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External Aerodynamics on the D8 "Double-bubble" Aircraft Design

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Abstract: The external aerodynamics of the proposed D8 "double-bubble" aircraft configuration are analyzed using an inviscid and a viscous simulation. The results are verified with a mesh refinement study and forces and moments are compared to experimental results for validation. The methods resulting from this clean configuration study establish the basis necessary to perform further studies with a boundary layer ingesting engine.

Keywords: Cartesian, Overset, Aerodynamics, boundary-layer ingesting engine.

1 Introduction

As a part of NASA's Aeronautics mission, a study to assess new technologies is being performed under the Subsonic Fixed Wing program. The N+3 initiative under this program is charged with studying technologies that may be used three generations in the future. This paper is a study of the external aerodynamics characteristics of the Massachusetts Institute of Technology (MIT) proposed D8 (double-bubble) design[1]. The objective is to validate computer simulations of the clean configuration (without the engines) against wind tunnel data to establish a baseline prediction method. Inviscid as well as viscous computations are performed. Inviscid computations employed an adjoint-based mesh refinement procedure on an unstructured Cartesian mesh. Viscous computations were performed using structured overset mesh technology. The inviscid mesh was used as a guide along with overset best practices to decide where to concentrate the mesh for the viscous computations. A mesh refinement study is presented along with validation against experimental data. A study of the effect of various turbulence models on the forces and moments is also presented.

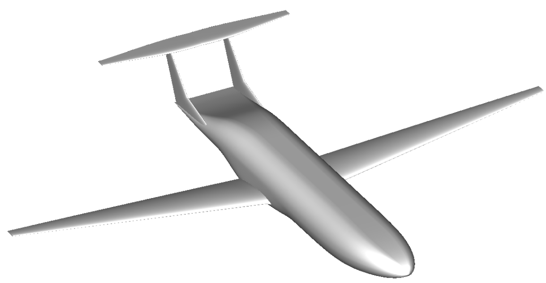

Figure 1: A computer model of the proposed D8 aircraft.

2 Configuration

The D8 is based on the idea that the aircraft fuselage can be designed so that a large boundary layer is present in the rear of the fuselage. Placing the engines on top of the fuselage in the boundary layer is more efficient than mounting them under the wing if the fan of the engine can be made so that it is distortion tolerant. To explore the possible advantages of this idea, the fuselage design shown in Fig. 1 is analyzed. The design consists of a fuselage made by putting two standard fuselage bubbles side by side and fusing them together along with a wing and an empennage. The empennage is made of two vertical tails on the back of the fuselage which are connected on the top by a horizontal tail. The engines are placed in between the two vertical tails, but in this paper we analyze the design without the engines.

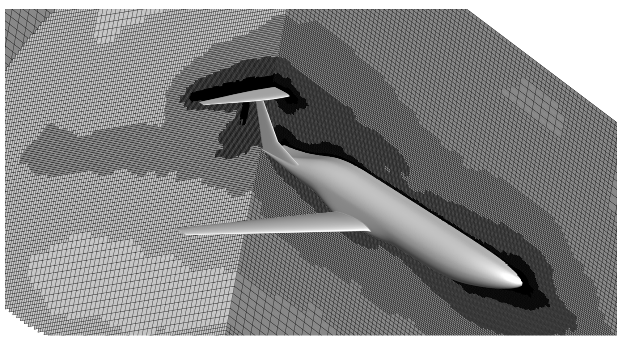

Figure 2: An automatically refined Cartesian embedded mesh for the D8 inviscid runs.

A 1:20 scale model of the aircraft was tested in the Wright Brothers Wind Tunnel (WBWT) at MIT at M=0.1578. This test data is used to compare the forces and moments obtained from the CFD simulation runs at various angles of attack.

3 Inviscid Simulations

The Cart3D code was used with its adjoint-based mesh refinement capability[2] to obtain inviscid solutions on the D8. The automatically refined mesh shown in Fig. 2 is a typical result of the refinement process and shows clustering of the mesh near the body, in the wing wake and in the viscinity of the empennage where we expect aerodynamic interference effects. The wind tunnel walls were included in the simulation to model the blockage effects due to the walls.

