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FLOW AND NOISE PREDICTION OF DOORS-ON M219 CAVITY THROUGH IMPROVED DELAYED DETACHED EDDY SIMULATIONS

Seyfettin COŞKUN*,Yusuf ÖZYÖRÜK†

*Turkish Aerospace (TA)
06100 Ankara, TURKEY
e-mail:seyfettin.coskun@tai.com.tr, web page: http://www.tai.com.tr

†Middle East Technical University (METU)
Professor, Department of Aerospace Engineering
06800 Ankara, TURKEY
e-mail: yusuf.ozyoruk@metu.edu.tr, web page: http://www.metu.edu.tr

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Abstract. High survivability and low observability requirements of modern fighter airplanes necessitate internal carriage of the stores. During their deployment the doors of internal weapon bays are opened transitionally, forming a cavity and hence a highly unsteady and nonlinear flow coupled with acoustic feedback mechanism. These processes present unsteady vibratory loads on the stores and structures. In the present paper, CFD computations of the doors-on M219 cavity with use of Improved Delayed Detached Eddy Simulation (IDDES) are carried out to predict the turbulent fluctuations and the associated noise. Computationally less expensive Unsteady Reynolds-Averaged Navier-Stokes (URANS) calculations with kω-SST model are also carried out. Comparisons of the attained overall sound pressure levels at various locations on the cavity ceiling with experimental data show the latter approach usually lacks accuracy with overpredicted values, while the former one predicts the levels quite well.

1 INTRODUCTION

High survivability and low observability of modern fighters require that the stores be carried internally. When the weapon bays are open at high speeds, they generate highly complex nonlinear fluid dynamic phonomena such as unsteady flow, turbulent structures, massive flow separation, shear layer instabilities, and so on [1, 2]. As a result of these complex flow phenomena, there are generated acoustic waves which interact with the fluid flow around, generating a feedback mechanism. If it is not taken care of, acoustic phenomena generated within the cavity may damage or cause unsafe operation of the weapons bay environment, including the stores carried [3].

Cavity flows are mainly classified as open, closed, and transitional cavities [4], depending on their width (W), depth (D), and length (L), as well as the flow speed. In open cavities ($L/D < 10$), separated flow forms a highly unsteady shear layer passage over the cavity opening, which in turn causes highly unsteady pressure distribution within it. Such a pressure distribution brings up an intensive acoustic environment within the cavity. In closed cavities ($L/D > 13$), on the other hand, separated flow impinges on the cavity ceiling, resulting in high pressure gradients, which is undesired for store separation characteristics of an internal weapons bay. Transitional cavity flows ($10 < L/D < 13$), exhibit both open and closed cavity characteristics, depending on the flow speed.

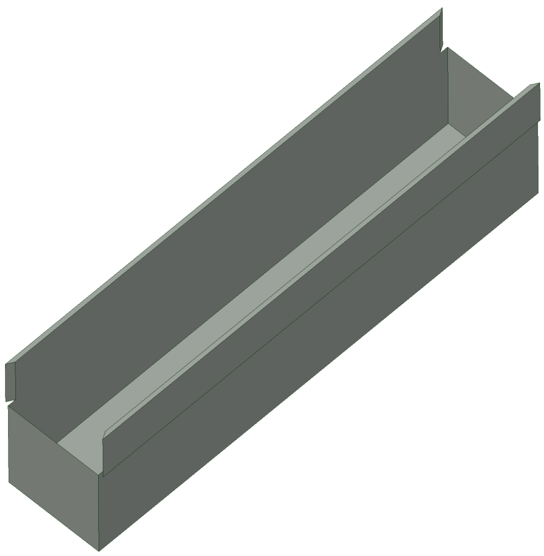
Due to the aformentioned complexity of the flow field of a cavity, it is important to resolve the turbulent flow structures instead of modelling. Therefore, for cavity flows scale resolving turbulence methods like Detached Eddy Simulation (DES) and Large Eddy Simulation (LES) are more suitable than Unsteady Reynolds Averaged Navier-Stokes (URANS) solutions. However, grid resolution requirements of scale resolving methods results in high computational costs, and because of this, URANS approaches are not completely abandoned in cavity flow analyses.

