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Investigation of Canard Missile with Planar and Grid Fins by using CFD Tool

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Abstract: The aerodynamic coefficients and flow surrounding a canard missile design were predicted using viscous computational fluid dynamics simulation. The computations were performed at speeds between 1.5 and 3.0. High-speed flight is possible with canard deflection angles of 0 to 10 degrees, as well as planar and grid tail fins. The estimated aerodynamic coefficients were found to be astonishingly close to those obtained in the wind tunnel once data from the wind tunnel was analysed.

It is possible that the flow visualisations produced by this work could lead to a better understanding of flow physics and the development of superior canard and tail fin designs for missiles and rockets among other things. Planar fins have a negative roll impact because of the pressure difference between the lowered fin and the canard trailing vortices. Grid tail fins improved the canards' ability to roll at low supersonic speeds by increasing their rolling efficiency.

Keywords: Missile, Fins, CFD, Canard, Control

I. INTRODUCTION:

Canards, or forward control fins, have been used in missile designs for a long time. "Lattice controls" have lately been offered as a viable solution to the roll control concerns of a plane's tail control surfaces. As the name suggests, a grid fin consists of an exterior frame that supports a grid of intersecting planar surfaces with small chords.

Using computational fluid dynamics (CFD), the Army Research Laboratory (ARL) is investigating grid fins, also known as lattice controls (CFD). Since 1985, the US Army has conducted research on grid fins. Aided by a computer The aerodynamic coefficients recorded in wind tunnel testing of a 13-calibre generic missile at the UK's Défense Evaluation and Research Agency (DERA) show very high agreement [2]. This variant has shown to be exceptionally dependable at speeds up to Mach 2.5 and attack angles ranging from 0 to 20 degrees. Concerning leeward grid fin normal force, this angle of attack had an effect. In addition to the theoretical and practical aspects, there is also

Fin lift properties are estimated using computational algorithms and grids. For the subsonic, trans- and supersonic zone, Edvard's theory and the vortex lattice theory have been established theory[3]. Many studies have shown that grid fins outperform traditional planar fins. Aerodynamic control at high Mach numbers has many advantages, including high and high Mach numbers, a low hinge moment, and compact storage. The grid fin concept has one major drawback: it has a larger drag than planar fins. Fortunately, good design can help decrease this drag to a manageable level[4]. It was determined that the unfavourable forces and moments observed by researchers in the wind tunnel were caused by flow mechanics that could be better understood using CFD simulations. First grid fin CFD simulations financed by DREV researchers in Canada.

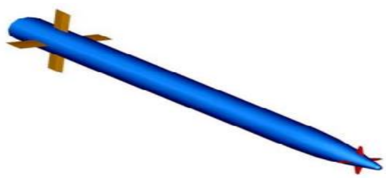

Fig.1. Canard Missile with planar fins

II. OBJECTIVE:

The investigation's goal is to compare experimental data with Navier-Stokes (N-S) models of a missile form with grid fins to determine which is more accurate. The results of this inquiry are the first viscous CFD calculations to be performed with grid fins[11].

III. Approach:

3.1 Numerical Approach:

CFD was used to determine the flow field and aerodynamic coefficients on a generic missile design with four fins and a calibre of 13 calibre (Figure 1). In addition to the 3-calibre tangent give, the missile has a fin pitch axis that is 1.5 diameters ahead of the missile's aft end. After much deliberation, it was decided to divide the study into three parts, which were as follows: the missile without fins, case B 1A (Figure 1 top); the missile with planar fins, case B lAC2R (Figure 1 middle); and the missile with a set of grid fins, case B 1AL2R (Figure 1 bottom) (Figure 1, bottom). In accordance with the DERA designations, names were given to the various configurations. The planar fin had a span and chord of 1. O calibre and a span of 1. O calibre. Each calibre of the chord and the grid fin measured 0.17 calibres and 1.1 calibres, respectively. All of the analyses were done on a single computer, which was used for everything. A minimum of three angles must be met, as well as a Mach number of 2.5[11]. Simulations were conducted performed in this case. Because of symmetry (the x-z plane) and symmetry (the cruciform (+) missiles), only a half-plane was modelled for this model (x-z plane).

