NASA-CR-196394

p-5

MCAT Institute
Annual Report
94-09

Design and Testing of an Oblique All-Wing Supersonic Transport

Christopher A. Lee

(NASA-CR-196394) DESIGN AND TESTING OF AN OBLIQUE ALL-WING SUPERSONIC TRANSPORT Annual Report (MCAT Inst.) 5 p

N95-12785

Unclas

G3/05 0019635

July 1994

NCC2-617

MCAT Institute
3933 Blue Gum Drive
San Jose, CA 95127

I. Introduction

During the past year applied aerodynamic research support has been given to the Oblique All-Wing (OAW) Design Group in the RAC branch of NASA Ames Research Center. This support has focused on the preliminary design of an OAW Supersonic Transport aircraft, and a corresponding wind-tunnel model that was tested in the NASA Ames 9- by 7-Foot Supersonic Wind Tunnel. The project was a cooperative effort involving NASA, Boeing, McDonnell Douglas, and Stanford University, with a main goal of determining the cruise performance (lift/drag ratio) of a realistically configured OAW.

In order to achieve an acceptable level of realism, it was necessary to consider many issues of design practicality. For instance, there needed to be a viable propulsion system, adequate control surfaces, landing gear, provisions for 450 passengers, and fuel to fly 5,000 nautical miles. The aircraft had to be stable, structurally sound, and needed to fit into airports across the world. Though much of MCAT's support was directed specifically towards integration of the propulsion system, there were notable contributions to many aspects of the configuration design, wind-tunnel model and wind-tunnel test.

Because the work done for this project is considered to be competitively sensitive technology, only a generic description is given here. Pictures are not allowed. For a more detailed account of the work, please see references 2 and 3.

II. Previous Work

The project work began in July of 1992 with OAW-0, the zeroth-order OAW configuration, as a starting point (see reference 1). By July 1993 the group had developed OAW-1 and OAW-2 designs, and was well on the way to freezing the eventual OAW-3. Between OAW-0 and OAW-2, support was given to the airfoil design optimization and wing design optimization efforts. The main tools used in these efforts were the Computational Fluid Dynamics (CFD) codes FLO6QNM, LBAUER, R22OPT, TranAir, and OVERFLOW. A thorough account of the wing design is given in reference 2. Other support given during this period was related to integration of the propulsion system. By the end of the OAW-2 work, a study of nacelle shapes and placements was nearly complete. Using TranAir, several different nacelle shapes were analyzed in a matrix of positions underneath the most current OAW wing configuration, in an effort to maximize favorable nacelle-nacelle interference and minimize unfavorable nacelle-wing interference.

III. Current Work

The past year's effort includes the completion of the baseline propulsion-integration work, and a presentation thereof at the First NASA/Industry High Speed Research Propulsion Airframe Integration Workshop in Cleveland, OH (reference 3). This work resulted in an 8.3% saving in inviscid drag for the OAW-2 wing-nacelles combination, compared with the OAW-0. The propulsion integration work continued with the design of the pylons. The first analysis in TranAir showed that the pylons had more than three times the expected drag increment. Analysis of a modified pylon showed only modest improvement (10% of the pylon increment) and prompted designers at Boeing to rethink their minimum-thickness constraints on the pylon. Using a new structure and stronger materials, the thickness of the engine pivot mechanism was cut in half, allowing for a thinner pylon. Unfortunately, this was done after the contracted machine shop had finished building the pylons for the wind-tunnel model. A retro-fit pylon was designed to try to take advantage of the reduced minimum thickness constraint. Even though it was not an optimal shape for the given thickness (since it had to fit the existing model) this thinner pylon was estimated to save nearly 50% of the incremental drag. It would have to be fabricated in the RA Division machine shop, however, as there was no money or time to have it done outside. In the end, the Division shop was unable to build the thinner pylon, owing to the very fine edges and small angles in the geometry. As a result, this pylon never got tested in the wind tunnel, though an analysis with CFD is planned.