During internal store separation from weapons bay, doors of weapon bay open transitionally. When this transition takes place and doors move from closed to open configuration, cavity flows exhibit closed, transitional and open type cavity characteristics, respectively, due to the doors limiting the shear layer development [5], changing the acoustic characteristic of the cavity. Hence, acoustic effects of the open cavity doors is studied in this work. The M219 test cavity is solved using the URANS an IDDES approaches in the present paper. The configuration setup is discussed below. This is followed by presentation and discussion of the results, and conclusions from the study are given at the end.

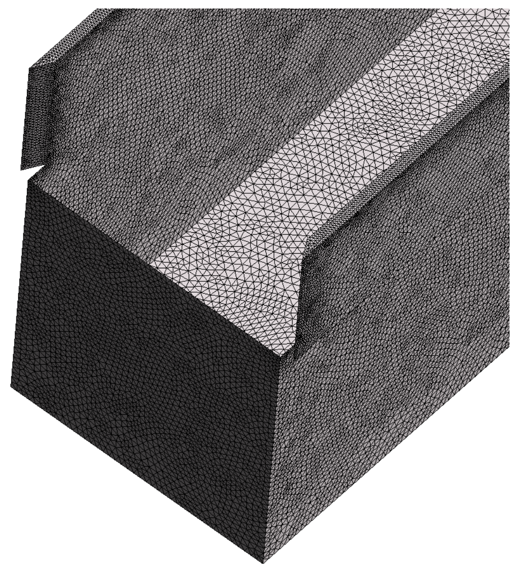
2 SIMULATION SETUP

M219 test cavity has a length-to-depth raio (L/D) of 5 and width-to-depth ratio (W/D) of 1. Such a cavity is classified as an open cavity. The operating conditions of M219 cavity in the experimental envionment are $M = 0.85$ and Re= 6.7×10^6 based on the cavity length, L.

Two cavity doors, each with $W/2$ width, are assumed to have opened to a 90 deg position as shown in Figure 1a. In Figure 1b, surface grid around the cavity walls and doors is provided. The grid was generated in compliance with the IDDES requriments.



(a) Doors-on M219 Geometry



(b) Surface Grid Around the Cavity

Figure 1: Doors-on M219 Cavity

In the computational analyses, both kω-SST URANS and IDDES methods are employed with a 25 millions of computational cells in the solution domain. ANSYS/Fluent is used as the solver. Dual-time stepping algorithm is employed with $\Delta t = 1 \times 10^{-5}$s and 30 subiterations. Solutions are carried out on a 1400-core High Performance Computing (HPC) platform.

3 RESULTS AND DISCUSSION

Cavities exposed to high speeds undergo highly unsteady and nonlinear fluid dynamics, which complicate the simulation of flow field. In turbulent flow and noise prediction of such a complex problem, high fidelity methods, like IDDES, are required. However, URANS methods are sometimes helpful to capture the dominant characteristics of the flow.

Figure 2 shows the instantaneous Mach contours in the near region of M219 cavity from the IDDES. Vortex structures and unsteadiness in the flow field have been captured reasonably well which is evident from the figure.

