In-flight control of MAV wing camber using Shape Memory Alloy Actuators and flex sensor

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ABSTRACT

Objective/Aim: A morphing system that can dynamically change the camber or shape of Micro Air Vehicle wing provides specific aerodynamic benefits by increasing the lift coefficient. Though many research papers have reported the benefits of morphing, there are hardly any reports on morphing of MAV during flight. The challenge is to measure, effect and control the deflection angle of the wing within the constraints of space (few square centimeter), power (< 5W) and weight (< 8g) in MAV. This paper presents a flex sensor and Shape Memory Alloy (SMA) based in-flight wing deflection measurement and control system. A novel method of transmission of deflection angle and SMA parameters along with other flight data to the Ground Control Station (GCS) and their transfer to MATLAB for online analysis is also presented.

Methods and materials: Fixed wing MAV, namely 'black kite' was chosen for the morphing trials. Morphing involved change of camber through drooping of wing Leading Edges (LE) along the plane's lateral axis. A flex sensor bonded to the wing, changes its resistance as a function of wing deflection. This was read as a voltage signal in the Ardu-ino flight controller. To overcome the inaccuracy of flex sensor, software-based auto nulling and averaging were implemented as a sub-function of auto pilot code.

The actuator requirements for morphing were experimentally determined and a NiTinol SMA wire of appropriate dimension was chosen. SMA actuator generates force and displacement due to temperature induced phase transformation, which can be controlled by varying the magnitude and duration of SMA current. This was realized by Pulse Width Modulation of SMA current through a MOSFET. A PID algorithm with integral reset implemented on the Ardu-ino controller, computes the required pulse width based on the error between actual and set deflection angles (commanded by the ground pilot or the auto pilot).

Using a Zigbee transceiver pair and by modifying the auto pilot and GCS codes (open source) the deflection angle and SMA parameters were transmitted, extracted and fed to MATLAB for online trending and other analysis.

Results: The SMA actuators drew less than 0.35A RMS current at 11.1V and deflected the leading edges upto 12°. Deflection angle could be measured with an accuracy of ±0.5°. Controller could maintain the deflection angle within ±0.2° error band around the set angle. The total weight of the wing deflection system is 6.5grams.

Conclusions: A lightweight, low power and MAV class wing morphing control system was developed using smart actuators and flex sensor. Wind tunnel tests have shown 10% increase in lift coefficient and 2g penalty in drag forces at higher angle of attack. Flight tests have demonstrated successful morphing, data transmission and online analysis in MATLAB. Open source auto pilot and GCS codes were exploited to provide additional camber control loop and data analysis without affecting the flight control functions.

Keywords: Camber control of Micro Air Vehicle, in-flight wing deflection sensor, smart actuator, ardu-ino controller, online morphing data analysis in MATLAB®.