Session:

Parametric Study of Cavity Leading-edge Rod Spoilers by Advanced Hybrid RANS-LES Methods

Kunyu LUO, Zhixiang XIAO*

School of Aerospace Engineering, Tsinghua University

Zhe WENG, Ning ZONG, Lidong DENG

AVIC Shenyang Aircraft Design & Research Institute

Description of Cases and Numerical Methods

Aiming at the suppression of the strong pressure fluctuation in cavities, performances of transverse rod spoilers at cavity leading-edge in supersonic flows are simulated and evaluated by improved delayed detached-eddy simulation. Incoming freestream Mach number is 0.9 and the corresponding Reynolds numbers based on cavity depth (D) is 5.7×10^5.

The cavity has a length-to-depth ratio (L/D) of 6. The local boundary layer thickness δ without spoilers at Ma=0.9 is 0.15D. Three transverse rods of different geometric parameters listed in Table 1 are studied. The total grid cell number reaches 12.7 million, of which 9 million are placed near the cavity and the rod.

Improved delayed detached-eddy simulation[1] used in present study is an improved version of the delayed detached-eddy simulation[2] (DDES). IDDES alters the turbulence length scale into the following blending form:

$$\begin{aligned} L_{\mathrm{IDDES}} &= \tilde{f}_d(1+f_e)L_{\mathrm{RANS}} + (1-\tilde{f}_d)L_{\mathrm{LES}} \\ \tilde{f}_d &= \max\left[(1-f_{dt}), f_b\right] \end{aligned} \tag{1}$$

and the grid scale is redefined as:

$$\Delta = \min\left[\max\left(C_w\Delta_{\max}, C_w d, \Delta_{\min}\right), \Delta_{\max}\right] \tag{2}$$

The elevation function f_e and the new grid scale ensure the correct reduction of the RANS Reynolds stresses and prevent the log-layer mismatch. Another highlight of IDDES is the combination of DDES with wall-modelled LES (WMLES). When $\tilde{f}_d = f_b$, IDDES actives its WMLES branch to respond to incoming turbulent fluctuations. Details of IDDES can be found in Refs [1] and [3].

Session:

Table 1 Geometric parameters of transverse rod spoilers with δ being the local boundary layer thickness δ without spoilers at *Ma*=0.9

Spoiler	Rod Diameter	Gap Height	Distance to Cavity Leading-edge
Rod1	1.0δ	1.0δ	1.0δ
Rod2	1.4δ	1.0δ	1.0δ
Rod3	1.0δ	0.6δ	1.0δ

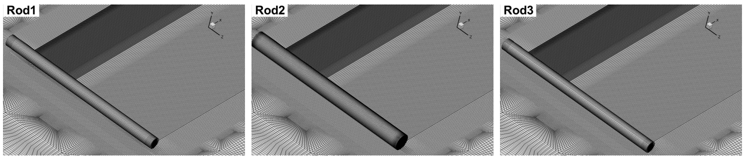

Fig. 1 Geometries and meshes for leading-edge transverse rod spoilers.

Preliminary Results

Figure 2 shows the spatial OASPL distribution and streamlines in cavities with and without spoiler Rod1. The rod spoiler changes the flowfield and reduces the pressure fluctuation inside the cavity. Vortex shedding could be found in the wake of the rod spoiler. POD and spectrum analysis will be used to explore the control mechanism. Influences of geometric parameters will also be discussed.

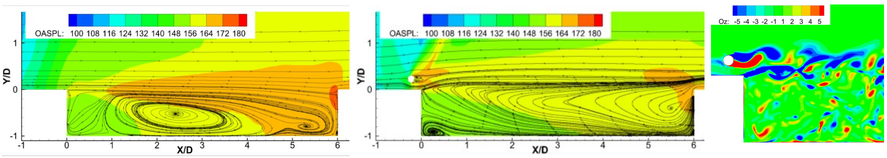

Fig. 2 OASPL and Ω_z contours inside the cavity. Left: Clean; Right: Rod1

References

[1] Shur M L, Spalart P R, Strelets M K, et al. A hybrid RANS-LES approach with delayed-DES and wall-modelled LES capabilities. International Journal of Heat and Fluid Flow, 2008, 29(6): 1638-1649.

[2] Strelets M. Detached eddy simulation of massively separated flows. AIAA-2001-0879. Reno: AIAA, 2001.

[3] Gritskevich M S, Garbaruk A V, Schütze J, et al. Development of DDES and IDDES Formulations for the k-ω Shear Stress Transport Model. Flow, Turbulence and Combustion. 2012, 88(3): 431-449.