

Editorial

Editorial for the Special Issue “Aircraft Modeling and Simulation”

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1. Introduction

New airplane and unmanned aerial system modeling, simulation, and design methodologies are very important in aerospace engineering. The best methodologies should be selected in order to reduce the need for a high number of expensive experimental data (and, thus, to minimize fuel consumption). These methodologies should be applied on an aircraft with the aim of certifying it for production. Experimental data are usually provided by use of wind tunnel and flight tests.

Therefore, in this Special Issue, numerical methodologies for computational fluid dynamics (CFD), structural dynamics, and controls were studied, and their results were compared and validated with experimental wind tunnel data and other numerical methodologies' results.

The aim of this Special Issue was to promote research and development on aircraft modeling and simulation technologies, while addressing their validation with a minimum possible amount of experimental data.

2. Summary of the Special Issue Contents

The Special Issue can be divided into three groups according to the disciplines and their applications on systems, covered by five articles. These disciplines are focused on aerodynamics, structural dynamics, and controls.

In the first group, focused on the aerodynamics or computational fluid dynamics (CFD) areas or research, two articles were published on the following: the first covered aerodynamics analyses applications on the droop nose leading edge (DNLE) with the morphing trailing edge (MTE) combination for the UAS-S45 morphing wing [1]; the second was focused on the following four different configurations: a flat plate, an airfoil near-wake, a backward-facing step, and a turbine cascade, also called the eleventh standard configuration [2]. These aerodynamic studies were performed using various CFD in-house and commercial software, and their results were validated with experimental data provided in the literature.

In the second group, focused on structural dynamics modeling area, two articles were published on an adaptive winglet finite element model (FEM) issue [3] and on the modeling of an oleo-pneumatic landing gear using MATLAB instead of FEM, which was considered as one of the originalities of this paper [4].

In the third area, focused on controls, one paper was written on the design and wind tunnel test validation of a disturbance rejection dynamic inverse control for a tailless aircraft [5].

2.1. Study Case—Unmanned Aerial System UAS-S45 Morphing Wing Aerodynamic Analysis

Among green aircraft technologies, one might include morphing aircraft systems development. Morphing or adaptive wing and winglets are able to change their structural



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shapes using actuators, sensors, and controls technologies in order to obtain better aerodynamic performances for the aircraft, as shown in the aerodynamics studies for morphing wings [1] and in the structural studies of an adaptive winglet [3].

In [1], an aerodynamic optimization new methodology was employed for a combination of the droop nose leading edge (DNLE) with the morphing trailing edge (MTE) of an UAS-S45 root airfoil by use of the Bezier-PARSEC parameterization. This methodology used a hybrid optimization technique, based on a combination of the particle swarm optimization (PSO) and pattern search algorithms.

The drag was minimized and the endurance maximized for the UAS-S45. The aerodynamic analysis results were obtained for the UAS-S45 airfoil using the XFOIL software, and for the UAS-S45 wing using the high-fidelity computational fluid dynamics (CFD) Ansys Fluent solver including the transition ($\gamma - Re\theta$) shear stress transport (SST) turbulence model. The aerodynamic optimization results were obtained for different flight conditions. Both the DNLE and MTE optimized airfoils have shown a significant improvement in the UAS-S45 overall aerodynamic performance, while the MTE airfoils increased the efficiency of $C_L^{3/2}/C_D$ by 10.25%, thus indicating better endurance performance. Therefore, both DNLE and MTE configurations have shown promising results in improving the aerodynamic efficiency of the UAS-S45 airfoil.

2.2. Study Case—Comparison between CFD and Experimental Results Using Three Different Software

In the aerospace industry, computational fluid dynamics (CFD) methodologies are researched for advancing aerodynamics studies on aircrafts. The results obtained by these methodologies are compared among themselves, and with experimental wind tunnel tests and flight tests results. The laminar, turbulent, and transition flow results are analyzed using these numerical methodologies.

In this study case [2], two turbulence models—the shear stress transport (SST) model and the Spalart–Allmaras (SA) model—were implemented in the UNS3D in-house code at the Texas A&M University, and their results were compared with those of FUN3D and CFL3D codes developed by NASA. The UNS3D code has two versions: UNS3D-SEQ (sequential version) and UNS3D-PAR (parallel version). In addition, these numerical results were compared with experimental results from the literature. The methodologies were applied on four different configurations: a flat plate, an airfoil near-wake, a backward-facing step, and a turbine cascade, also called the eleventh standard configuration.

