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Computational Aerodynamic Prediction for Integration of an Advanced Reconnaissance Pod on a 5th Generation Fighter Type Aircraft

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ABSTRACT

In this paper a computational aerodynamic prediction to support the aeromechanical integration of an advanced reconnaissance pod on a 5th generation fighter type aircraft is presented. The aim of the activity was to compare the aerodynamic characteristics of the new pod to a previous one already cleared on the same aircraft fleet, given verified inertial and structural similarity. Verifying the aforementioned aerodynamic similarity without involving extensive flight test activity was a must, to save time and to reduce costs. A two steps approach was required by the Certification Authority to verify, initially, the performance data compatibility in terms of aerodynamic coefficients of the old pod with the new one, in order to allow performance flight manual data interchangeability (a quantitative comparison was required); afterwards, a qualitative assessment was conducted to verify the absence of unsteadiness induced by the introduction in the external structure of the new pod of an auxiliary antenna case. Computational results are presented both for Straight and Level Un-accelerated Flight and Steady-Sideslip flight conditions at different Angles of Attack.

Keywords – Computational Fluid Dynamics, Envelope Expansion, Flight Test, Store Integration, Modeling and Simulation

NOMENCLATURE

AAU = Auxiliary Antenna Unit
AoA = Angle of Attack
AoS = Angle of Sideslip
C_D = Drag Coefficient
C_L = Lift Coefficient
C_Y = Side-force Coefficient
CAD = Computer Aided Design
CFD = Computational Fluid Dynamics
FQ = Flying Qualities
HQ = Handling qualities
ISA = International Standard Atmosphere
M = Mach Number
SLUF = Straight and Level Un-accelerated Flight
y^+ = Dimensionless Wall Distance

I. INTRODUCTION

Any time a new aircraft is introduced into service, or an old aircraft undergoes substantial modifications or needs to be certified to carry and employ new stores, the store separation engineer is faced with a decision about how much effort will be required to provide an airworthiness certification for the aircraft and the stores. Before operational use, all aircraft/store configurations must be certified for safe loading, carriage and jettison/release.

Generally, there are three approaches that have been used: Wind Tunnel Testing, CFD analyses and Flight Testing. During the past thirty years there have been considerable advances in all three areas. Nowadays, it is possible to combine these three approaches in a unique process that permits to reduce risks and lowering costs, optimizing the application of ground and flight testing ([1],[2],[3],[4]).

In this paper a computational aerodynamic prediction to support the aeromechanical integration of an advanced reconnaissance pod on a 5th generation is presented. The aim of the activity was to compare the aerodynamic characteristics of the new pod to a previous one already cleared on the same aircraft fleet, given verified inertial and structural similarity. Verifying the aforementioned aerodynamic similarity without involving extensive flight test activity was a must, to save time and to reduce costs ([5],[6]).

II. AIM OF THE ACTIVITY

In this paper the computational results relative to the comparison of two different reconnaissance pods are presented. These analysis were performed in order to evaluate the effect of the new pod on the aircraft performances and flying qualities.

The following name tags were assigned to the two following configurations:

- Configuration A = Aircraft + OLD pod;
- Configuration B = Aircraft + NEW pod.

In order to permit the read-across of the performance data of the old pod, without performing additional flight tests, it was considered that a variation of the global drag coefficient between the two aforementioned configurations not higher than a 5% could be considered adequate. Moreover, it was also necessary to evaluate the effect of the shape of the new pod on the aircraft flying qualities in order to affirm that no aerodynamic instabilities were generated.

In order to speed up the computational phase, the requirements were expressed at store system level.

Overall, the test team decided to investigate the following main technical areas in order to confirm that the new pod was suitable for the operational goal:

- form, fit, function (mechanical interface compatibility);
- avionics (human machine interface, electromagnetic compatibility, software integration);
- structural loads (static and dynamic);
- flight control system store management (different inertial properties);
- performance definition (declaration of acceptable degradation - 5%);
- flying/handling qualities assessment.

The first four areas are not object of the present study, which will focus on the last two topics.

III. SIMULATION APPROACH

3.1 CAD GENERATION

Before starting the fluid-dynamic analysis, the first necessary activity was the generation of the CAD drawings of the reconnaissance pods. The description of the geometry as provided by the manufacturer was totally unsuitable for fluid-dynamic analysis. After fine-tuning this geometry applying the techniques described in [7] was possible to obtain the geometries presented in Figure 1 and Figure 2.

As showed in Figure 1 and Figure 2, the main differences between the two pods is the presence in the new pod of an auxiliary antenna unit case; the evaluation of the effect of this external case on the aerodynamic characteristics of the new pod was the main subject of the present study.

