Experimental Optimization and Uncertainty Quantification of Flapping Wing of a Micro Air Vehicle

Anirban Chaudhuri[δ,*] , Raphael T. Haftka[δ], Peter Ifju[δ], Diane Villanueva[δ], Kelvin Chang[δ], Jason Rue[δ], Christopher Tyler[†], Tony Schmitz[†]

[δ]University of Florida, Gainesville, FL, USA
{a.chaudhuri@ufl.edu, haftka@ufl.edu, kc3635@ufl.edu, ifju@ufl.edu, dvillanu@gmail.com, gatorrue@ufl.edu}

[†]University of North Carolina at Charlotte, NC, USA
{ctyler6@uncc.edu, Tony.Schmitz@uncc.edu}

Abstract

Recently, there has been an increase in interest in flapping wing micro air vehicles as they are capable of hover and forward flight with high maneuverability. Flapping wing flight is difficult to simulate accurately as it is a much more complex phenomena than fixed wing or rotorcraft. Consequently the optimization of flapping wing based on simulation is challenging and, therefore, we have elected to optimize a wing experimentally. Specifically, we use experimental data to optimize the flapping wing structure for maximum thrust production in hover mode. The flapping wing has a quarter-ellipse planform made of a nylon membrane (Capran 1200 Matte) with unidirectional carbon fiber battens making unique structural patterns.

Experimental optimization is hampered by noisy data, which for our wing is due to manufacturing variability and testing/measurement errors. These uncertainties need to be reduced to an acceptable level, and this requires us to quantify them. Multiple wings with identical nominal geometry are constructed to quantify manufacturing uncertainty and multiple tests on the same wing are conducted to quantify testing uncertainty. Then improvements in manufacturing and testing procedure are undertaken in order to reduce the noise.

Another challenge is to reduce the number of experiments performed as it is time consuming and expensive to manufacture and test wings. This is done by using surrogates or meta-models to approximate the response (in this case, thrust) of the wing based on an initial design of experiments. In order to take into account the uncertainty or noise in the response we use gaussian process surrogates with noise and 2nd order polynomial response surface. Then a surrogate-based optimization algorithm called Efficient Global Optimization is used with different sampling criteria and multiple surrogates. This enables us to select multiple points per optimization cycle which is especially useful in this case as it is more time efficient to manufacture multiple wings at once. In this study, we have selected aspect ratio, leading edge stiffness and batten configurations as the design variables based on prior experience.

*** Corresponding Author**