1-1-2019

Design and Development of an Actuation System for Morphing Wings

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Preliminary Analysis & Design of Morphing Winglets for UAVs

Project Description: The goal of the proposed work is to conduct an analysis and develop a morphing (adaptive) multi-winglet capable of reducing the strength and size of wingtip vortices, resulting in improved aircraft performance. Induced drag accounts for roughly 40% of the total drag on an aircraft and therefore, reduction of the induced drag would significantly reduce fuel consumption, cost of operation, and the carbon footprint of the aircraft. Wingtip modifications can either move the vortices away in relation to the aircraft longitudinal axis or reduce their intensity. Nowadays, winglets are offered as standard equipment on new aircraft and are also available as retrofit installations on existing commercial airplanes to increase aircraft range capability along with reducing fuel consumption. Conventional winglets are static aerodynamic devices with an optimized shape while introducing significant loads into the main wing structure that may diminish aerodynamic optimization. Morphing multi-winglets (Fig. 1), where the geometry can be adjusted real-time to the changing flow conditions, have the potential to improve the aerodynamic performance during climb and/or high-speed off-design conditions by providing adapted wing lift distribution throughout the flight envelope. These devices such as winglets, tip-sails, and multi-winglets, take energy from the spiraling airflow in this region to create additional traction and thus achieve expressive gains on efficiency. Range, endurance, and take-off distance are just a few examples of the types of performance that can be evaluated, compared, and optimized for unmanned aerial vehicles (UAVs). Long-endurance UAV glider for surveillance/topography applications for instance, the aircraft must be able to climb effectively at low speeds, as well as being able to glide efficiently at high speeds, thus a successful design must balance the conflicting requirements of climbing and cruising over a broad range of possible soaring conditions.

Fig. 1: Flow visualization of wing tip vortices from multi-winglet configuration. [M.J. Smith et al. Performance Analysis of a Wing with Multiple winglets].
The RCEU student’s tasks in the project include:

i.) Design two morphing winglets.

ii.) Use optimization tools (Tornado, XLFR5) to optimize the designs.

iii.) Build the qualified design and integrate it on a wind tunnel wing model.

**Student Prerequisites**

The student will be required to have the following skills: i) Strong background in aerodynamics and aerospace structures; ii) Very good knowledge of Solid Edge/ SolidWorks and Abaqus; iii) Experience with 3D printing; iv) Experience with writing technical reports; v) A minimum GPA of 3.2 is required.

**Student Duties & Deliverables**

The project will require an extensive laboratory effort and hands-on work. During these experiments the student will require to use analytical and observational skills. The experimental results must be routinely logged (e.g., log-book) and quality controlled. Repetition of testing is required to assure repeatability but also determine the inaccuracies of the observations. The student will present current results and report progress on a weekly basis. A final report will be submitted during the ~12th week and evaluated by the mentor. The student can also have the opportunity to present the findings in UAH seminars for undergraduate research or national symposiums/conferences. A tentative timeline for 12 weeks is as follows:

**Weeks 1-2:** Introduction to the lab and familiarization with the equipment (wind tunnel and particle image velocimetry).

**Weeks 3-5:** Review literature on winglet design and present a design and a design alternative.

**Weeks 6-8:** Finalize designs and start optimization process using computational tools.

**Weeks 9-10:** 3D print the qualified design and integrate it to a wind tunnel model.

**Weeks 11-12:** Analysis and documentation of the results including a poster.

**Mentor Supervision and Interaction**

During the summer semester, the mentor will spend the majority of his time working in the lab and assist students during experiments. Thus, the mentor will have regular interactions with the RCEU student. The student will also have daily interactions with the graduate student who work and conduct research in the lab. Direct supervision, mentoring, and evaluation of the project by the mentor will occur weekly at regularly scheduled project meetings. In the weekly meetings the current status of the project, recent results, difficulties encountered, next steps, and address any other issues that may come up will be discussed.