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MORPHING WING DESIGN FOR ORNITHOPTERS

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ABSTRACT

Birds and insects fly by flapping their large wings respect to their size at very high frequencies and control the motion precisely to create the lift forces. To obtain the lift forces with less complicated mechanisms passive morphing is one of the options. The forces applied to a passive morphing wing are studied in this paper experimentally. Experiments were performed at a series of operating conditions to let the researchers evaluate the performance of the wing.

INTRODUCTION

Millions of different species of insects, bats, and birds fly and perform incredible maneuvers with flapping wings. Many scientist, biologist, and aerodynamicist have been interested in discovering the mechanism and secrets of flapping wing fly for a long time [1]. Designing and building ornithopters are fascinating since these devices simulate the motion of the biological flying objects very closely. In addition to the competitions, many potential users desire to use micro air vehicles (MAV) for delivery and observation purposes. Many ornithopters have been designed, tested and competed with in the last decade. Their sizes vary from several centimeters ones to large gas powered ornithopters with wingspans reaching to 2 meters. However, still a small (palm-sized) and lightweight (<15 grams), electrically powered ornithopter have not been developed for practical applications [2].

Micro air vehicles, (MAVs), are a class of aircraft with a maximum size of about 150 mm and are capable of operating at speeds of 15 m/s or less [3]. The concept is for a small, inexpensive and expendable platform that can be used for missions of surveillance and measurements in situations where larger vehicles are not practical such as low altitude battlefield, urban and wildlife surveillance. Practical applications of MAVs are becoming more achievable with the ever-decreasing size and weight of the payload components that could include video cameras, chemical sensors, electronics, and communication devices.

Morphing aircraft design continues to evolve as new technologies in actuators and flexible structures become available. New designs allow vehicles to undergo a much more complex shape change than can easily be described by one or two parameters [4]. Market research shows great interest in this kind of equipment, in particular from the Fire Rescue Department. The police and security companies are also interested in the use of such an MAV. Interestingly, the Fire Department have indicated, that the size of a micro-vehicle is not as crucial as its endurance [4].

Many researchers has been working on various Micro Air Vehicles (MAVs) to develop better monitoring and fighting systems with the wing span of 15cm or less [5,6]. Three desired capabilities of them are long range, speed and hovering capabilities. Unfortunately, these capabilities severely conflict with each other when we try to implement current mechanical designs of fixed and rotary wing aircraft. One proposed approach is to inspire from the biological systems and to develop ornithopters. Flapping wing design improves efficiency, creates more lift respect to size, and reduces noise compared to rotary-propeller driven air vehicles. Researchers have studied the flight characteristics of insects [7,8], small birds and tried to mechanically duplicate them [9] to operate efficiently at their range of Reynolds numbers. Various flapping wing designs have been developed [10] and flexible wings have been proposed [11]. Further miniaturization will be desired in the future to operate them safely and at a lower cost in civilian applications, and to increase their military capabilities.

Researchers currently work on ornithopters (flapping wing MAVs) to solve the low aerodynamic lift force experienced by the very small aircraft (MAVs) [12-15]. Recently, electrically powered palm-sized ornithopters have been tested in the wind tunnels. They used titanium-alloy [2, 16] and carbon fiber [17] wings. Addition to reliable flying capability, hovering is desired by many potential MAV users and first examples have been developed [18]. Park and Yoon presented four ornithopter designs with the wing spans between 10 cm and 40 cm [17]. Their weights ranged between 5 g and 45 g [17].

In the following sections, the proposed small morphing wing, experimental work, results and conclusion will be presented.

PROPOSED PASSIVE WING DESIGNS

We designed a simple passive morphing wing with flexible sections which were supposed to open during wings motion up but close while the wing moves down (Fig.1). The small wing models in Fig.2 were prepared and two of them were tested to evaluate the morphing wing concept.

