Picatinny Arsenal keeps soldiers safer with realistic simulation

By Nick O'Donohoe

When civilians talk of an army and a mission, they usually think of soldiers in the field—patrolling through a combat zone in an armored vehicle, for instance. At the U.S. Armament Research, Development and Engineering Center (ARDEC) at Picatinny Arsenal in New Jersey, USA, one critical mission behind the field operations is every bit as important: the analysis and testing of protective vehicle armor so that those soldiers return to base safely. Picatinny Arsenal uses Abaqus (SIMULIA) to analyze and improve strength of armor subjected to blast waves.

ARDEC's tradition of armament research at Picatinny stretches back a century. Due to the Center's expertise and vast amounts of accumulated physical data, it is occasionally tasked with proving out armor designs.

One such project was the structural assessment of an overhead cover add-on for the Objective Gunner Protection Kit (OGPK) used on the High-Mobility Multipurpose Wheeled Vehicle (HMMWV). The OGPK, which received an Army Greatest Invention Award for 2007, is an integrated armor and ballistic glass cupola shield mounted on top of tactical and armored vehicles. It provides 360-degree protection from small arms fire and explosions while retaining visibility for the gunners. The mission for ARDEC was to ensure that the overhead cover provided effective protection during exposure to blast loading.

One of the best tools in their arsenal to accomplish this mission was finite element analysis (FEA) software, which they were already using extensively—but this time, engineers at Picatinny had a vision of how they could greatly increase the accuracy of their simulations and account for the effects of the shock interactions, including oblique blast waves on the OPGK due to reflections from the top of the HMMWV.

ACHIEVING SIMULATION ACCURACY

In the past, engineers at ARDEC had developed a standard process for structural analyses that involved using simplified blast parameters and manually applying pressure loads to a 3D model in Abaqus/Explicit software from SIMULIA, the Dassault Systèmes brand for realistic simulation, to simulate a particular blast loading.

After weighing various simulation methods, the engineers at Picatinny decided to explore something new: conducting the blast load analysis using the fully Coupled Eulerian-Lagrangian (CEL) capability within Abaqus. The CEL capability enables the user to simulate a fluid or gas (the Eulerian domain) interacting with a structure (the Lagrangian domain). Here, the structure to undergo blast loading is surrounded by a volume of air. The blast wave that would exist at the inlet of the air domain is created through boundary conditions. The wave then propagates through the Eulerian domain and subsequently interacts with the Lagrangian structure located some distance from the inlet.

Before attempting a full-scale blast load analysis, the engineers at Picatinny validated the performance of the CEL method in Abaqus. They did this by verifying that the software could realistically model the reduction in strength of the shock wave as it propagated through the air (Eulerian domain) and that it could simulate normal and oblique reflections against the Lagrangian model accurately.

REALISTIC SIMULATION GUIDES FUTURE WORK

The simulated deflections on the armor panels were compared to previously conducted analyses that used simplified pressure loads on the surfaces exposed to the blast. Overall the comparison was favorable, with the CEL analysis providing more realistic results than previous analyses did.

Picatinny anticipates that CEL could be valuable in the design phase of new armor systems, since it provides an understanding of how a given armor system model responds to blast loading. This same analysis could be applied to any structure that might experience blast loading—for instance, an explosive test facility or buildings in a high-risk (combat) area.

One of the advantages of using the CEL approach is that Abaqus can execute all the shock interactions automatically, so that the analyst is not required to calculate the angle of incidence for each surface interaction in order to find the correct reflected

Picatinny greatly increased the accuracy of its simulations to account for the effects of shock interactions, using Abaqus from SIMULIA.

pressures on each oblique surface. A new alternative to the manual technique can be found in SIMULIA's recent addition of ConWep to Abaqus, which can automatically calculate the correct distance and angles incidence in a blast model and assign the appropriate pressures. Another important feature of CEL is that the Lagrangian structure can be easily reoriented within the Eulerian domain to analyze any angle of incidence that is required.

The ARDEC engineers concluded that the CEL approach for modeling blast loading shows great promise in its ability to provide valuable insight and realistic results. It also enables the analysis of very complex geometries that were previously impossible to solve accurately with more simplified methods. ARDEC intends to continue exploring Abaqus and CEL to thoroughly validate the new technique so that it may eventually be used to conduct predictive analyses.

For more information:
www.pica.army.mil

Overhead cover add-on for the Objective Gunner Protection Kit (OGPK) used on the High-Mobility Multipurpose Wheeled Vehicle (HMMWV).