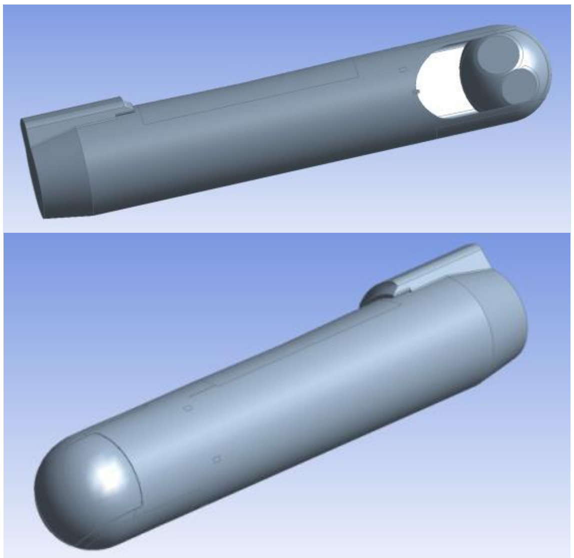


Figure 1: Old pod CAD geometry

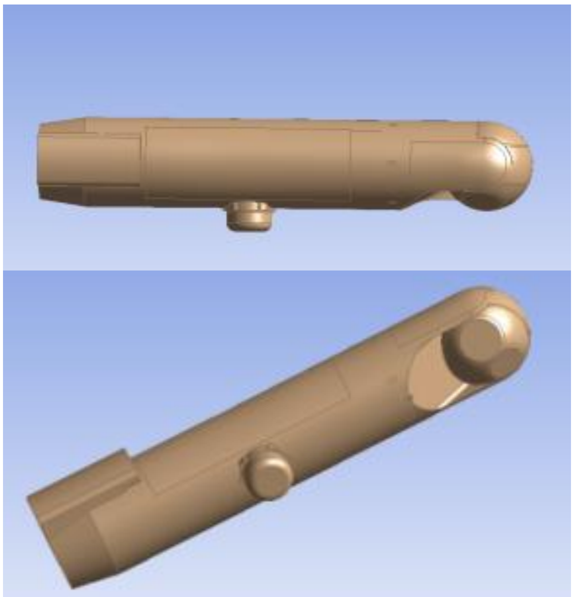


Figure 2: New pod CAD geometry

3.2 MESH GENERATION

The meshes were generated using the ANSYS Meshing tool. The generated grids were viscous hybrid meshes; this particular type of mesh uses a layer of prism elements along the wall to discretize the boundary layer with tetrahedral elements in the bulk flow region. The prismatic cells allow you to resolve the normal gradients associated with boundary layers with fewer cells. High quality prism elements are created near the boundary and tetrahedral elements in the rest of the domain. Compared to all-tetrahedral meshes, viscous hybrid meshes result in dramatic savings, with far fewer elements required to accurately resolve boundary layers and give good near-wall prediction of shear stress, heat transfer, and flow separation.

The generated grids were considered of satisfactory quality concerning the values of y^+ (Figure 3), skewness (≤ 0.92) and aspect ratio. The total number of cells for both the grids was about 1.7 M and the boundary layer was composed by 30 layers of structured cells.

Figure 4 and Figure 5 illustrate the grids for the old and the new pod geometries showing also details of the grids in the boundary layer region.

