FLOW CONTROL with PITCHING MOTION of UAV using MEMS FLOW SENSORS

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ABSTRACT

A new pitch controller for our developed small airplane was designed, and its ability was confirmed by simulation. In the pitch controller, outputs from the MEMS flow sensor and the transfer function determined by the results of the wind tunnel tests are used. MEMS technology is a key technology of this pitch controller.

Key Words: UAV, pitch control, MEMS flow sensor

1. Introduction

We have developed a small and lightweight airplane. The airplane has a flight controller and can make an autonomous flight. The flight controller was also developed by us in cooperation with Y'sLab Corp. The details of the flight controller are shown in Ref.1. At present, the pitch control is made as follows : The pitch rate is measured by a rate gyro. The angle of elevons is varied so that the longitudinal dynamics is stabilized. This pitch controller can stabilize the pitch motion of the aircraft. For more accuracy of pitch control, we are proposing a new method of pitch control where the flow measurements with MEMS sensors are made. In this paper, the results in the wind tunnel tests with the MEMS sensors are shown and a flight controller based on the new method is designed.

2. Experiment Procedure

Figure 1 shows our developed airplane[2]. The span length and the weight are 40cm and 270g, respectively. It was found by our previous wind tunnel test that this airplane makes a trimmed flight when the pitch angle, the elevon angle and the forward velocity are 11deg, -15deg and 5m/s, respectively. The momentum of this aircraft, which is given by multiplying the mass by the forward velocity, is so small that it does not injure us seriously when it hits on us. The size, weight and forward speed were determined for safety.

Figure 2 shows a photograph taken by an onboard camera. The number of picture elements is 2million. The image is so clear that the airplane with the onboard camera can be used for getting information from a high altitude.

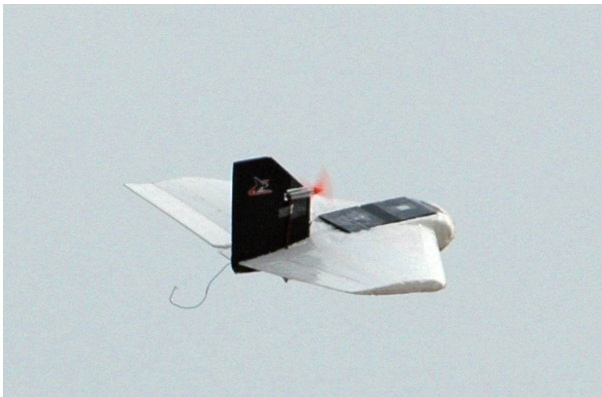

Fig.1 Our developed airplane

Fig.2 A photograph taken by an onboard camera

Figure 3 shows a flow sensor mounted on a wing of the airplane for a new pitch controller. The flow sensor is composed of a chip, which is removed form the commercial flow sensor (D6F-W04A1;OMRON), and a vinyl cover over the sensor on the chip. The cross section of the vinyl cover is nearly semicircle and its diameter is about 5 mm. The output from the sensor can is related to a flow volume through the tunnel by the vinyl cover. And the output from the sensor is positive and negative when the flow goes from A to B and from B to A, respectively. The arrangement of the four flow sensors are shown in Fig.4.

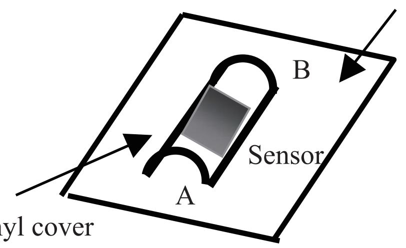

Fig.3 MEMS flow sensor

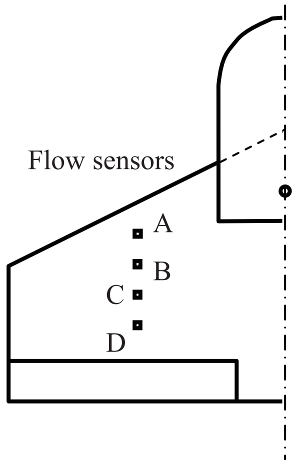

Fig 4. Arrangement of sensors

We made two kinds of wind tunnel tests about the airplane with the sensors on the wing. In both the tests, the airplane was set in a wind tunnel whose wind velocity was 3m/s. The wind velocity is a little smaller than the forward velocity at the trimmed flight stated above. However, the results obtained by these wind tunnel tests are available for a flight with the forward velocity of 5m/s, which is a value of the trimmed flight. This is because the Reynolds number effect on the transfer function and the constraint condition used in a new pitch controller, which will be stated later, are expected to be small.

