Aerodynamic analysis of high-cambered morphing airfoils for Micro Unmanned Aerial Vehicles applications

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Abstract:

UAVs are the fastest developing branch of aviation these days. There are numerous ways to preserve a UAV landing manoeuvre, but the most difficult to land and most vulnerable to damages are UAVs without landing gear. Existing concepts of preserving landing manoeuvre with UAV without landing gear mainly focus on minimizing the impact force and loads overstressing the structure of the UAV. Authors created revolutionary concept combining perched landing method with morphing airfoils. This solution could not only contribute to minimizing the damage occurring to the UAV during landing, but also to improving the aerodynamic efficiency of the UAV during flight. Morphing airfoils with variable camber are currently wide researched in terms of aerodynamic efficiency improvement of commercial aircraft. The development of materials in the last few decades enabled researchers to conduct various technical solutions for morphing wings, allowing to create more revolutionary concepts. Recently researchers started to examine morphing airfoils on micro UAVs and low Reynolds numbers. Authors of this work examined the fascinating ability of morphing airfoils to create drag in high-cambered stage. The target-aircraft was Micro Unmanned Aerial Vehicle (Micro UAV). Authors prepared six two-dimensional geometries, based on NACA24012 profile. The front section of NACA24012 airfoil was fixed and only the back section varied in shape [Fig. 1].

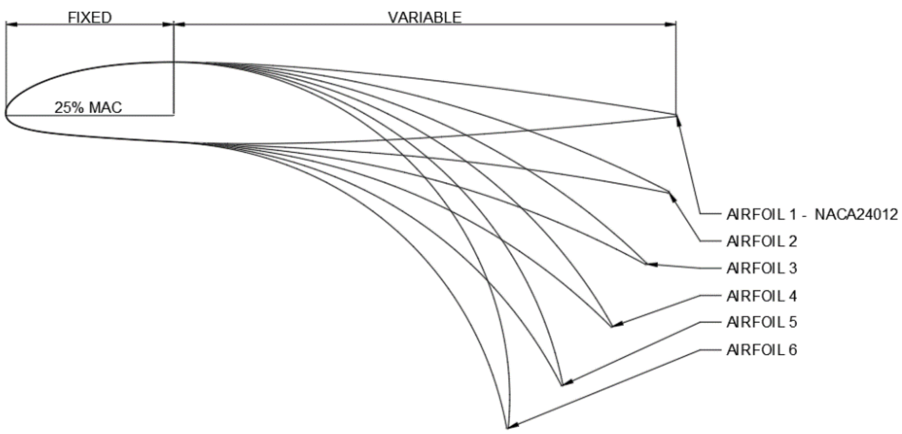

Fig. 1. The visualisation of prepared geometries

The research was conducted both, numerically and experimentally. Both investigations were obtained in two-dimensional environment.

EXPERIMENTS

Experiments were performed in hydrodynamic tunnel on low Reynolds number using PIV method. Obtained results of the velocity field distribution were the average value from 500 frames of the high-speed camera. The results were used to validate the CFD numerical model.

CFD

Numerical simulations were conducted in two-dimensional domain with k-ω SST turbulence model. Computational domain's size was in rectangular shape with the lengths of the walls corresponding to "Airfoil 1" camber. Numerical grid underwent numerous refinements and the Arbitrary Mesh Interface (AMI) was created to change airfoil's angle of attack without changing boundary conditions on the inlet. The final mesh y+ parameter value was obtained significantly below 1.

RESULTS

The results show the change of the lift force and drag coefficients change with the change of the camber of the airfoil. The lift-to-drag ratio was also discussed. Two setting angles were selected to demonstrate the influence of the camber morphing on the coefficient characteristics change. The increase of the aerodynamic efficiency is observed only for low-cambered airfoils, and with the increase of the camber the drag coefficient is increasing significantly, lowering the overall lift-to-drag ratio for high-cambered airfoils. During performed research, the flow separation point was observed for different morphing stages, separation regions, and velocity distribution [Fig. 2].

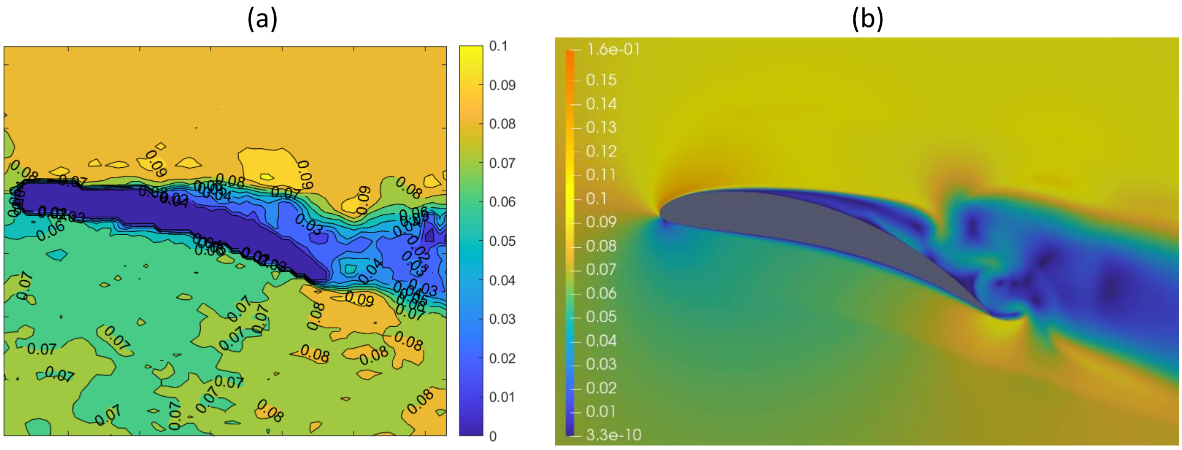

Fig. 2. Visualization of velocity distribution around tested airfoil: a) PIV method, b) CFD method

Micro UAVs are an excellent solution for supporting human missions in a variety of environments. As the most dangerous phase of the UAV flight is the landing phase, the authors created a revolutionary morphing airfoil design which could decrease the overall damage of the UAVs during landing and increase the aerodynamic efficiency of the aircraft. Results show promising ability of the morphing airfoils to create drag in high-cambered stage. Low morphing stages of the airfoil could be utilized during take-off manoeuvres like conventional flaps, while high morphing stages are considerable solution for Micro UAV's during landing phase, especially in rough terrain. Higher drag force during last phase of landing manoeuvre could provide lower speed during touchdown and lower risk of damaging the aircraft structure.