Concepts of Coupled FEA-CFD Analyses for Vehicle Structures under High-Pressure Shock Compression

***Arash Ramezani[1] and †Hendrik Rothe[1]**

[1]Department of Measurement and Information Technology, University of the Federal Armed Forces, Germany.

*Presenting author: ramezani@hsu-hh.de
†Corresponding author: rothe@hsu-hh.de

Abstract

In the security sector the partly insufficient safety of people and equipment due to failure of industrial components are ongoing problems that cause great concern. Since computers and software have spread into all fields of industry, extensive efforts are currently made in order to improve the safety by applying certain numerical solutions.

To deal with problems involving the release of a large amount of energy over a very short period of time, e.g. explosions and impacts, there are three approaches. As the problems are highly non-linear and require information regarding material behavior at ultra-high loading rates which is generally not available, most of the work is experimental and thus may cause tremendous expenses. Analytical approaches are possible if the geometries involved are relatively simple and if the loading can be described through boundary conditions, initial conditions or a combination of the two. Numerical solutions are far more general in scope and remove any difficulties associated with geometry. They apply an explicit method and use very small time steps for stable results.

For problems of dynamic fluid-structure interaction and impact, there typically is no single best numerical method which is applicable to all parts of a problem. Techniques to couple types of numerical solvers in a single simulation can allow the use of the most appropriate solver for each domain of the problem.

The goal of this work is to develop and demonstrate an efficient finite element analysis/computational fluid dynamics (FEA/CFD) coupling technique for vehicle structures under high-pressure shock compression. The coupling is achieved by an iterative procedure between FEA and CFD calculations using CATIA, ANSYS Autodyn, and ABAQUS.

ANSYS Autodyn provides shock compression data and the knowledge of shock-wave properties. ABAQUS and CATIA (both developed by Dassault Systèmes) implement the numerical models with all relevant information. Here, the major challenge is to establish a continuous and fully automatic transfer of blast loadings with high-variation rates from ANSYS Autodyn to ABAQUS.

For this purpose, there are basically three types of approaches. One is generally called “strong coupling”, where data have to be transferred between ANSYS Autodyn and ABAQUS in every single time step. A “semi-strong coupling” can get along with a smaller set of date, using mathematical interpolation for a sufficient approximation. The third concept is a “weak coupling” solution. Here, neural networks and deep learning can be used to replicate blast effects on different vehicle structures.

A good agreement of blast load test data and simulation results was observed. Furthermore, it is shown that the coupled solutions can be obtained in sufficiently short turn-around times for use in design. These solutions can be used as the basis of an iterative optimization process. They are a valuable adjunct to the study of the behavior of vehicle structures subjected to high-velocity impact or intense impulsive loading. The combined use of computations, experiments and high-strain-rate material characterization has, in many cases, supplemented the data achievable by experiments alone at considerable savings in both cost and engineering man-hours.

Keywords: CFD-FEM coupling methods, fully automatic structure analyses, high-performance computing techniques, blast loading, vehicle structures.