8th. World Congress on Computational Mechanics (WCCM8)
5th. European Congress on Computational Methods in Applied Sciences and Engineering (ECCOMAS 2008)
June 30 – July 5, 2008
Venice, Italy

Towards LES Application for Shock-Boundary Layer Interaction

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Key Words: *LES, Transonic Flow, Shock-Boundary Layer Interaction, CFD.*

ABSTRACT

Transonic flows at moderate to high Reynolds numbers are by far the most difficult to predict using CFD. This is partially due to the difficulties in resolving the interaction between shocks and boundary layers and partially due to the inherently unsteady nature of these flows [1]. At present, CFD is presented by a challenge in providing accurate solutions, for transonic flows of engineering importance, using statistical turbulence models based on the Unsteady Reynolds-Averaged Navier-Stokes equations (URANS) or even hybrid techniques based on the Detached-Eddy Simulation methods that recently appeared in the literature [2]. The key issue with URANS is that the predicted frequency of the flow, as a result of the shock-boundary layer interaction, is narrow and covers some of the low-end part of the spectrum. Consequently, the unsteadiness of the flow is under-predicted and phenomena documented in experiments are poorly predicted even in a qualitative way.

Large-Eddy Simulation, could potentially offer higher fidelity results by resolving a larger part of the spectrum and consequently predicting flow unsteadiness. Along these lines, several transonic interactions have been studied using both URANS and LES in order to identify the limitations of URANS and highlight the benefits LES has to offer. Figure 1 presents indicative results for a flow around a bump at transonic conditions [3] using the method described in reference [4]. The separated flow region predicted by URANS and LES near the trailing edge of the bump is also shown. The URANS solution was found to be steady predicting a very narrow part of the unsteady flow spectrum. The obtained LES solution required two weeks of computation on 72 processors and has been obtained on a grid approximately seven times the size of the URANS one. The results, however, suggest that some of the flow unsteadiness is better captured. Still, LES is not without problems and substantial effort must be put in resolving the near-wall turbulence as well as initialising the flow properly with a realistic incoming boundary layer. Figure 1c presents a comparison between CFD and experiments for the pressure trace near the trailing edge of the bump and the obtained results show that substantial part of the frequency content of the experiment was captured by the CFD.

At present, this research is directed towards a detailed evaluation of the LES for transonic flows using high-fidelity experimental data obtained as part of the UFAST F6 research project. A detailed comparison will be presented at the final paper.

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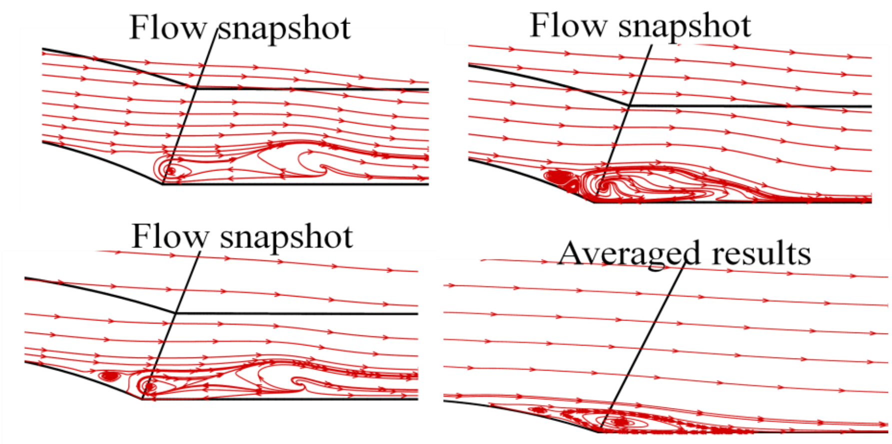
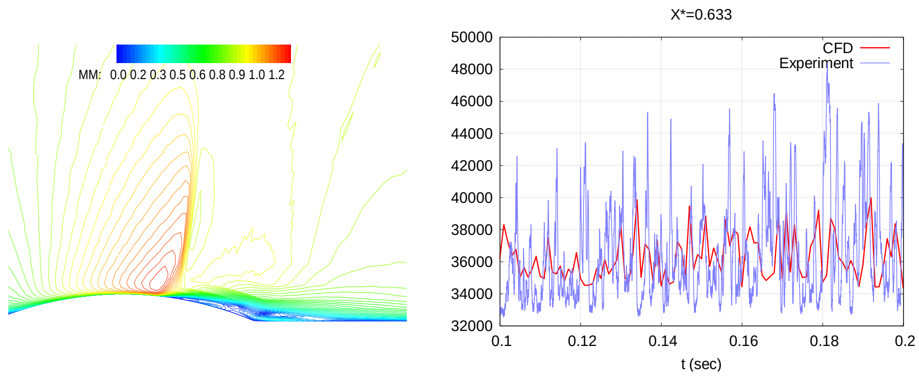


(a)



(b) (c)

Figure 1: (a) Flow snapshots and averaged CFD results for the LES simulation of the transonic flow over a bump. (b) Averaged Mach number field. (c) Comparisons between experiments [3] and CFD results for the pressure history near the trailing edge of the bump.