CAESD: Computer-Aided Engineering Simulation for Defense and Security

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***Abstract*—In times of social and political turbulence, security is a future market with enormous growth potential. Modern technologies, products and services are in demand like never before. The prosperity and growth of our industrial societies are dependent upon critical infrastructures that are globally networked. Their breakdown or destruction could result in unpredictable economic and social damage as a consequence. Dissipating borders between interior and exterior security, as well as between public and private security are making state institutes that are responsible for public safety face challenges that, up until now, were unknown. Examples of this include terrorism at an international level, transnational organized crime, as well as the effects of local natural disasters and major accidents which are, in part, felt at a global level. In order to recognize a variety of risks early, be able to avoid these to the greatest extent possible, and in order to minimize subsequent damage after their occurrence, comprehensive technological security solutions and accompanying methodical, procedural and tactical concepts are being developed. In the past years, there has been considerable activity regarding the current computer-aided design and computer-aided engineering capabilities in the defense and security industry. Computer-aided engineering covers the use of computers in all activities from the design to the manufacture of a product. It is at the forefront of information technology and of crucial importance to economies around the world. It is a vital part of many global industries including those of automotive, aerospace, oil, defense, finance and health. Here, simulation is a very helpful and valuable work tool. Simulation provides a low cost, secure and fast analysis tool. It also provides benefits, which can be reached with many different system configurations. This special session deals with the current challenges of the defense and security sector by introducing modern simulation mechanisms. Computer-aided engineering affects the old-fashioned methods of research and development.**

Keywords-computer-aided engineering; warfare simulation; numerical simulation; defense; security; optimization; armor systems.

I. Introduction

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 computer-based solutions. There is talk of computer-aided engineering (CAE).

CAE is the broad usage of computer software to aid in engineering analysis tasks. It includes finite element analysis (FEA), computational fluid dynamics (CFD), multibody dynamics (MBD), and optimization. Software tools that have been developed to support these activities are considered CAE tools. CAE tools are being used, for example, to analyze the robustness and performance of components and assemblies. The term encompasses simulation, validation, and optimization of products and manufacturing tools. In the future, CAE systems will be major providers of information to help support design teams in decision making. Computer-aided engineering is used in many fields such as automotive, aviation, space, and shipbuilding industries [1].

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 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 [2].

For structures under shock and impact loading, numerical simulations have proven to be extremely useful. They provide a rapid and less expensive way to evaluate new design ideas. Numerical simulations can supply quantitative and accurate details of stress, strain, and deformation fields that would be very costly or difficult to reproduce experimentally. In these numerical simulations, the partial differential equations governing the basic physics principles of conservation of mass, momentum, and energy are employed. The equations to be solved are time-dependent and nonlinear in nature. These equations, together with constitutive models describing material behavior and a set of initial and boundary conditions, define the complete system for shock and impact simulations [3].

The governing partial differential equations need to be solved in both time and space domains. The solution over the time domain can be achieved by an explicit method. In the explicit method, the solution at a given point in time is expressed as a function of the system variables and parameters, with no requirements for stiffness and mass matrices. Thus, the computing time at each time step is low but may require numerous time steps for a complete solution.

II. Content

This special session is dealing with modern warfare simulation and numerical methods for the simulation of impact and blast phenomena.

The paper “Developing an Interface between ANSYS and Abaqus to Simulate Blast Effects on High Security Vehicles” presents an interface between ANSYS and Abaqus, both leading software suites for finite element analysis and computer-aided engineering. The goal 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 Systmes) 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.

In the next paper titled “Modeling and Analysis of Enterprise Architectures to Examine the Feasibility of Network Centric Operations” the modeling and analysis of NCOs using the method of architecture is described. Thereby architecture supports interoperability, cost effectiveness and a common understanding of the concept of NCO.

In the late 1990s the principle of Network Centric Operations (NCO) (also called Network Centric Warfare) was developed to achieve information superiority as well as firepower and command superiority involving an optimized mission execution [4], [5]. The attainment of these benefits requires an essential transform in thinking and acting of respective military forces. Organizational, structural and technical changes are necessary as well. Furthermore, just like any other new development, there are risks and problems to face.

Since a couple of years the German Federal Armed Forces have used scientific approaches to analyze and document the forces’ progression and transformation with the objective to realize NCOs. The concept of the Federal Armed Forces presets the theory of NCO as the groundwork for all missions of the German forces.

Therefor all missions are performed by reconnaissance, command, joint fires and support networks in all dimensions (land, air, navy, space, cyber).

III. Conclusion

New concepts and models can be developed and easily tested with the help of modern simulation methods. The initial design approach of the units and systems has to be as safe and optimal as possible. Therefore, most design concepts are analyzed on the computer. Estimates based on experience are being more and more replaced by software.

Using numerical simulation, meshing is considered to be one of the most difficult tasks. If creating the mesh is considered a difficult task, then selecting and setting the solvers and obtaining a solution to the equations (which constitute the numerical model) in a reasonable computational time is an even more difficult task. The difficulty is associated with a variety of challenges.

To develop better, smarter constructions requires an analysis of a wider range of parameters. However, there is a simple rule of thumb: the more design iterations that can be simulated, the more optimized is the final product. As a result, a high-performance computing (HPC) solution has to dramatically reduce overall engineering simulation time.

The gained experience is of prime importance for the development of modern armor. By applying the simulation model a large number of potential defense and security schemes can be evaluated and the understanding of the interaction can be improved.

The most important steps during a computer-aided analysis are the evaluation and interpretation of the outcomes followed by suitable modifications of the simulation model. For that reason, ballistic trials are necessary to validate the simulation results. The next steps provide these trials as the basis of an iterative optimization process.

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