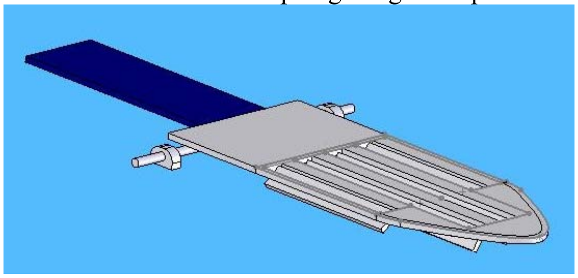

Fig 1. The designed simple morphing wing

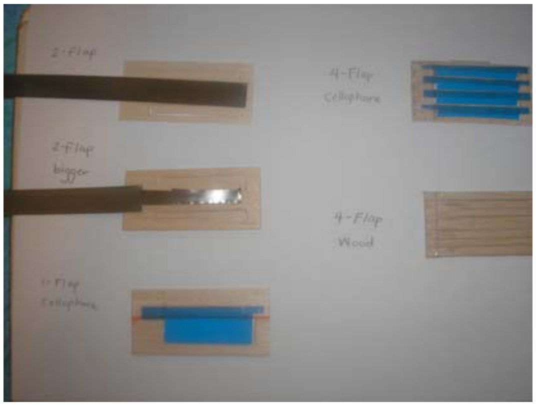

Fig. 2. Simple wings to test the morphing wing concept.

EXPERIMENTAL SETUP AND DATA COLLECTION

In this study to monitor the forces on the body which carry the wings, the experimental setup in Fig.3 was prepared respectively. The beam was attached to a V6100-6 VT5 Vibration Test System. A harmonic signal was generated by using a BK Precision 4017 signal generator connected to the MacroTech Crown XTI 1000 power amplifier of the exciter. The wing was fixed on Kistler 9272 type dynamometer. Kistler 5804, 3 channel charge amplifier conditioned the signal of the dynamometer and signal was monitored by a Nicolet Integra 10 digital oscilloscope. The data was collected when the wing was flapped with shaker.

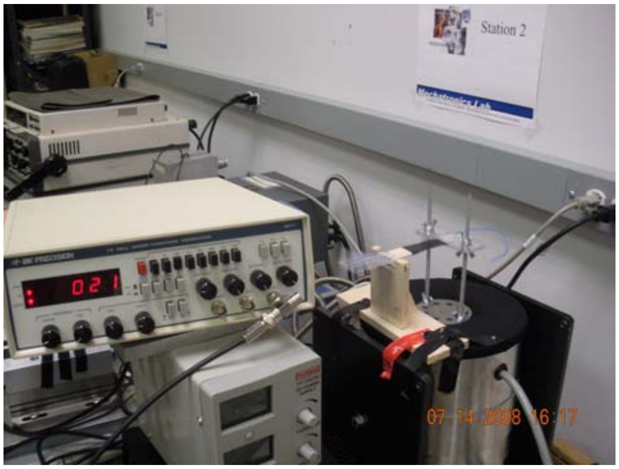

Fig 3. Experimental setup to excite the wings. Piezoelectric element and flapping wing. Piezo is moved by electrodynamic actuator at 21 Hz.

The pictures of the wings were taken with small time intervals and inspected to evaluate the realization of the morphing (Fig.4). A Kistler 9272 4-component dynamometer was used to measure the forces (Fig.5).

