Influence of Blunt-Body Base Protuberances on Near-Wake Unsteadiness

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Abstract: This work aims to assess the influence of protuberances on the base of a blunt body (*i.e.* a sting in an experiment) on the near-wake unsteadiness using scale-resolving simulations. In this study, three sting configurations and two types of flows are considered to evaluate the geometrical sensitivities pertaining to near-wake unsteadiness. Additionally, simulation results will admit the identification of the dominant physical phenomena associated with the near-wake unsteadiness for each case.

Keywords: Turbulence Modeling, High-Speed Wakes.

1 Introduction

Wake flows have generated significant interest over the years due to both the fundamental complexity of the flowfield, as well as their relation to numerous practical applications. The goal of this work is to assess the influence of stings on the near-wake unsteadiness using high-fidelity scale-resolving simulations. Three sample sting configurations are considered; a 'centered-sting' configuration (*i.e.* where the sting axis is aligned with the body axis), an 'offset-sting' configuration (*i.e.* where the sting axis is *not* aligned with the body axis), and a 'no-sting' configuration. These three sting configurations are tested on two different flows, namely a Mach 2.49 cylinder wake [1], and a Mach 8 sharp cone wake [2]. Simulation results aim to identify differences in the near-wake unsteadiness between the cases, and identify the physical phenomena associated with the dominant processes.

2 Methodology

Wall-modeled Large-Eddy Simulations (WMLES) are performed to replicate the representative experiments of [1] and [2] using the Sandia Parallel Aerodynamics and Reentry Code (SPARC). In our approach, time-integration is performed using a 2^{nd}-order implicit method, inviscid fluxes are discretized using the low-dissipation 2^{nd}-order scheme of Subarreddy and Candler [3], viscous fluxes are treated with a 2^{nd}-order scheme, and wall-modeling is performed using a simple equilibrium algebraic function. Additionally, to accurately reproduce the turbulent boundary layer present in experiments, we seed the inflow plane with an incoming turbulent boundary layer generated by the synthetic digital filtering method of Adler *et al.* [4]. Simulation results will be gathered on additional grids for at least one case per flow (*i.e.* cone or cylinder wake) to quantify solution convergence.

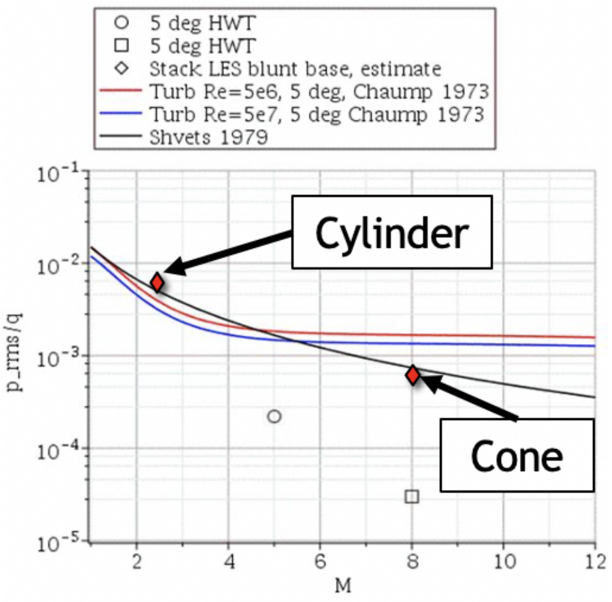

Figure 1: Comparison of P_{rms}/q_∞ between computations (diamonds), cone experiments (circle and square), and theory (black line).

3 Preliminary Results

A comparison of P_{rms}/q_∞ between theory [5], no-sting simulations, and offset-sting cone experiments is shown in Figure 1. It is clear the simulations compare quite well to the theory, while the experimental unsteadiness is lower than theory and simulation for the Mach 8 case. The cause for this behavior is largely unknown, and is the primary objective of this study.

4 Conclusion and Future Work

Comparative no-sting simulations to the Mach 8 cone offset-sting experiments indicate a discrepancy in base pressure unsteadiness between experiment and computation/theory. In the final paper, results from the suite of simulations will be compared to available experimental data, and analyzed to identify the physical mechanisms associated with the experimental disagreement.

References

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