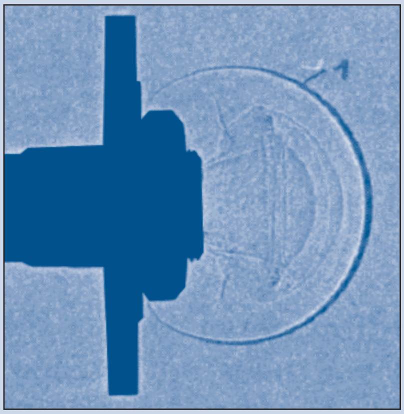
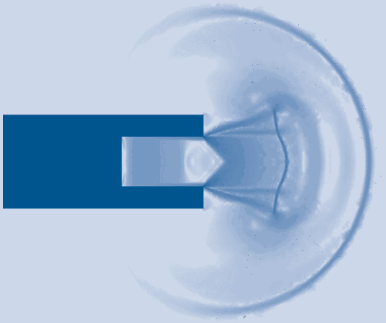
Tank and Artillery Cannon Muzzle Brakes – Reducing Gun Recoil QUIETLY

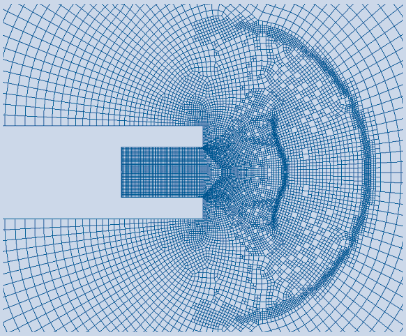
By Daniel L. Cler, Benet Laboratories, US Army, Watervliet, NY; and Christoph Hiemcke, Fluent Inc.



Experimental results showing the flow field at 350 microseconds before the shot exit[2] illustrated using a shadowgraph imaging technique, where the second derivative of density is used to mark wavefronts and shocks



Contours of density gradient from FLUENT results at 350 microseconds before the shot exit; displaying the density gradient corresponds to the Schlieren imaging technique used to identify wavefronts and shocks experimentally
visualization by EnSight from CEI



Adapted grid at 350 microseconds before the shot exit

Benet Laboratories is a US Army research laboratory involved in the development of cannon and mortar tubes for tanks and artillery. Cannon recoil imparts very high loads on tanks and artillery vehicles. These large loads are typically managed by the mass of the vehicle in conjunction with a recoil system. The current trend in the development of new tank and artillery vehicles is toward much lower vehicle weight, while at the same time the muzzle velocities of projectiles are increasing. These changes combine to make it far more difficult to manage the recoil loads.

One mechanism for reducing recoil is the muzzle brake. Muzzle brakes are used to turn some of the propellant flow behind an exiting projectile sideways or aft to reduce recoil. There are deleterious effects associated with muzzle brakes, however, such as very high peak pressures and powerful acoustic waves. The resulting noise can potentially harm personnel operating the vehicle. For nearly twenty years, Benet Laboratories has fostered the use of CFD to simulate the unsteady wave propagation from cannon muzzle brakes in order to predict peak over-pressure of new muzzle brake designs.

By using a design tool such as CFD, the Army hopes to develop efficient muzzle brakes that reduce recoil imparted to the vehicle while at the same time keeping the high noise levels manageable. In the past, the only way to measure peak over-pressure was to test cannon hardware and record the value using dynamic pressure instrumentation. Typically, scaled prototype cannons (20mm) can be fired for preliminary results early in the development programs, but because of the high cost involved, full scale testing is done later on. Experimental results from scaled cannons often jeopardize the program, as non-ideal behavior such as ground plane reflections, interaction with the vehicle hull, and differences between scale and full-sized ammunition alter the scale testing results. It is hoped that by using CFD early in the design cycle, much of the risk involved in muzzle brake design can be averted.

To accurately and efficiently predict the performance and peak over-pressure of gun muzzles and muzzle brakes, special CFD techniques for modeling unsteady wave propagation are required. By using the adaption tools in FLUENT, one is able to create and destroy grid along propagating shock fronts, thereby efficiently targeting the computational effort on the features of the unsteady blast. Without adaption, it would not be feasible to model unsteady wave propagation, since the refined grid needed throughout the region of activity would dramatically increase the number of cells. Using adaption, the grid can be not only refined as needed, but coarsened once a shock wave passes a given location. In order to develop a methodology and to validate FLUENT for this class of problem, the CFD results were compared to an experimental data set from a 7.62mm NATO G3 rifle[1]. A series of experimental shadowgraph images acquired from test firings of the G3 were used.

