# Adaptive Mesh Refinement and Turbulence Modeling

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**Abstract:** Adaptive mesh refinement will be essential in turbulence modeling.

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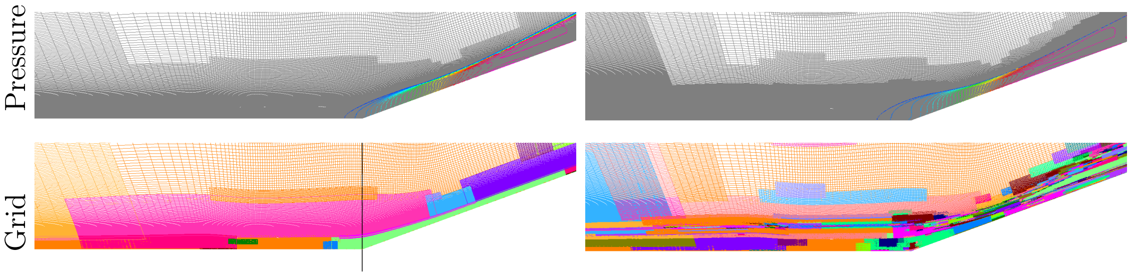
## 1 Introduction

The benefit of adaptive mesh refinement (AMR) is that grid converged solutions may be obtained with much lower memory requirements and without a priori knowledge of solution details. In assessing turbulence model behavior, this enables the analyst to obtain the predictions of a given turbulence model without the confounding effects of discretization error.




(a) 1 Level Refinement

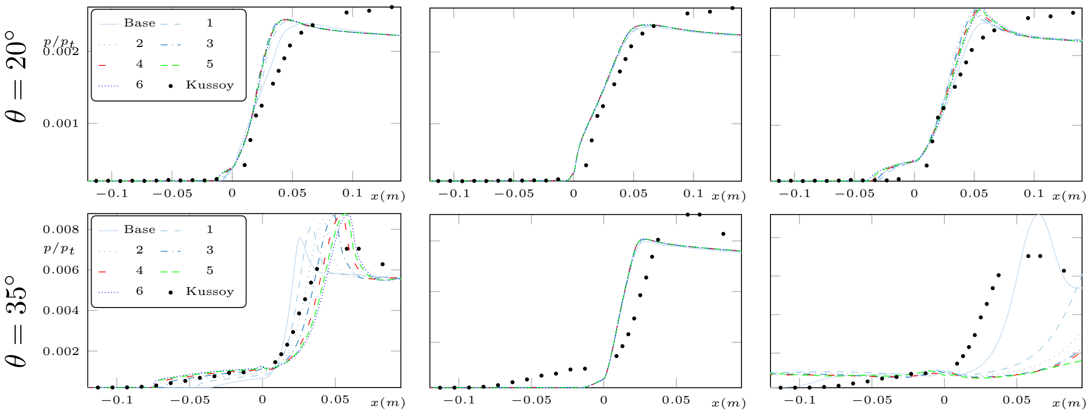
(b) 6 Levels Refinement

Figure 1: Pressure field and grid in shock/boundary-layer interaction region

## 2 Problem Statement

Previous work in this vein [1] suggested that velocity profile predictions in high speed flows might require much more grid resolution than previously thought. In that paper, the surface quantities, both pressure and skin friction, were surprisingly insensitive to the additional refinement, suggesting that for eddy viscosity models, previous results were still valid, since the prediction of viscous drag and surface pressure are the primary goals of turbulence models predicting vehicle flowfields. The real point of that work, however, was the discussion and exploration of an algorithm to use the AMR available in OVERFLOW to obtain an arbitrarily accurate approximation to the "exact" solution for a given flowfield case.

With this new tool in hand, a grid-converged solution, to a previously run, and already reported case [2] was desired, merely to confirm that what had been reported was indeed grid-converged: the $M_\infty = 7$ cylinder-flare case of Kussoy[3]. Surprisingly, for all cylinder flare angles in that dataset, there were differences, and most importantly the more grid-converged solution for the largest flare angle (35°) which exhibits the largest separation had surface pressures, (along with the more sensitive wall heating, and velocity profile) which were significantly different from those previously reported ("Base" in Fig. 2).




(a) Lag-$\nu_T$ (b) SA (c) SST

Figure 2: Surface pressure, for lowest and highest flare angle. Numbers in legends denote grid refinement levels from Baseline grid

## 3 Conclusion and Future Work

Turbulence models were tuned using grids that were thought to be sufficiently fine, but with the benefit of a tool where reaching arbitrarily fine solutions is possible this assessment needs to be revised. While for attached flows the difference have not been found to be significant, in separated flows the differences are larger. These are large enough to suggest that the models may be more capable at prediction than thought. It will also allow model tuning that is much more precise than is justified without it.

Grid convergence analysis will be brought to bear on this flow, both on the surface quantities and the more sensitive velocity profile quantities. Other high speed flows will be investigated, and the grid independence evaluated. Model tuning (for the Lag-$\nu_T$ model) that was cosmetic at grid levels attainable without AMR will be evaluated.

## References


[1] Olsen, Michael E. and Lillard, Randolph P., "Using Adaptive Mesh Refinement to Study Grid Resolution Effects for Shock-Boundary Layer Interactions," *AIAA 2018-3085*

[2] Olsen, Michael and Coakley, Thomas and Lillard, Randolph, "The Lag Model Applied to High Speed Flows," *AIAA 2005-101*

[3] Kussoy, M.I. and Horstman, C.C. "Documentation of Two and Three-Dimensional Hypersonic Shock Wake/Turbulent Boundary Layer Interaction Flows," *NASA TM X 10175*, January, 1989