In addition to the propulsion integration work, MCAT was simultaneously immersed in many other research activities. After analyzing a vertical fin design from McDonnell Douglas and finding poor pressure contours and trim results, the design of a simpler fin was undertaken. Following the determination of the shape and position of the fins (upper and lower), the fin incidences were tuned with TranAir to give yaw trim and equal loading. The effect of fin twist was looked at briefly as well. Subsequently, a TranAir analysis of the full configuration was performed for OAW-3 with wing, vertical fins, nacelles and pylons. This was the first time the whole aircraft had been analyzed with a nonlinear CFD code.

Viscous analysis of the OAW was of obvious interest as well. TranAir, with its boundary layer options, was tried but shown to give poor results. The boundary layer implementation in TranAir is not well suited for highly swept, or forward swept wings. Attention then turned to OVERFLOW, a Navier-Stokes code with overset (chimera) grid capability, developed at NASA Ames. OVERFLOW was run on the wing alone, the wing with fins, and the full configuration, with and without the wind-tunnel mounting blade included, for analyses on a total of six configurations. In some cases the research support entailed construction of the chimera grids, running of the solutions, and post processing of the data. In other cases, these three steps were shared among researchers.

The results from OVERFLOW were compared with Pressure Sensitive Paint (PSP) and experimental force and moment data during the wind-tunnel test in a demonstration of the IofNEWT program (Integration of Numerical and Experimental Wind Tunnels). It is interesting to note that some of the moments measured in the wind tunnel were significantly different from those predicted by the CFD analyses of the wing without the wind-tunnel mounting blade. This prompted the running of more CFD analyses *during* the test to ascertain the increments in performance due to the presence of the blade. The data from the with-blade CFD analyses showed remarkable agreement with wind-tunnel data, as witnessed by researchers at Ames, and others from Boeing and McDonnell Douglas who participated via the new Remote Access Wind Tunnel (RAWT) link.

The balance of the support provided by MCAT related directly to the running of the wind tunnel test. Research duties included the following:

- Reconciling the design specifications with the wind-tunnel model as built (e.g., comparing the designed pressure tap locations with those measured, and correcting the corresponding databases for use in the test).

- Helping set up the run schedule.

- Working as OAW Project Shift Engineer, overseeing the run schedule and keeping the test log up to date.

- Aiding in the equipment setup and operation for the PSP, IofNEWT and RAWT systems.

Research support will continue through the end of the OAW Project. Work will include performing any remaining CFD analyses (thinner pylons, flight Reynolds number, individual nacelle increments, etc.), helping with post-processing and interpretation of the wind-tunnel data, and helping with documentation of the design effort.

IV. Conclusion

The OAW Project has been a successful cooperative research effort, with MCAT playing an important role. The OAW team designed a realistic supersonic transport aircraft, steadily improving it from OAW-0 to OAW-3. The gains in the OAW's performance were achieved mainly through the iterative application of CFD, including the application of automated design-by-optimization schemes. Finally, the predicted cruise performance of OAW-3 was verified experimentally in the Ames 9- by 7-Foot Supersonic Wind Tunnel. The excellent agreement in the data clearly demonstrates the utility and value of CFD.

References

1. Waters, M.; Ardema, M.; Roberts, C.; and Kroo, I.: *Structural and Aerodynamic Considerations for an Oblique All-Wing Aircraft,* AIAA 92-4220, 1992.

2. Saunders, D. A.; Kennelly, R. A.; Cheung, S.; and Lee, C. A.: *Oblique Wing Design Experience II,* NASA Publication (publication specification to be determined), est. November 1994.

3. Lee, C. A.; Fletcher, M. J.; and Kulfan, R. M.: *Nacelle Location Study for an Oblique All-Wing Supersonic Transport,* Conference Publication from the First NASA/Industry High Speed Research Propulsion/Airframe Integration Workshop, NASA Lewis Research Center, Cleveland, OH, October 26-27, 1993, NASA CP-(number to be assigned upon end of restrictions).