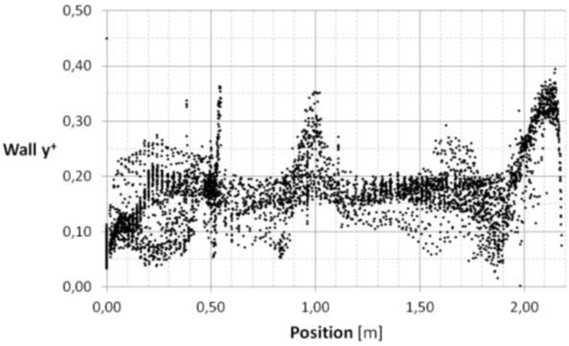


Figure 3: Dimensionless wall distance for new/old pod grids

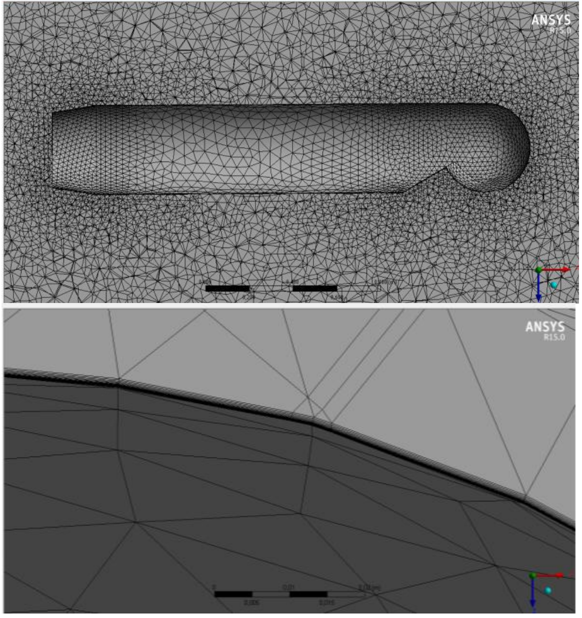
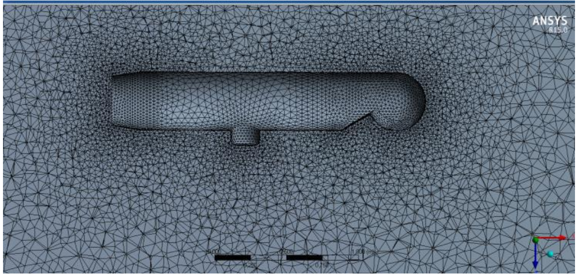


Figure 4: Old pod grid



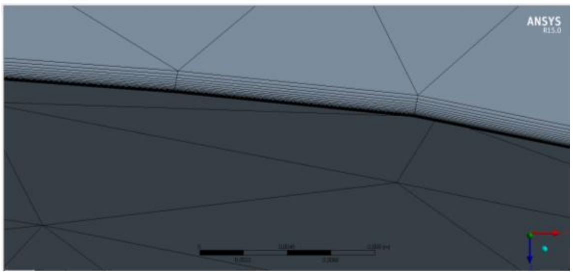


Figure 5: New pod grid

IV. RESULTS

4.1 PRELIMINARY ANALISYS

Before starting the simulations on the new pod, preliminary evaluations were conducted on the old pod in order to validate the generated geometry and grid. Therefore, a comparison with wind tunnel and semi-empirical data ([8]) was conducted at Mach number equal to 1.20 for different values of Angle of Attack

As shown in Figure 6, the results obtained calculating the aerodynamic coefficients with ANSYS Fluent matched the Wind Tunnel Test Data better than the predictions obtained using a semi-empirical method; presenting a maximum deviation of the 8% instead of the 10% obtained with the semi-empirical method.

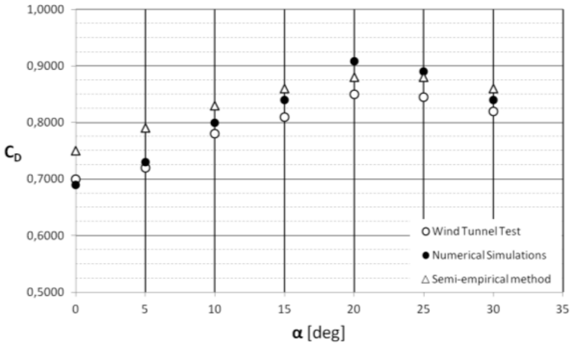


Figure 6: Old pod data comparison

4.2 EFFECT OF THE NEW POD ON AIRCRAFT PERFORMANCES

For the new pod the aerodynamic coefficients, the associated pressure distribution and the velocity field were analyzed in the entire operational envelope showing full compliance with the performance requirements (difference between the two pods not higher than 5%).

As an example of the relevant calculated data, Figure 7, Figure 8, and Figure 9 show the drag coefficient, the lift coefficient and the aerodynamic polar of the new pod and the old pod at Mach number equal to 0.60 for a range of total AoA [-30°;30°], at sea level in ISA conditions.

