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Experimental Study of the Flapping Amplitude Effect and Flexible Shell on the MAV Aerodynamic Performance in Hovering Flight

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1-Introduction

Flapping wings are a type of aerovehicles which generate the required aerodynamic forces for their own flight with the utilization of flexible wings and a mechanism supplying flapping motion. The oscillating motion of the wings is the main source of generating aerodynamic forces in birds including translational and rotational motions with two or more DOFs. Thereby, the generated wake flow creates the thrust force. In recent decades, flapping wings among other types of the aerovehicles have attracted more attention due to their high maneuvering ability, high thrust efficiency and the minimal rate of energy consumption.

Since thousands of years ago, mankind has observed birds' flight and made the aerovehicles by imitating their flying mechanism. However, no scientific study has been reported until around the nineteenth century. Consequently, the rate of investigations carried out by researchers has had a very gradual growth.

In the latest research works in MAV's (Micro Air Vehicle) area, Mazaheri and Ebrahimi (2010, 2011) used a flapping system and some sensors in measuring the aerodynamic forces and the usage power in order to experimentally investigate the unsteady forces including the generated lift and thrust. Thereby, the number of parameters for several kinds of wings were measured comprising unsteady aerodynamics and inertia forces, consumption power and angular velocity of the flapping motion in different flapping frequencies and a range of wind velocities in the forward flight.

In this paper, an experimental setup has been designed and constructed including a flapping mechanism with the ability of flapping amplitude variation and a load cell for measuring the generated unsteady thrust force of the flapping motion in the hovering flight and different flapping frequencies. Hence, the mechanism has been used in order to examine the effect of the flapping angle and wings' flexibility in a variety of conditions.

2- Test setup

The flapping mechanism is the main part of the setup which makes the flapping motion. This mechanism consists of a system for converting rotational motion to translational motion (Fig. 1).

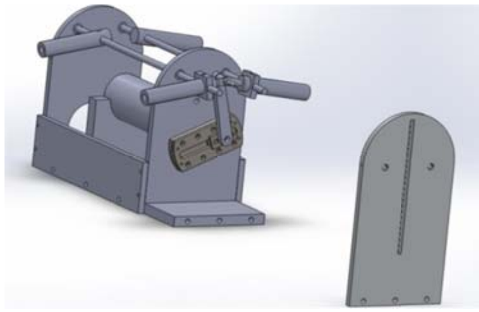

Fig. 1. The flapping mechanism

The mechanism is attached to a DC servo motor (BLD10-R-42BL105L2) in order to adjust the rpm and or flapping frequency up to 5 Hz via the special software (SCLUtility). Moreover, a one-axis load cell (S-type STC Lasoux) is used for measuring the thrust force generated by the flapping motion. The experimental test setup is shown in Fig.2.

Fig. 2. The experimental test setup constituted flapping wing and load-cell

3- Prototype wings

In this part of the present research, two wings with different shell materials have been utilized in order to study the effect of the flapping angle (flapping amplitude) on generating thrust force in the hovering flight. Therefore, two types of wings were constructed with the same dimensions and area and different wing materials, as shown in Tables 1 and 2. A schematic of these wings and marking their dimensions are presented in Fig. 3.

Table 1. Dimension characteristics of the wings A and B

Aspect ratio	Area (m^2)	d (cm)	c (cm)	b (cm)	a (cm)
2.18	0.0309	15	13	26	7.8

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Table 2. Shell and skeleton properties for wings A and B

Skeleton diameter (mm)	Skeleton material	Shell thickness (mm)	Shell material	wing
2	Carbon	0.03	Plastic	A
2	Carbon	0.09	Plastic	B