Figure 4. Wing Opening and Closing Time

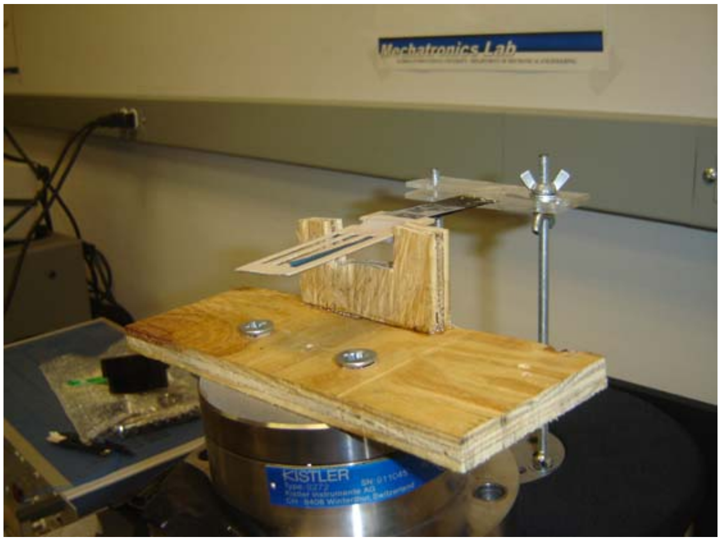

Fig. 5. One of the tested wings with three slots on the dynamometer

RESULTS and DISCUSSION

The observed forces are presented in Fig.6 and Fig.7 when we tested wings with one large and three small slots respectively. The experiments were repeated three times since there were large forces coming from the actuator and inertia forces. The actuator and inertia forces were measured by performing the tests only with the frame without the plastic sheet covering the opening. Performance of the flexible wing was evaluated when the plastic sheet was fixed from both sides. The morphing was observed when the plastic sheet was hold only from one side and allowed to open during the up stroke.

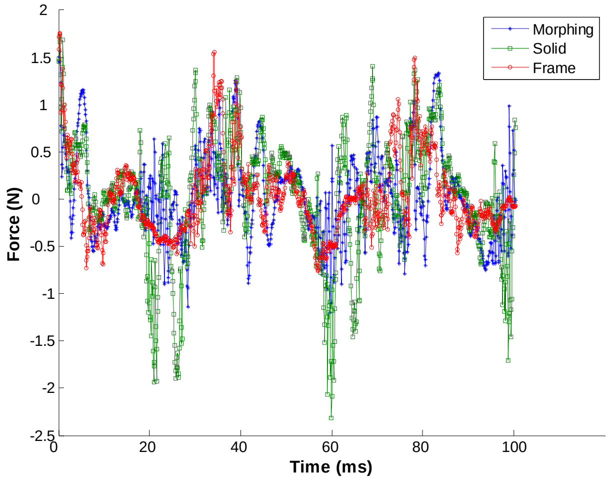

Fig. 6. Force variation of wing with single opening

There are three traces in the Fig.6 and Fig.7. The "frame" demonstrated the forces applied by the actuator and the inertia of the frame. The "solid" is when the flexible sheet covering the opening of the frame is fixed to the frame. In case of "morphing", the plastic sheet was hold from one side of the frame and opened during the upstroke to reduce the air resistance.

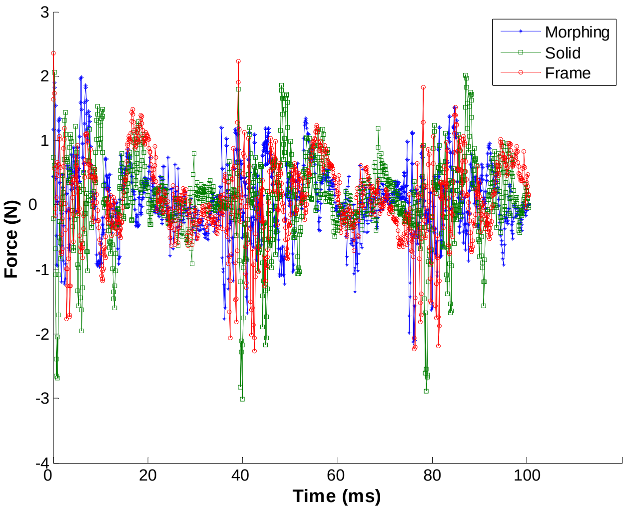

Fig 7. Force variation of wing with three slots

CONCLUSION

The effectiveness of passive morphing on the wing force creation was studied experimentally. The study demonstrated that 3 component dynamometer may be used to measure the forces created by the wing motion. The inspection of the results demonstrated that the proposed passive morphing concept may be used to develop reasonable lift forces without designing complex joints between the body and the wings.

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