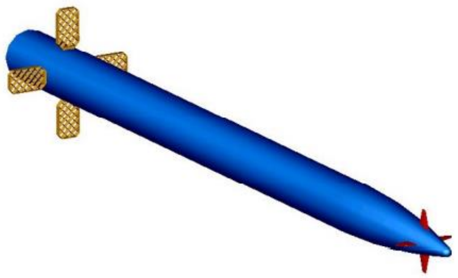

Fig.2 Canard Missile with grid fins

3.2 Geometry and Simulation Parameters:

It is being used to determine the flow field and aerodynamic coefficients for a 16-calibre canard-controlled missile with four fins and a canard control system. After DREV's experimental wind tunnel investigation, this research was conducted [1]. For the test section of the DREV wind tunnel, the design dimensions are 0.61 metres by 0.61 metres. The test portion of the DREV wind tunnel has design dimensions of 0.61 metres by 0.61 metres.

Flowing air from an atmospheric pressure tank to a vacuum tank in this wind tunnel has Reynolds numbers that are lower than free-flight values at high Mach numbers, which makes it more efficient[6]. The geometry of the wind tunnel models was used in the computational fluid dynamics analysis. The fins were aligned with four canards on the give, which helped to stabilise the ship[7]. There were two types of fins investigated: classic planar fins and grid fins. Traditional planar fins were the first to be studied. Figure 1 depicts the planar fin geometry, while Figure 2 depicts the grid fin geometry.

The Reynolds number of a wind tunnel varies from 1.56 x 107 m-1 at M = 1.15 to 4.7 x 106 m-1 at Mach 4.

To determine the aerodynamic coefficients, the viscous and pressure forces were combined along the missile body and fin surfaces. In missile-based coordinates, the normal force (Cz), axial force (Cx), and pitching moment (Cm) coefficients are shown.

3.3 Planar Fin Case:

The CFD Fluent solutions were used to derive the aerodynamic coefficients. For the FLUENT computations, the computed coefficients are presented at cx = 0", 10", and 20". The normal force and pitching moment coefficients calculated correlate extremely well with the actual values of aerodynamic coefficients. The largest discrepancy in pitching moment coefficient (Pmc) between calculated and measured values was roughly 2.3 per cent. The estimated and measured normal force coefficients differed by as much as 0.8 per cent. The planar fin model's CFD calculations include a portion of the wind tunnel sting.

3.4 Grid Fin Case:

The aerodynamic coefficients obtained from the CFD Inviscid solutions are plotted as a function of the y-axis. For CFD examples, the calculated coefficients are indicated at the points a = O", l0', 12", and 20" on the graph. The normal force and pitching moment coefficients that were generated are in great agreement with the aerodynamic coefficients that were used in the calculations [9]. The difference between the estimated and measured pitching moment coefficients was as large as 6.2 per cent.

3.5 Solver:

The flow field was computed using the commercial CFD code FLUENT Version 5.5 and steady-state computations[8]. The unstructured-mesh solver was utilised, which was implicit, compressible (coupled), and unstructured. The finite volume approach is used to solve the three-dimensional (3-D), time-dependent Reynolds Averaged Navier-Stokes (RANS) equations:

$$\frac{\partial}{\partial t}\int_V \mathbf{W}\,dV + \oint [\mathbf{F}-\mathbf{G}]\cdot dA = \int_V \mathbf{H}\,dV \,,$$

Where,

$$\mathbf{W} = \begin{Bmatrix} \rho \\ \rho u \\ \rho v \\ \rho w \\ \rho E \end{Bmatrix}, \quad \mathbf{F} = \begin{Bmatrix} \rho \mathbf{v} \\ \rho \mathbf{v} u + p\mathbf{i} \\ \rho \mathbf{v} v + p\mathbf{j} \\ \rho \mathbf{v} w + p\mathbf{k} \\ \rho \mathbf{v} E + p\mathbf{v} \end{Bmatrix}, \quad \mathbf{G} = \begin{Bmatrix} 0 \\ \boldsymbol{\tau}_{xi} \\ \boldsymbol{\tau}_{yi} \\ \boldsymbol{\tau}_{zi} \\ \boldsymbol{\tau}_{ij} v_j + \mathbf{q} \end{Bmatrix}.$$

The aerodynamic coefficients obtained from the CFD Inviscid solutions are plotted as a function of the y-axis. For CFD examples, the calculated coefficients are indicated at the points a = O", l0', 12", and 20" on the graph. The normal force and pitching moment coefficients that were generated are in great agreement with the aerodynamic coefficients that were used in the calculations. The difference between the estimated and measured pitching moment coefficients was as large as 6.2 per cent.