Early calculations using the coupled explicit solver in FLUENT 6.0 accomplished the dynamic adaption by means of text user interface (TUI) commands that were executed at regular time intervals using the “Execute Command” functionality. FLUENT’s adaption routines were written primarily for steady flow fields, so this comprised a new application. For each adaption, the refinement was unproblematic and could be done in a single step. By contrast, the coarsening had to be done in several steps in order to keep the number of marked cells low. In addition, maintaining stability while solving the second order flow equations was difficult. Nonetheless, the results were promising, with FLUENT’s shock structures matching the shadowgraph very closely. ■

references:

1 Günter Klingenberg and Joseph M. Heimerl. “Gun Muzzle Blast and Flash.” Volume 139, Progress in Astronautics and Aeronautics. American Institute of Aeronautics and Astronautics: Washington, D.C., pp. 134-148 (1992).

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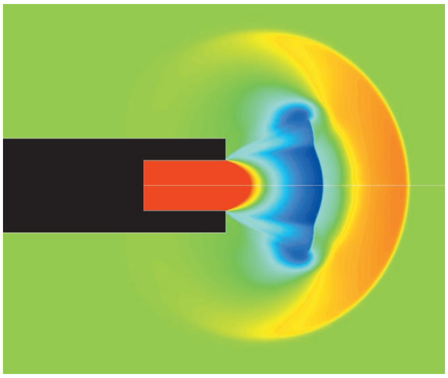
Dynamic Adaption in FLUENT 6.1

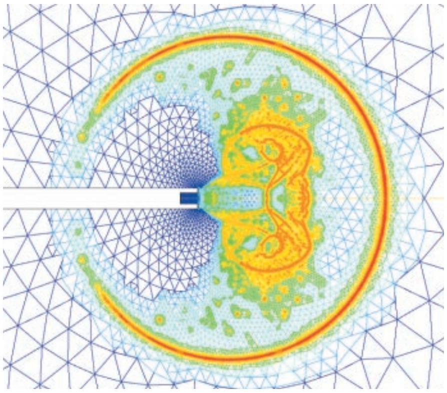
By Thomas Gessner, Fluent Inc.; and Daniel L. Cler, Benet Laboratories, US Army, Watervliet, NY

In contrast to the creative but cumbersome approach of using FLUENT’s “Execute Command” functionality for dynamic solution-based adaption, FLUENT 6.1 provides an easy to use dynamic adaption capability for transient, as well as steady state computations. In addition to the derivatives FLUENT 6.0 uses to control the adaption, FLUENT 6.1 provides scaled and normalized derivatives (gradient and curvature) that do not require the user to readjust the adaption parameter during the computation.

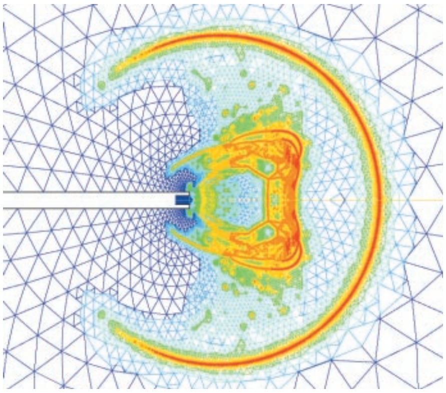
Recent simulations have made use of the new dynamic adaption capability. Benet Laboratories has kindly provided the geometry and flow conditions, and this challenging case will become part of the test matrix used to validate future versions of FLUENT 6. Density contours at 350µs are in very good accordance with the experimental results from the previous article. The resolution of the shocks has improved, because a higher level of refinement can now be used. Finally a sobering statistic on the efficiency of dynamic adaption: if the entire domain (a rectangle of 7,000 by 3,500mm) were resolved to the same level as the resolution of the shock in the present example, about 133 million cells would be required. Given the 135,000 cells used for the adapted case, the cell count is better by a factor of 1,072! ■



Contours of density at 350 microseconds before the shot exit (compare with the top figure from the previous article)



Grid colored by cell refine level (100,000 cells) at an intermediate time



Grid colored by cell refine level (135,000 cells, with a maximum adaption level of seven) shortly before the shot exit