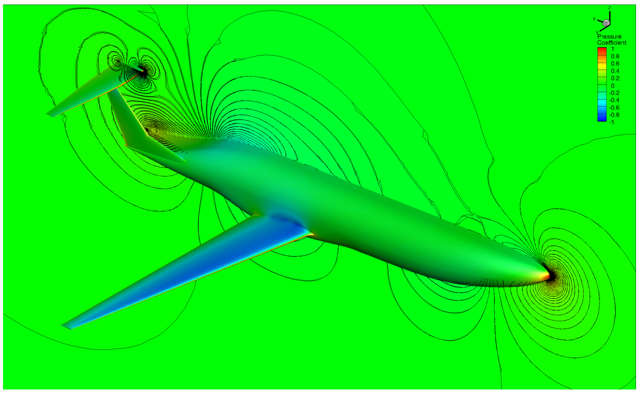

Figure 3: Coefficient of pressure on the surface and symmetry plane of the D8 aircraft.

4 Viscous Simulations

Overset grid technology[3] was used to perform viscous simulations on the D8. The CGT scripting tools[4] were used to generate an overset structured mesh on various components of the aircraft. The resulting mesh was used with the Overflow2 code[5] to obtain viscous solutions for the D8 external aerodynamics. A surface mesh size sensitivity study was performed on the fuselage, wing, and empennage components. Various near-wall spacings were also used to assess the effect of mesh refinement in the wall-normal direction. Finally, force/moment results from three turbulence models are compared to assess the effect of how turbulence is modeled.

For all computations, the wind tunnel walls are modeled as inviscid boundaries.

5 Results

Fig. 4 shows C_p contours on the surface and symmetry plane from the viscous simulation at zero angle of attack on a mesh with 70 million points. The final paper will consist of flow field comparisons of the inviscid results to the viscous results. The inviscid and viscous results will also be compared to the WBWT experimental data. Various mesh refinement studies will be presented along with comparison of results from several turbulence models. Verification and validation will be discussed in these contexts.

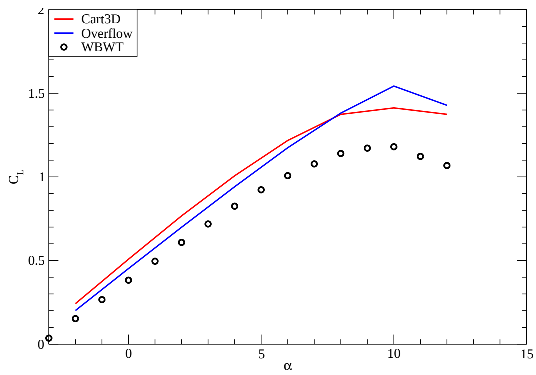

Figure 4: Lift as a function of the angle of attack.

6 Summary

The external aerodynamics environment of the D8 aircraft proposal is characterized with inviscid and viscous simulations. The results will be verified with a mesh refinement study and validated against the WBWT test results. The present methods will establish the basis for future studies with a boundary layer ingesting engine fan.

References

[1] M. Drela. Development of the D8 Transport Configuration. AIAA Paper 2011-3970, 2011.

[2] M. Nemec and M J. Aftosmis Adjoint-Based Adaptive Mesh Refinement for Complex Geometries AIAA Paper 2008-0725, 2008.

[3] W. M. Chan. Overset Grid Technology Development at NASA Ames Research Center. *Computers & Fluids*, 38:496-503, 2009.

[4] S. A. Pandya and W. M. Chan Automation of Structured Overset Mesh Generation for Rocket Geometries. AIAA Paper 2009-3993, 2009.

[5] P. G. Buning, D. C. Jespersen, T. H. Pulliam, G. H. Klopfer, W. M. Chan, J. P. Slotnick, S. E. Krist, and K. J. Renze. OVERFLOW User's Manual. NASA, 2005.