Numerical Modeling of Fragment and Blast Loaded Concrete Structures Using Massively-Parallel Coupled CFD-CSD Techniques - COMPLAS 2019

Orlando Soto*, Michael Giltrud*, Joseph Baum*, Rainald Löhner* and Fumiya Togashi*

* Applied Simulations Inc. (ASI)
1211 Pine Hill Road, Mclean, VA 22101, USA
e-mail: orlando.a.soto@appliedsimulations.com

ABSTRACT

This paper describes the application and numerical formulation of a state-of-the-art coupled computational fluid dynamics (CFD) and computational structural dynamics (CSD) methodology to the simulation of steel case fragmentation and explosively loaded reinforced concrete structures.

The objective of the study was to predict the case fragmentation, response of the structures, initial debris launch, and pressure responses within, and external, to the structure. A bare plastic explosives reference test was selected to assess the effectiveness of a coupled CFD-CSD simulation. A steel case weapon simulation is also shown. The simulations address HE initiation, detonation, wave propagation through the HE, case fragmentation, air blast and fragments impact on the concrete structure and structural response, structural failure and debris launch, and propagation of air blast to the far field.

Over the last several years we have developed a numerical methodology that couples state-of-the-art CFD and CSD methodologies. The flow code solves the time-dependent, compressible Euler and Reynolds-Averaged Navier-Stokes equations on an unstructured mesh of tetrahedral elements. The CSD code solves the large deformation, large strain formulation dynamic equations on an unstructured grid composed of bricks and tetrahedral elements, and uses VMS (variational multi-scale) stabilization to improve the robustness and stability of the numerical solution. The codes are coupled via a loose coupling approach which decouples the CFD and CSD sets of equations and uses projection methods to transfer interface information between the CFD and CSD domains. Both codes are parallelized using a distributed memory technique (MPI): The flow and solid domains are divided in several sub-domains which communicates through their respective inter-domain points. Also, the solution on each sub-domain uses share-memory parallelization (OpenMP "loop" parallelization). The final presentation will describe in detail the implementation of the concrete fracture, weapon fragmentation, and contact algorithm for the mentioned MPI/OpenMP parallelization scheme, which allows spectacular simulation speed-up for real life applications.

The results of the simulations compare well with the experimental data. The predicted structural disassembly agrees well with the high speed photography. The predictions exhibit similar failure mechanisms, failure locations and times of failure. The far field pressures exhibit similar decay with range as the experimental data though the pressure is slightly higher. Finally, the initial structural debris and weapon fragmentation sizes distribution and velocities follows the experimental ones.

REFERENCES

[1] Soto, O.A., Baum, J.D., Lhner, R, Frank, R, "Coupled CFD/CSD Simulations of Dust Production by Fragmenting Charges Using Stabilized Linear Elements". *MABS25* (2018) The Netherlands.