ATTITUDE CONTROL OF UAV USING DBD PLASMA ACTUATOR

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Keywords: *DBD plasma actuator, UAV*

Abstract

The applicability of the attitude control of unmanned aerial vehicle (UAV) using dielectric barrier discharge (DBD) plasma actuator was investigated using a low speed wind tunnel at JAXA. The test flow speed was 7.0 [m/s]. The wingspan of the test vehicle is 2400 [mm]. The test vehicle is mounted on the sting through the spherical rolling joint. By using this mount system, the attitude of the vehicle changes according to the change of the aerodynamic force. In the wind tunnel experiments, the onboard sensor measured the attitude of the vehicle. The results suggest that DBD plasma actuator could affect the aerodynamic characteristics of the main wing and the attitude of the vehicle.

1 Introduction

Dielectric Barrier Discharge (DBD) plasma actuator has become popular for suppression of the flow separation around the airfoil at high angle of attack [1], which is expected to improve the aerodynamic performance of Unmanned Aerial Vehicle (UAV) flying at high angle of attack. There have been numerous studies for DBD plasma actuator. Most of them are focused on the suppression of the flow separation around the airfoil. But the airfoil that may cause a severe flow separation will not be selected for design of the UAV. In other words, most of the airfoil used for UAV will not cause a severe flow separation. This indicates that the aerodynamic performance of UAV will not be improved if the DBD plasma actuator is used just for suppression of the flow separation around the airfoil at high angle of attack.

The DBD plasma actuator is mainly used for suppression of the flow separation by adding the induced flow to main flow inside the boundary layer as shown in Fig. 1. Of course, the direction of the induced flow is almost same as the main flow. If the direction of the induced flow is opposite to the main flow as shown in Fig. 2, the flow separation will be initiated, which may increase the aerodynamic drag and reduce the aerodynamic lift. This means that DBD plasma actuator could change the aerodynamic force and, as a result, the aerodynamic characteristics of UAV even at low angle of attack. In other words, DBD plasma actuator could control the attitude of UAV. To verify this concept we performed a wind tunnel testing using the flyable UAV.

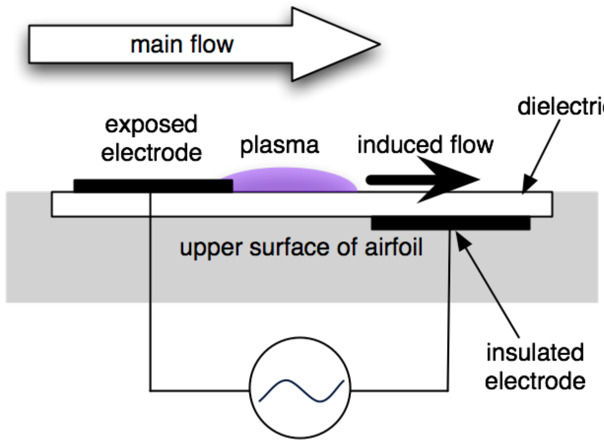

Fig. 1 SDBD plasma actuator placed in the direction following to the main flow

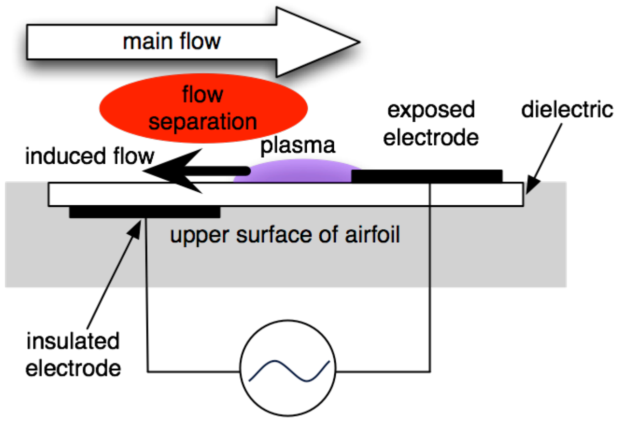

Fig. 2 SDBD plasma actuator placed in the direction facng to the main flow

2 Experimental Setup

The DBD plasma actuators are placed on the main wing of the test vehicle as shown in Fig. 3. To create the asymmetry of the aerodynamic force of the main wing, only the right side of the DBD is used. The left side of DBD is placed to keep the symmetry of the aerodynamic force when the DBD is turned off.

