed in terms of the electrode geometry and waveform (M. Forte 2007). The increase in velocity of ionic wind through array of electrode was conducted (Flint O 2009).

In this paper, profile drag was minimized using a flexible thin-film used as a dielectric. The flexible DBD actuator can be installed easily on complex models as the film has flexible properties.

2. Experiment

Fig. 1 shows the schematic of experiment set up for operating flexible DBD actuator. Three types of dielectric having the different permittivity were used such as PVC (polyvinyl chloride) film, PP (polypropylene) film and PC (Polycarbonate) film. Width and length of dielectric were fixed as a same size of 5x18 cm. High-voltage amplifier (Trek 20/20C) was used to generate the plasma. Voltage and frequency were controlled by a function generator (Agilent 33220A). High-voltage and current sensors were installed and recorded by Oscilloscope (LeCroy). Pitot-tube was used to measure the velocity of ionic wind, which was measured at 8 point along x-axid.

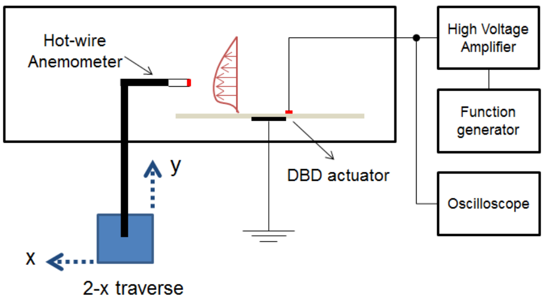

Fig. 1 Schematic of the experimental setup for evaluating the flexible DBD actuator

Table 1 Dielectric specification

	Permittivity	*Thickness (μm)*	*Electrode gap (mm)*
PP	1.5	410	5, 7, 10
PC	2.9	80	5, 7, 10
PVC	3.4	180	2~5,10

3. Experiment result

3.1 Effect of voltage and frequency

Table.1 shows the dielectric specifications. Thickness of dielectric was different and its permittivity was also different. Fig. 2 shows the actuator performance as increasing voltage. All actuators increased in velocity as increasing the voltage. Maximum velocity of each actuator was different. Required voltage was different initially to generate ionic wind. Actuator using PC material generated approximately 1.5 m/s of ionic wind at relatively low voltage. On the other hand, PP generated 1.0 m/s of electric wind when 16 kV of voltage was applied to the electrode.

Excellent performance was shown in the order, PVC, PC and PP. The reason for the different performance can be explained by thickness of dielectric and material type. Resistance of a solid dielectric was reduced; as a result, solid dielectric was destroyed due to increasing temperature by current and electron avalanche. These phenomena are determined by the thickness and material type. Thus, the thickness and material type was involved in the performance.

Fig. 5 shows the actuator performance according to the frequency. Velocity of ionic wind was faster by increasing the frequency. However, flexible actuator using high frequency was easily heating and destroyed. Thus, operating condition should be within appropriate frequency.

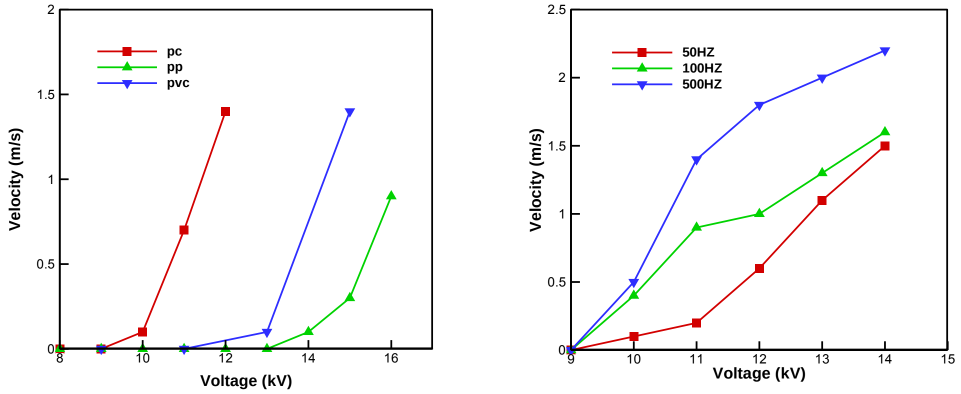

Fig. 2 Velocity profile as discharge condition

3.2 Effect of electrode gap

Fig. 4 shows the velocity and power dissipation of the flexible DBD actuator in a function of electrode distance. Voltage (13 kV) and frequency (100 HZ) are fixed. Velocity was faster by increasing the voltage but the velocity was reduced gradually by increasing the electrode gap. Ionic wind was not generated when the electrode gap increased in 7mm. We were confirmed that more high voltage was required for generating the plasma. Power consumption was largest when the actuator had an electrode gap of 3 mm but the actuator used a little power by increasing the electrode gap. As a result, the high voltage was required as the electrode gap increased but this confirmed that the high velocity was obtained when more high voltage was applied. Appropriate design was needed since the actuator installation was complex as well as a high voltage was required when the electrode gap increased highly.

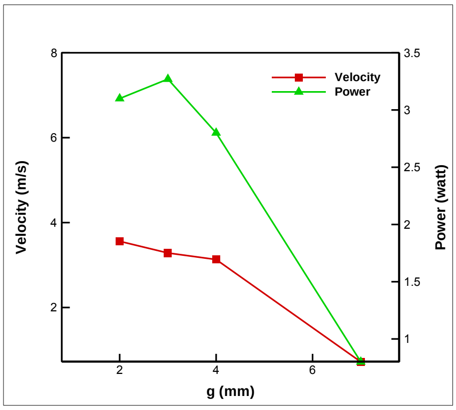

Fig. 3 Velocity profile as electrode gap condition

4. Summery

In this paper, a flexible actuator was produced for energy savings and performance evaluation was conducted as discharge condition and geometry. Actuators should be considered because the performance depends on thickness and material. Looking for ideal dielectric and actuator is made for powerful plasma actuator.

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