IV Solution Methodology:

4.1 Computational Mesh and Boundary Conditions:

Using the pre-processor in Ansys FLUENT, I was able to create geometry and an unstructured mesh. Because of the canard deflection and angle of attack, symmetry and periodicity were unable to be utilised, necessitating the creation of a complete 3-D mesh. For the meshes near the missile body and fin surfaces, the boundary layer mesh spacing was used in conjunction with the boundary layer mesh spacing. To solve the equations between the wall and the first point above the surface, two-layer zonal models were employed in conjunction with each other[10]. In order to determine the aerodynamic coefficients of the missile, it was necessary to include the combined effects of viscous and pressure forces. Using missile-based coordinate systems, it is able to see the normal (z), axial (x), and pitching moment (Cm) coefficients, among other things. The pitching moment of the missile is calculated using the nose of the missile. The derived coefficients are compared to data from the DERA wind tunnel. The forces on the missile base were not taken into consideration while calculating the results from the DERA wind tunnel simulation. In general, the aerodynamic coefficients measured in the DREV wind tunnel were fairly similar to the estimates. There were approximately 144 cells on each of the four grid fins of the missile on each of its four sides. Figs. 3 and 4 show surface mesh representations of the tail and give regions, respectively. The grid fin case was addressed by using a combination of hexagons and tetrahedrons.

Although these values aren't ideal for estimating the grid fins' boundary layer properties, they did not affect the missile's aerodynamic coefficients.

If any tail fin surfaces are not placed extremely close to the missile's base, an appropriate approach has been identified in the situation of supersonic flow[5]. For all solid surfaces, a nonslip wall boundary condition was used.

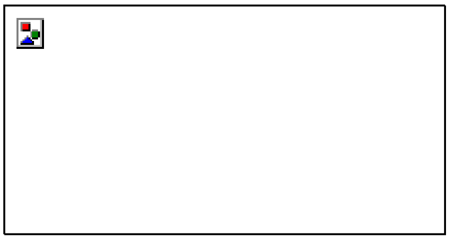

Fig. 3 Mesh View of tail region

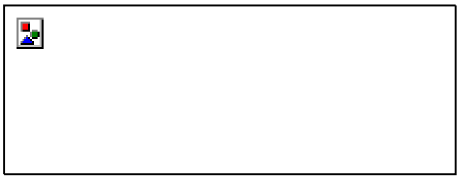

Fig 4 Mesh view of the tail region

V. Results of Aerodynamic Coefficients:

5.1 Aerodynamic Coefficient

When calculating the aerodynamic coefficients, it was necessary to incorporate the viscous and pressure forces throughout the surface of the missile body and fins. This section presents the coefficients of the normal force (z), axial force (x), and pitching moment (Cm) in the context of missile-based coordinates. The pitching moment of the missile is described in terms of the nose of the missile.

A comparison is made between the predicted coefficients and the results of wind tunnel tests done at DERA. The forces acting on the missile's base were not taken into account in the coefficient calculation based on the DERA wind tunnel data. Every one of the computed aerodynamic coefficients was found to be in very close agreement with the experimental values obtained in the DREV wind tunnel.

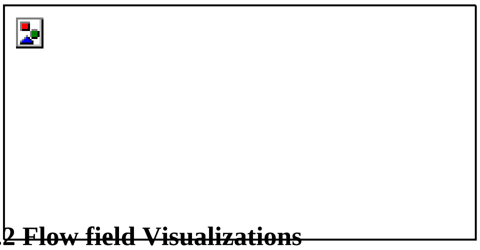

Fig 5 Flow field Planar Fin case

5.2 Flow field Visualizations

According to visualisations of the flow field, the canard deflection had a considerable influence on the forces acting on the missile during its flight. Planar fin scenarios with = 10 deg at 4 and 10 degrees are depicted in Figure 11 as the centre of pressure distribution on missile surfaces.

It was discovered that the canard trailing vortices interacted with the missile flow field, causing pressure distribution throughout the missile's body and tail fins to change. M = 1.5 produces the most obvious impact, with a huge low-pressure zone on the missile's starboard side. M = 2.0 produces the least noticeable effect.

5.3 Forces on Fins

It is necessary to utilise the FLUENT to compute the normal force coefficients on each of the grid fins individually. In addition, there is a wind tunnel where measurements can be taken. At the "+" configuration, while looking forward from the rear of the missile, the fins are numbered 1 through 4, with Fins 1, 3, and 4 located in the Fin 3 o'clock position and Fin 4 located in the Fin noon position, respectively. It was decided to employ simulations.