Fig. 3 DBD plasma actuator on the main wing

The position and the geometry of DBD are shown in Fig. 4 and 5. Figure 4 shows the location of DBD. To investigate the impact of the position of DBD, we prepared two different position in the spanwise direction and 3 different positions in the chordwise direction as shown in Fig. 4. The geometry of DBD is shown in Fig. 5. The material for the dielectric is polyimide film of 0.15 [mm] in thickness. The copper tape of 6 [mm] in width and 0.03 [mm] in thickness is used as an electrode.

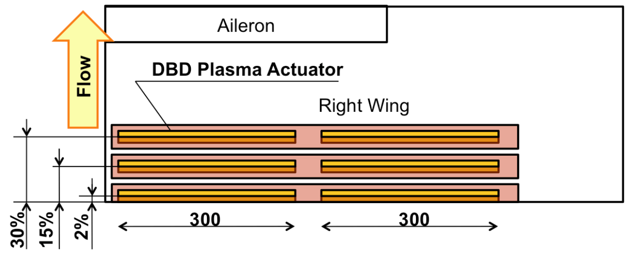

Fig. 4 Location of DBD plasma actuator on the main wing

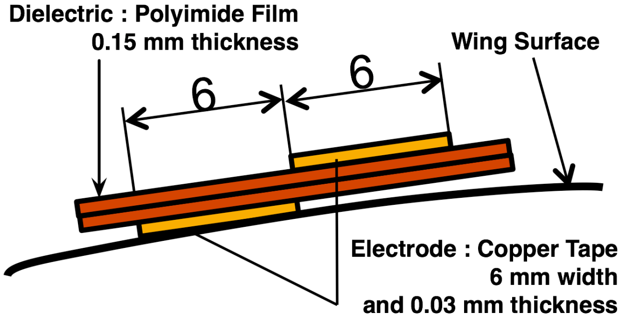

Fig. 5 Geometry of DBD plasma actuator on the main wing

Table 1 Specification of the test vehicle

Airfoil	NACA 2313
Chord Length	400 [mm]
Wing Span	2423 [mm]
Body Length	1896 [mm]

The specification of the test vehicle is summarized in Table 1. The test vehicle is mounted on the sting in the wind tunnel. The vehicle is connected to the sting with spherical ball joint. By using the present mount system the vehicle can rotate in three directions according to the aerodynamic force. In the test vehicle, the radio control system is installed to control the attitude of the vehicle by adjusting the control surface such as elevator, rudder and aileron. The change of the aileron is measured to check the change of the roll angle in the experiments. In the experiments we used a low speed wind tunnel JAXA. The test section of the wind tunnel is 6.5 [m] x 5.5 [m]. Figure 6 shows the outlook of the test vehicle on the sting.