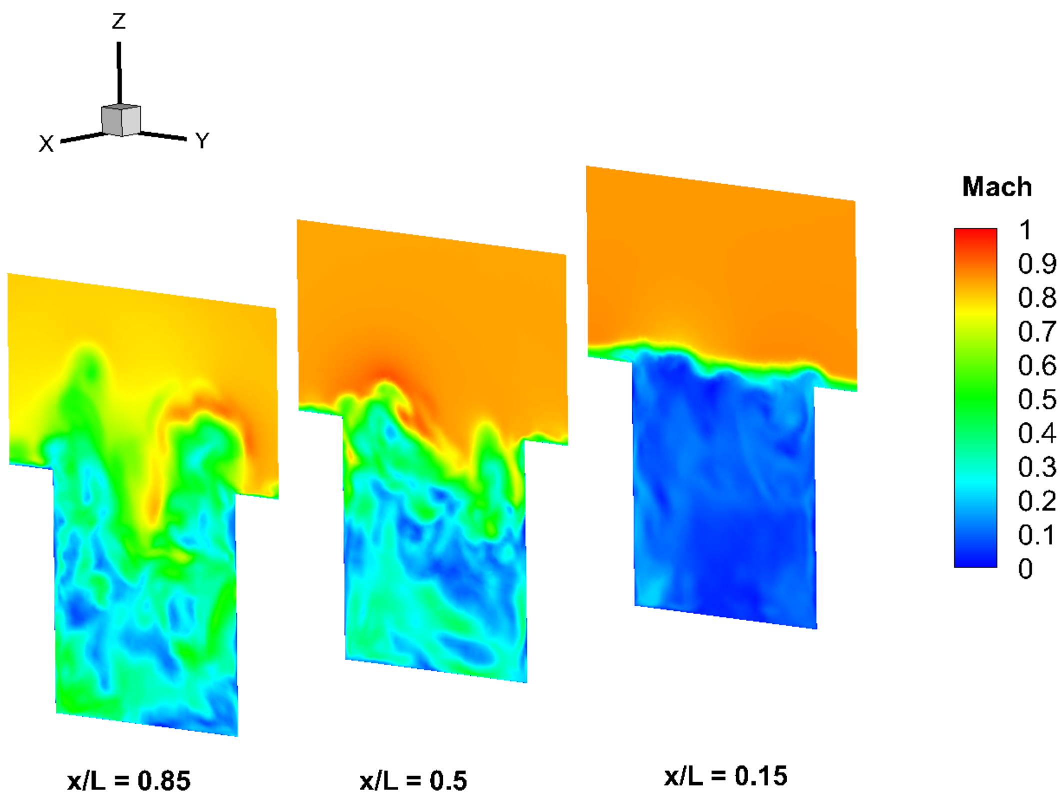


Figure 2: No-Doors Configuration, Instantaneous Mach Contours

Figure 3 shows for the doors-on configuration instantaneous Mach contours, as obtained by IDDES at the same instant as the no doors case. Comparing the two figures we observe that the doors of the M219 cavity further complicates the flow, affecting the shear layer generation and vortex structures within the shear layer.

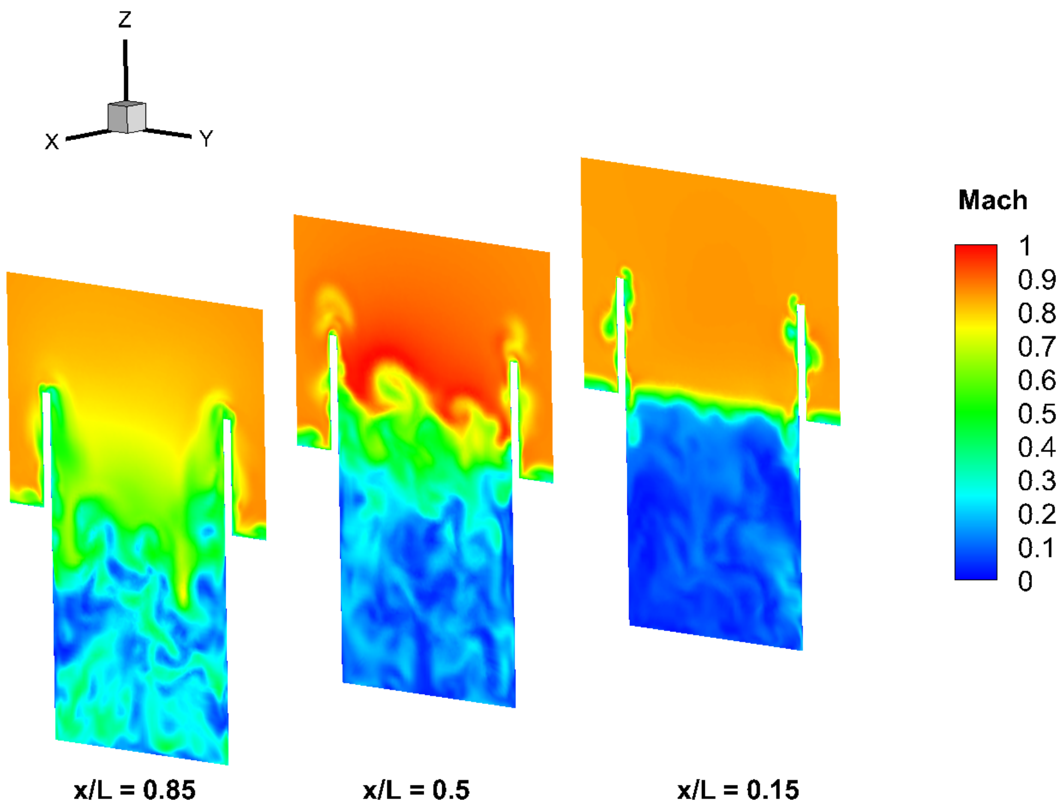


Figure 3: Doors-on Configuration, Instantaneous Mach Contours

Figure 4 shows the general trends of the overall sound pressure level (OASPL) variation along the cavity ceiling were captured both by the URANS and IDDES solutions. However, the OASPLs were predicted by IDDES very accurately, while the URANS computations overpredicted them with a few decibels.