Regarding the comparison of the results, the solutions' residuals were very small, more precisely, less than 10^{-11} . The SST model predicted, better than the SA model, the turbulent fluctuations and skin friction coefficients in comparison with experimental data, while the SA model predicted better than the SST model, as the flow went away from the backward-facing step. In fact, most of the results obtained using the SST model fitted the experimental data better than the SA model, while the main disadvantage of the SST model resided in its computational execution time, that was higher than the SA model execution time, with its values between 4–38%.

2.3. Study Case—Structural Analysis of an Adaptive Winglet

Adaptive and morphing surfaces of aircraft are studied worldwide with the aim of improving aerodynamic performance. Among these surfaces, winglets are often studied. At CIRA, in Italy, the structural team has been continuously working in this interesting area.

The finite element modeling (FEM) issues for an adaptive winglet skeleton design at CIRA are discussed by [3]. For example, in this paper, a study was presented on the structural architecture adaptation for a winglet morphing system in order to allow its deformations within the safety margins. Regarding this structural morphing winglet design, FEM solver problems occurred as the safety factors (including those for severe load conditions) were highly dependent on the mesh sizes. As the mesh was refined, the singularities were represented through single points or lines. This study was focused mainly

on the presentation of causes and their effects on the results. In addition, some experimental issues were also discussed in this paper regarding the adaptive winglet skeleton.

2.4. Study Case—Oleo-Pneumatic Landing Gear System Drop Impact Dynamics

Oleo-pneumatic landing gear is a complex component and system that is usually designed in parallel with other components of an aircraft, such as the fuselage and wings. FEM is usually employed for modeling and analyzing this system, which might have a high impact on the structural aircraft dynamics.

In [4], a new methodology is shown, in which four state variables are considered for the modeling and simulation of the oleo-pneumatic landing gear drop impact dynamics. The forces obtained during the drop were simulated on both horizontal and vertical axes. The well-known MATLAB software considered a set of intercommunicating routines, and it was used instead of FEM software for modeling and simulating the drop impact dynamics, and the numerical results were validated with experimental data. The advantages and limitations of these studies were discussed in this paper.

2.5. Study Case—Analysis and Wind Tunnel Tests for the Nonlinear Dynamic Inversion (NDI) Control Methodology on a Tailless Aircraft

In [5], the design and wind tunnel tests of the validation of a disturbance rejection dynamic inverse control for a tailless aircraft are presented. In this paper, nonlinear dynamic inversion (NDI)-based disturbance rejection control methodologies were designed, and then wind tunnel tests were used to validate the numerical methodologies' results.

A nonlinear affine mathematical model was obtained numerically for the tailless aircraft model supported with a 3-DOF rig in the wind tunnel. A baseline NDI controller was designed to stabilize and control the aircraft attitude; this controller was further augmented with a disturbance observer, and became an NDI-DO controller, that was used to reject the lumped disturbances. The simulation has shown that the robustness of the NDI-DO augmented controller was higher than the robustness of the baseline NDI controller, and that the anti-windup (AW), modified disturbance observer recovered the control performance from the actuator saturation.

Finally, wind tunnel tests were successfully conducted, and their experimental results validated the simulation results obtained by the NDI-DO control methodology; thus, the experimental results fitted the simulation results using the NDI-DO controller very well, which demonstrated a higher tracking and more robust performance than the NDI-PI (proportional integral) controller. However, the NDI-AW controller was not implemented and tested due to the absence of sensors for the actual surface deflections.

3. Conclusions

As seen in this Special Issue, "Aircraft Modeling and Simulation", aerodynamics, structures, and controls engineering analyses and experimental tests were presented for different aircraft systems and configurations for aircraft and unmanned aerial systems. Morphing aerodynamic and structural analyses studies were presented for a morphing wing of the UAS-S45 from Hydra Technologies in Mexico, and for an adaptive structural winglet study with the aim to advance green aircraft technologies, by improving aerodynamic performance in terms of fuel consumption and greenhouse emissions reduction. A deep CFD analysis study using an in-house developed software UNS3D code was also performed for four configurations, and its results were compared with other NASA software results and experimental data. A structural analysis of an oleo-pneumatic landing gear was presented by use of MATLAB instead of classical FEM analysis, while a control analysis was numerically and experimentally tested in the wind tunnel for a tailless aircraft. Finally, these studies are extremely important in the advancement of aircraft engineering research.

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