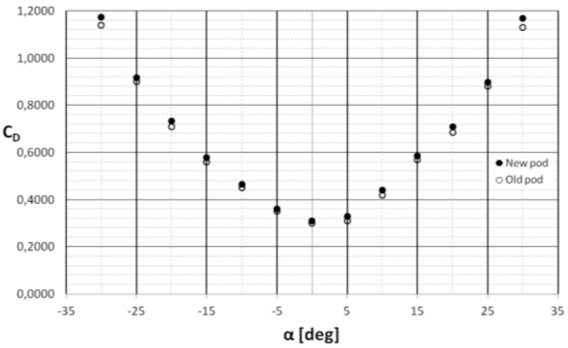


Figure 7: Numerical drag coefficient prediction

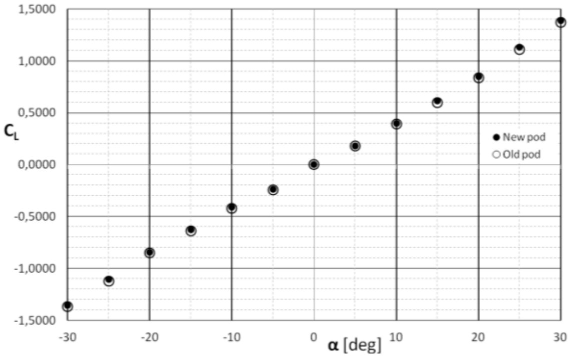


Figure 8: Numerical lift coefficient prediction

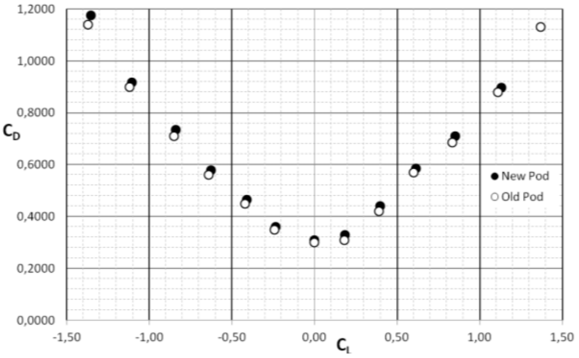


Figure 9: Numerical aerodynamic polar prediction

Figure 10 shows the effect of the Mach number on drag and lift coefficients of the new pod; it is possible to observe that the drag coefficient trend presents the classical exponential increase passing through the transonic area. The lift coefficient is almost zero, slightly negative, probably due to the asymmetric combined effect of the pod air intake and AAU in the lower portion of new pod.

Some minor convergence issues were faced in the sonic area, partially solved via inflation, however further investigation is still required in order to discriminate the problem.

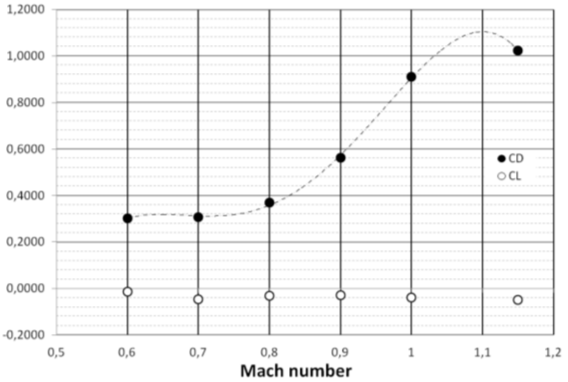


Figure 10: Effect of Mach number on Lift and Drag coefficient for the new pod

However, in order to validate the aerodynamic analysis performed on the new pod 10 test flights were performed (3 completely dedicated to performance evaluation). Figure 11 shows the test points executed (flight envelope picture not representative of the analyzed jet).

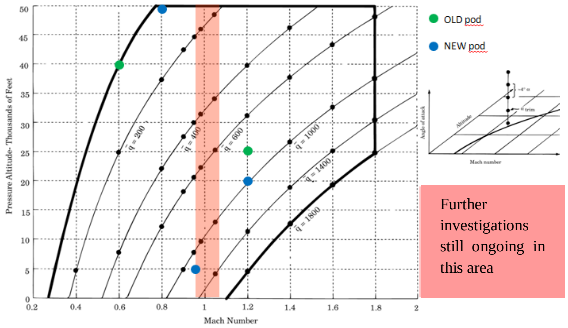


Figure 11: Flight Test spot checks.

The result of the flight test phase was a good agreement between new pod predictions and data gathered in flight, no more than 7% off including the area around Mach=1.0; less than 5% excluding that area. As aforementioned, it is still pending a verification around the M=1.0 area.

Overall, being the performance of the new pod within the required tolerances, a Declaration of Acceptable Performance Degradation was released by the Certification Authority and the following data were read across from previous cleared old pod:

- fuel consumption charts (cruise, climb in MAX CONTINOUS/MAX REHEAT);
- takeoff-landing performance (airspeed, distance);
- specific excess power charts;
- time to climb charts;
- dive recovery parameter.

4.3 EFFECT OF THE NEW POD ON AIRCRAFT FQ

Further analysis were conducted in order to eventually confirm the predicted minor effects that the introduction of the AAU could have had on the FQ of the total asset. The aim of the analysis was to ensure that the introduction of the AAU would have not generated any flow unsteadiness.