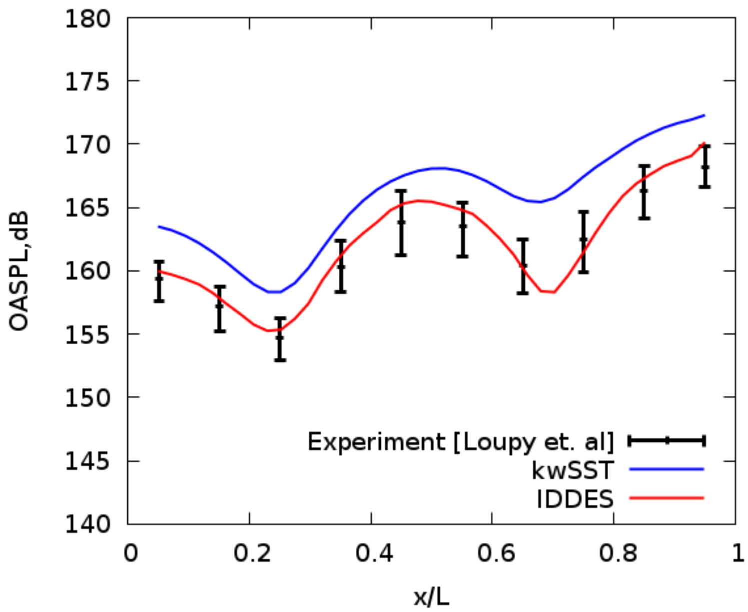


Figure 4: URANS and IDDES Noise Predictions of Doors-On M219 Cavity

The effect of the doors on the shear layer generation is also observed on the acoustic field of the configuration. Since the shear layer impingement on the aft wall of the cavity is directly responsible for the acoustic waves generation, any intervention in the unsteady shear layer directly shows up its effects on the acoustic characteristics of the flow field. Therefore, the effect of the doors appears as some increase and a shift toward a W-shaped variation along the cavity ceiling at the mid-plane as evident in Figure 5.

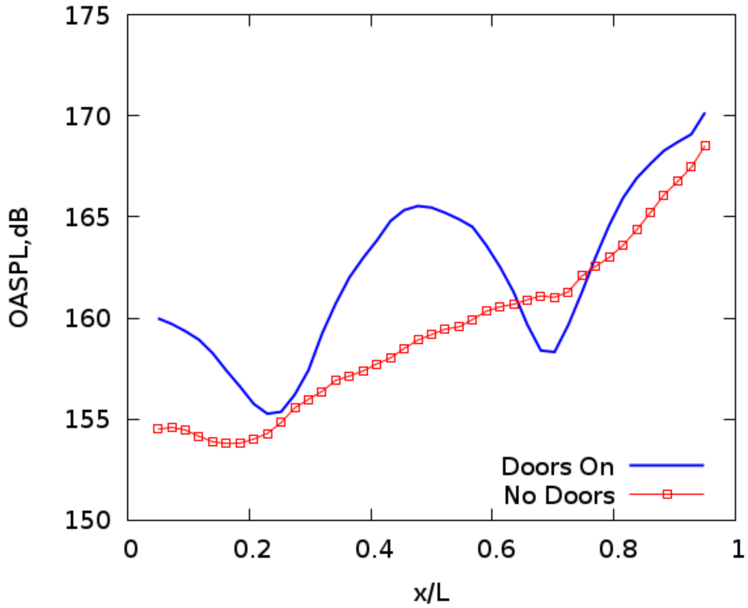


Figure 5: Doors Effect on OASPL of M219 Cavity (IDDES)

Results will be elaborated with further discussions in the full paper.

4 CONCLUSIONS

Both IDDES and kω-SST URANS methods are utilized in the present flow and noise prediction studies of doors-on M219 cavity at an operating conditions of $M = 0.85$ and $\mathrm{Re}_L = 6.7 \times 10^6$. The results indicate that IDDES almost yields quite accurate predictions while kω-SST URANS modelling overpredicts the noise levels with a few dB difference from the experiment.

Conclusions will be elaborated further in the full paper.

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