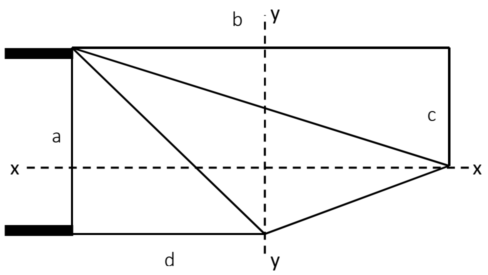

Fig. 3. Marking the wing dimension on a schematic of a prototype wing

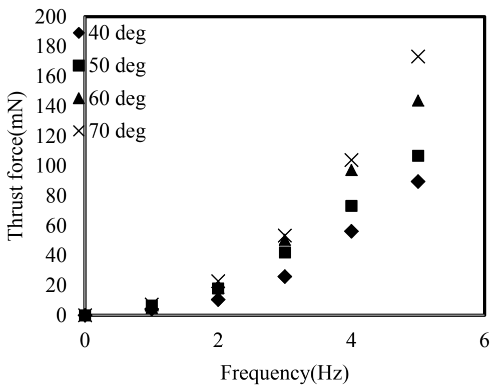

Fig. 4. The measured thrust versus the flapping frequency for wing A

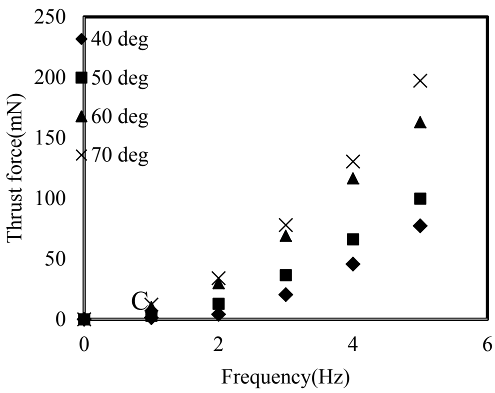

Fig. 5. The measured thrust versus the flapping frequency for wing B

4- Results and Discussion

As it can be seen in Figures 4 and 5, the measured thrust forces versus the flapping frequency are illustrated for wings A and B in different flapping angles including 40, 50, 60 and 70 degrees. It is noted that the wing angle of attack is equal to zero in all of the tests. Having scrutinized the data attentively, we can clearly assert that the amount of thrust force increases as flapping frequency and flapping angle increase so that a second order polynomial can be fitted in these data.

In order to compare the aerodynamics results of the two wings including generated thrust and power consumption, the endurance factor can be defined by T/P as a unique parameter. Figures 6 and 7 reveal the endurance factor for two flapping angles of 40 and 50 degrees in the flapping frequency of up to 5 Hz.

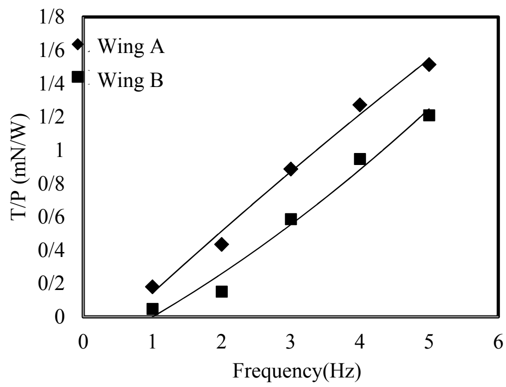

Fig. 6. The endurance factor versus the flapping frequency for wings A and B in the flapping angle of 40 degrees

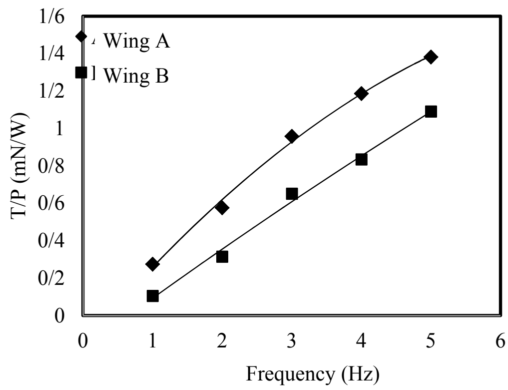

Fig. 7. The endurance factor versus the flapping frequency for wings A and B in the flapping angle of 50 degreeS

5- Conclusion

In this research, the flapping amplitude effect and flexible shell on the MAV aerodynamic performance in the hovering flight are experimentally investigated. For this purpose, a flapping membrane wing mechanism and an experimental measurement setup for measuring the generated thrust were designed and constructed. In these tests, for two wings with different flexibilities, the generated thrust and power usage were measured in the range of the flapping frequency and the amplitude. In general, flapping wing which generated thrust increases with a raising flapping amplitude. The thrust force for a more flexible wing is more than other wings in the flapping amplitude of below 50 degrees, but for an amplitude of more than 50 degrees this trend becomes reversed.