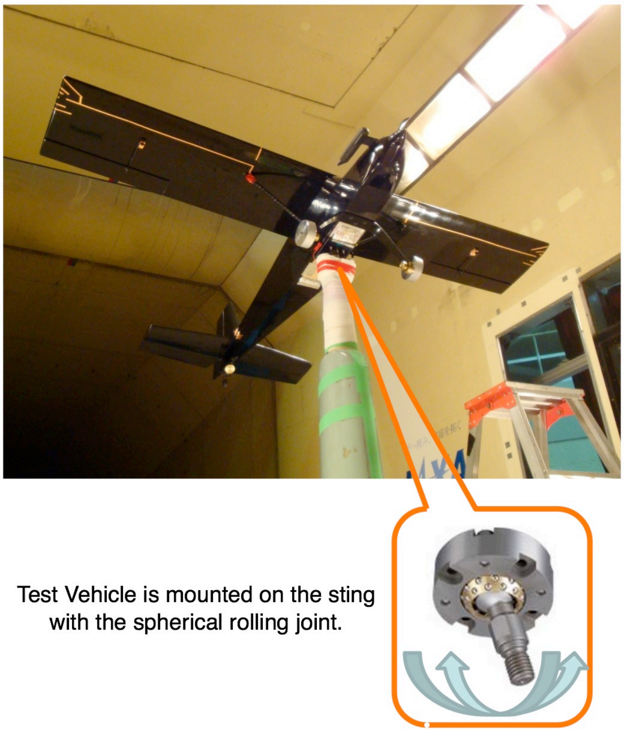

Fig. 6 Outlook of the test vehicle on the sting with the spherical rolling joint

3 Results and Discussions

In the experiments the time history of the attitude of the test vehicle such as the roll angle and the roll angle velocity was recorded on the data logger through the onboard sensor and the change of the aileron angle applied by the radio control system was also recorded simultaneously. The control of the aileron angle by radio control system is used to prepare the "good" initial condition. The "good" initial condition is similar to the level flight. After the "good" initial condition is achieved, the plasma actuator is turned on and we measured the change of the attitude of the test vehicle. During the measurement of the attitude, all the control surface is fixed. The test flow velocity is 7.0 [m/s]. The applied voltage is 12 [kV p-p].

Figure 7 shows the time history of the roll angle (cyan), the roll angle velocity (red), and the aileron angle (green), respectively. The signal (blue) that shows the plasma actuator is turned on is also shown in the same figure. From this figure, we can observe that the roll angle and the roll angle velocity changes just after the plasma actuator is turned on. Just after the plasma actuator is turned on, the roll angle velocity starts to decrease to the negative value. After that, the roll angle starts to decrease. This indicates that the plasma actuator could affect the aerodynamic force of the main wing and the attitude of the test vehicle.

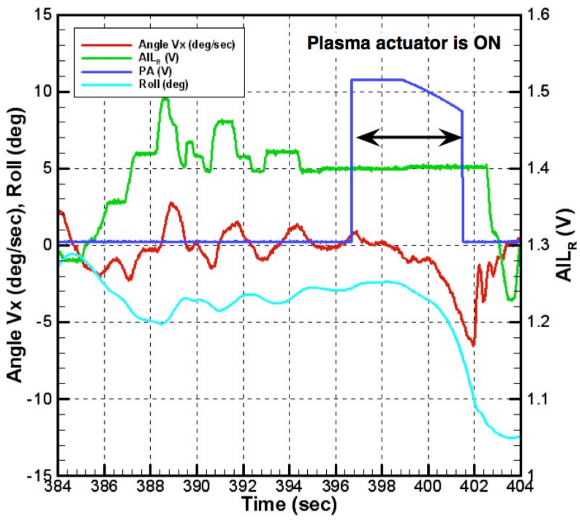

Fig. 7 Time history of the roll angle (cyan), the roll angle velocity (red), the aileron angle (green), and the signal for plasma actuator (blue)

But, in some cases, the roll angle and the roll angle velocity change even if we did not turn on the plasma actuator because the static stability in the longitudinal direction is unstable due to the present mount system. This "instability" is necessary to observe the change of the roll angle by the plasma actuator.

The present result shows that the plasma actuator could affect the attitude of the vehicle qualitatively but not quantitatively. To assess the present experimental result quantitatively, we will perform the numerical analyses to solve the motion of the vehicle under the present condition.

4 Concluding Remarks

In the present study, we performed the wind tunnel experiments to investigate the applicability of DBD plasma actuator to control the attitude of the flight vehicle. The DBD plasma actuator is placed on the main wing to create the flow separation and increase the drag force and decrease the lift force. In the wind tunnel, the test vehicle is mounted on the sting with the spherical rolling joint to keep the vehicle rotate in the three directions according to the aerodynamic force.

The experimental results indicate that DBD plasma actuator on the main wing could control the attitude of the test vehicle. But due to the inherent instability of the present method in the longitudinal axis rotation, we could not assess the result quantitatively.

References

[1] Post, M.L., and Corke, T.C., "Separation Control on High Angle of Attack Airfoil using Plasma Actuator",*AIAA Journal.* 42. 2177 (2004).

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