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HIGH PERFORMANCE COMPUTING VIRTUAL FLY-OUT SIMULATIONS WITH EMPHASIS ON INITIAL CONDITIONS

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ABSTRACT

A multidisciplinary computational study has been undertaken to model the flight trajectories and the free-flight aerodynamics of both a finned projectile and a spinning projectile. Advanced computational capabilities both in computational fluid dynamics (CFD) and rigid body dynamics (RBD) have been successfully fully coupled on high performance computing (HPC) platforms for "Virtual Fly-Outs" of munitions similar to actual free flight tests. Time-accurate Navier-Stokes computations have been performed to compute the unsteady aerodynamics associated with the free flight of a finned projectile at a supersonic speed and a spinning projectile at subsonic speed using an advanced scalable unstructured flow solver on a highly parallel Linux Cluster. Initial conditions are critical to the overall accuracy of the time-accurate virtual fly-out simulations. New initial conditions procedures have been developed and applied. The effect of this initial conditions procedure on the accuracy of the computed solutions has been examined. Some results relating to the portability and the performance of the flow solver on the Linux clusters are also addressed.

Numerical simulations of the virtual fly-outs have been carried out at ARL Major Shared Resource Center using 64 processors on a Linux Cluster requiring thousands of hours as part of Grand Challenge Project. Computed results have been obtained at an initial supersonic speed, M = 3.0 and angle of attack, α = -5° for a finned projectile using an unstructured time-accurate Navier-Stokes computational technique that includes grid motion capabilities. Dual time-stepping was used to achieve the desired time-accuracy for time-accurate CFD computations of unsteady flow fields. In addition, the projectile in the coupled CFD/RBD simulation actually moved along with its grid as it flew downrange. Figure 1 shows the computed pressure contours at a given time or at a given location in the trajectory. It clearly shows the orientation of the body at that instant in time and the resulting asymmetric flow field due to the body at angle of attack. The orientation of the projectile of course changes from one instant in time to another as the projectile flies down range. Computed positions and orientations of the finned projectile along the flight trajectory in supersonic flight have been compared with actual data measured from free flight tests and are found to be generally in good agreement. The time histories of the pitch and yaw angles are often customarily presented as a motion plot where the pitch angle is plotted versus the yaw angle during the flight of the

projectile. It represents the path traversed by the nose of the projectile during the flight trajectory (looking forward from the back of the projectile). Such a motion plot is shown in Figure 2. Effect of initial conditions procedures on the total aerodynamic forces will be illustrated. Computed results obtained for a spinning projectile configuration with the virtual fly-out technique at a low subsonic speed also show the potential of these techniques for providing the unsteady aerodynamics associated with its free flight. The full paper will include the details of the coupling and the initial conditions procedures. Computed results obtained using these methods for both finned and spinning projectile cases will be included.

This work demonstrates a coupled method with special emphasis on the initial conditions procedure to accurately predict the time-accurate unsteady aerodynamics and the flight trajectories of projectiles at various speeds. The present CFD/RBD simulations clearly show the capability of the coupled approach and the improved initial conditions procedure.

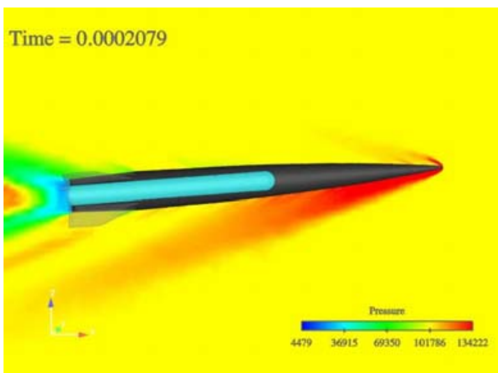
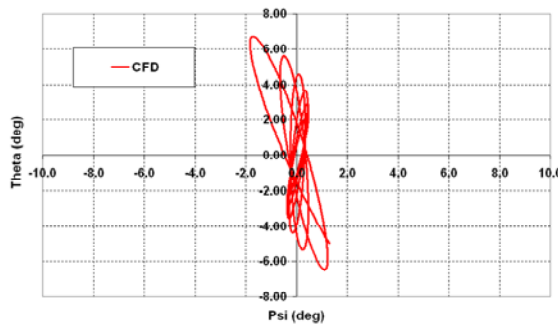
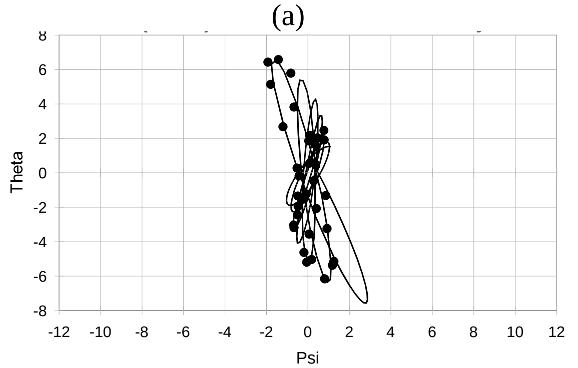


Figure 1. Computed pressure contours for a finned projectile.



(a)



(b)

Figure 2. Motion plot (Euler pitch angle vs yaw angle), (a) computation, (b) flight test