The most relevant result was that no unsteadiness was introduced in the flow by the AAU for AoS [0°;23°], therefore reduced number of additional test flights were required for lateral-directional dynamics characterization. However, as graduation exercise and for structural verification purposes, the following subset of flight test maneuvers in the corners of the new pod operating envelope were performed:

- steady heading side slips (in order to evaluate the aircraft static stability);
- rudder doublets (in order to evaluate the aircraft dynamic stability);
- scissors, bank-to-bank, rolling pull-out and push-over (for parameter identification purposes);
- zero error/boundaries avoidance point tracking and off-set landing (to verify the aircraft+pod operational suitability);

As a side-result, which come out ride along the evaluation, it was noticed that increasing the Mach number, the presence of a vortex area underneath the new pod in the sensors area had a positive stabilizing effect on the airflow (Figure 12). Nevertheless, this effect, decreased with incremental “pilot’s pedal”, translating from the jargon “increasing the angle of sideslip”.

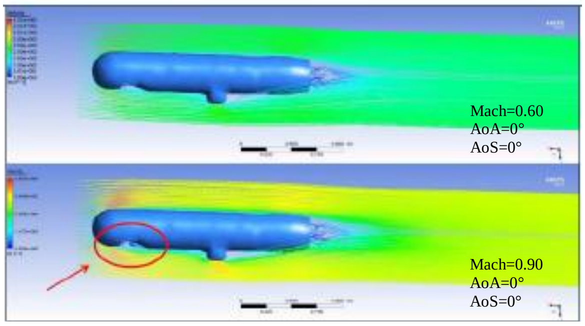


Figure 12: Effect of Mach number on the streamlines in the sensor area

Additional simulations were performed in order to evaluate the quantitative effect of the sideslip angle on the aerodynamic coefficients, also for structural verification purposes (of particular interest was the side-force C_Y). Figure 13 shows the lift, drag and side-force coefficients, at Mach number equal to 0.60 and AoA=0° for a range of AoS [0°; 23°], at sea level in ISA conditions. It is possible to observe that the drag coefficient showed small variations with the AoS, less than 10%, while the lift coefficient increased and the side-force coefficient showed a linear trend with the increasing of the angle of sideslip.

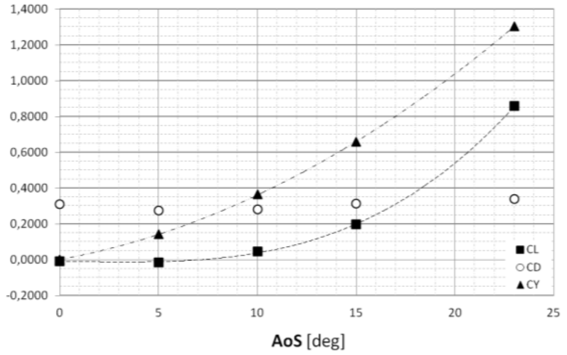


Figure 13: Sideslip angle effects on aerodynamic coefficients

V. CONCLUSION

Overall, it was demonstrated a good match between semi-empirical, numerical and wind tunnel test data for the old pod. Flight tests confirmed the accuracy of the computational results obtained.

The main goal, to achieve an operational capability reducing the number of required experimental flights and associated time and costs, was attained. The operational clearance, partially by read across, was released within 36 days and 10 successful flights (more than 20 flight hours).

REFERENCES

[1] *Simulation in Support of Flight Testing*, (RTO-AG-300 Vol.19, September 2000)

[2] *Aircraft/Stores Compatibility, Integration and Separation Testing, (*STO-AG-300 Vol.29, September 2014)

[3] *Aerodynamics of Store Integration and Separation*, (AGARD-CP-570, April 1995)

[4] Cenko A., *Store Separation lessons learned during the last 30 years*, 27th International Congress of the Aeronautical Sciences.

[5] d’Argenio A., *Computational Fluid Dynamics to support Military Jet Aircrafts Flight Tests using Optimization Techniques*, doctoral diss., Università di Napoli “Federico II”, Napoli, Italy, 2015

[6] Natale N., d’Argenio A., De Paolis P., de Nicola C., *CFD in Support of Flight Testing for Aircraft/Stores Integration*, International CAE Conference, Pacengo del Garda, 2013.

[7] Ping Fu, *Reverse Engineering, an Industrial Perspective*, (Edited by: Vinesh Raja, Kiran J. Fernandes, Springer 2008)

[8] Bock, K.-W., Fuchs, H., Lehra, H., «The missile coefficient program AAV», Dornier Report BF 9/87 B, May 1987