The first measurements, where the airplane had no motion, were made as follows: The elevon angle was fixed and the angle was -15deg, which is for the trimmed flight. The measurements were made as a parameter of the pitch angle of airplane. The second measurements, where the airplane had pitch motion, were made as follows: The pitch angle of the airplane was varied by a servo motor and the axis of the pitch motion is close to the center of gravity of the airplane. The pitch angle was recorded with a potentiometer.

3. Results and Discussion

Figure 5 shows the results of the first test, where the airplane had no motion. This figure shows the relation between the pitch angle and the outputs from the four sensors. Note that these outputs cannot be compared between the sensors because the characteristics of the sensors are not common. The output from the sensor C is 0V when the pitch angle is 11deg, which is an angle of attack for the trimmed flight. So, we selected the output from sensor C as an indicator for pitch control whose details will be stated later. This is because the output obtained at the wind velocity of 3m/s is equal to that at the wind velocity of 5m/s, which is the forward velocity at the trimmed flight, just when the former value is equal to 0V.

Figures 6 and 7 show the results of the second test where the airplane had pitch motion. Figure 6 shows the time variation of pitch angle. The time variation includes components with various frequencies. Note that the maximum pitch angle is less than the stall angle of 18deg. Figure 7 shows the measured output from sensor C. The transfer function indicating the relation between the pitch angle and the measured output form sensor C are given by

$$G_a(s) = \frac{-2.2\times10^{-2}s^3 - 8.7s^2 - 7.1\times10^2 s - 5.0\times10^{-4}}{s^3 + 2.3\times10^2 s^2 + 1.5\times10^{-4}s + 1.4\times10^{-5}}$$

We designed a new controller for pitch motion, where the output of flow sensor C and the transfer function are used. The actuators in this controller are also the elevons as well as in the present pitch controller. And the new controller is expected to be used together with the present pitch controller for high accuracy in the pitch control. It was confirmed by simulation that the pitch angle can be converged on the value at the trimmed flight quicker by using simultaneously both the present controller and the new controller than by using no controller, when the external pitching moment is applied on the airplane with the forward speed of 5m/s. Note that the airplane itself has dynamic stability and that the pitch angle can be converged on the value at the trimmed flight without a controller. The details of the new controller will be indicated in Ref.3.

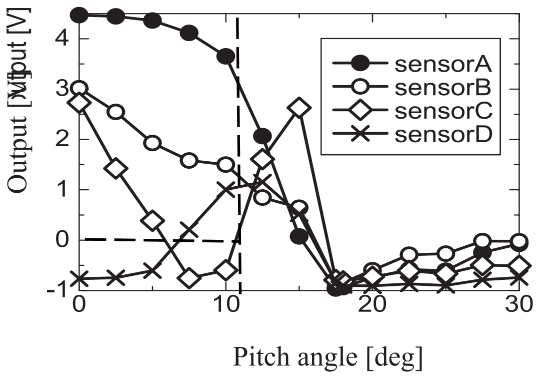

Fig.5 Output of sensors

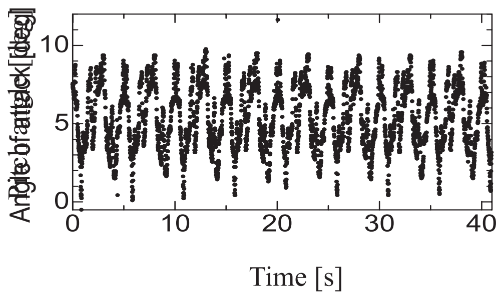

Fig.6 Time-variation of pitch angle

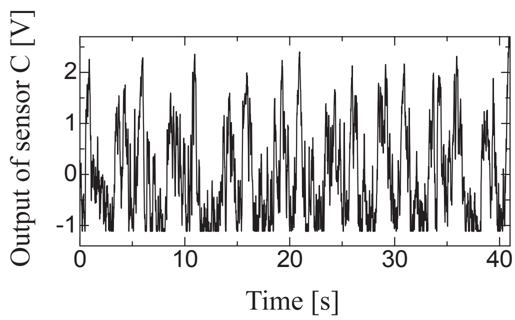

Fig.7 Time-variation of output of sensor C

4. Summary

A new pitch controller for our developed small airplane was designed, and its ability was confirmed by simulation. In the pitch controller, output from the MEMS flow sensor and the transfer function determined by the results of the wind tunnel tests are used. MEMS technology enables this pitch controller. In future, the ability of the pitch controller will be confirmed by a flight test.

References

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