The normal force acting on the fins was accurately predicted, with a deviation of up to 11% from the actual force acted on the fins The attack angles of some fin segments will be effective negative angles, but the attack angles of other fin portions will be effective positive angles[7].

The axial force coefficients of individual grid fins were 2–3 times greater than those of planar fins. The viscous component of the axial force of the grid fin was 1 – 5 times greater than the component of the axial force of the planar fin.

VI. CONCLUSIONS

Using viscous computational fluid dynamics, it was possible to predict the aerodynamic coefficients and flow field surrounding a generic canard-controlled missile configuration in supersonic flow (CFD). In order to verify this, a comparison of the computed aerodynamic coefficients with those obtained from wind tunnel testing was performed, and the results were found to be correct. The downwash and canard following vortices formed in the low-pressure zone on the starboard side of the missile are visible inflow field visualisations while the missile is travelling at low supersonic speeds, as is the canard following vortex when travelling at high supersonic speeds. In experiments, increasing the supersonic speed resulted in a considerable reduction inside force. When travelling at low supersonic speeds, grid tail fins improved the effectiveness of the canards' roll by reducing drag.

In order to do this, the grid fin is designed in a different manner than the planar fin, resulting in lower side forces and a smaller roll moment than with the planar fin.

References:

[1] Allen, J. M., and Blair, A. B., Jr., "Comparison of Analytical and Experimental Supersonic Aerodynamic Characteristics of a Forward Control Missile," Journal of Spacecraft and Rockets, Vol. 19, No. 2, 1982, pp. 155-159.

[2] Blair, A. B., Jr., Dillon, J. L., and Watson, C. B., "Experimental Study of Tail-Span Effects on a Canard-Controlled Missile," Journal of Spacecraft and Rockets, Vol. 30, No. 5, 1993, pp. 635-640.

[3] Blair, A. B., Jr., "Supersonic Aerodynamic Characteristics of a Maneuvering Canard Controlled Missile with Fixed and Free-Rolling Tail Fins," Society of Automotive Engineers, SAE Paper 90-1993, Oct. 1990.

[4] Miller, M. S., and Washington, W. D., "An Experimental Investigation of Grid Fin Drag Reduction Techniques," AIAA Paper 94-1914-CP, Jun. 1994.

[5] James DeSpirito, Milton E. Vaughn Jr.* and W. David Washington" CFD Investigation of Canard-Controlled Missile With Planar And Grid Fins In Supersonic Flow" AIAA Atmospheric Flight Mechanics Conference and Exhibit 5-8 August 2002, Monterey, California

[6] Simpson, G. M., and Sadler, A. J., "Lattice Controls: A Comparison with Conventional, Planar Fins," Proceedings of the NATO RTO Applied

Vehicle Technology Panel Symposium on Missile Aerodynamics, RTO-MP-5, NATO Research and Technology Organization, Neuilly-Sur-Seine Cedex, France, 1998, pp. (9-1)–(9-10).

[7] DeSpirito, J., Edge, H., Weinacht, P., Sahu, J., and Dinavahi, S. P. G., "Computational Fluid Dynamic (CFD) Analysis of a Generic Missile with Grid Fins," ARL-TR-2318, U.S. Army Research Laboratory, Aberdeen Proving Ground, MD, September 2000.

[8] Fluent 5.0 Users Guide, Vol.2. Lebanon, NH: Fluent, Inc., 1998. 17. Spalart, P. R., and Allmaras, S. R., "A One-Equation Turbulence Model for Aerodynamic Flows," AIAA Paper 92-0439, January 1992.

[9] AIAA 2001-0257 "Viscous CFD Calculations of Grid Fin Missile Aerodynamics in the Supersonic Flow Regime" J. DeSpirito and J. Sahu U.S. Army Research Laboratory Aberdeen Proving Ground, MD

[10] Abate, G. L., Duckershein, R., and Hathaway, W., "Subsonic/Transonic Free-Flight Tests of a Generic Missile With Grid Fins," AIAA Paper 2000-0937, January 2000.

[11] AIAA 2000-0391 CFD Analysis of Grid Fins for Maneuvering Missiles J. DeSpirito, H.L. Edge, P. Weinacht, and J. Sahu U.S. Army Research Laboratory