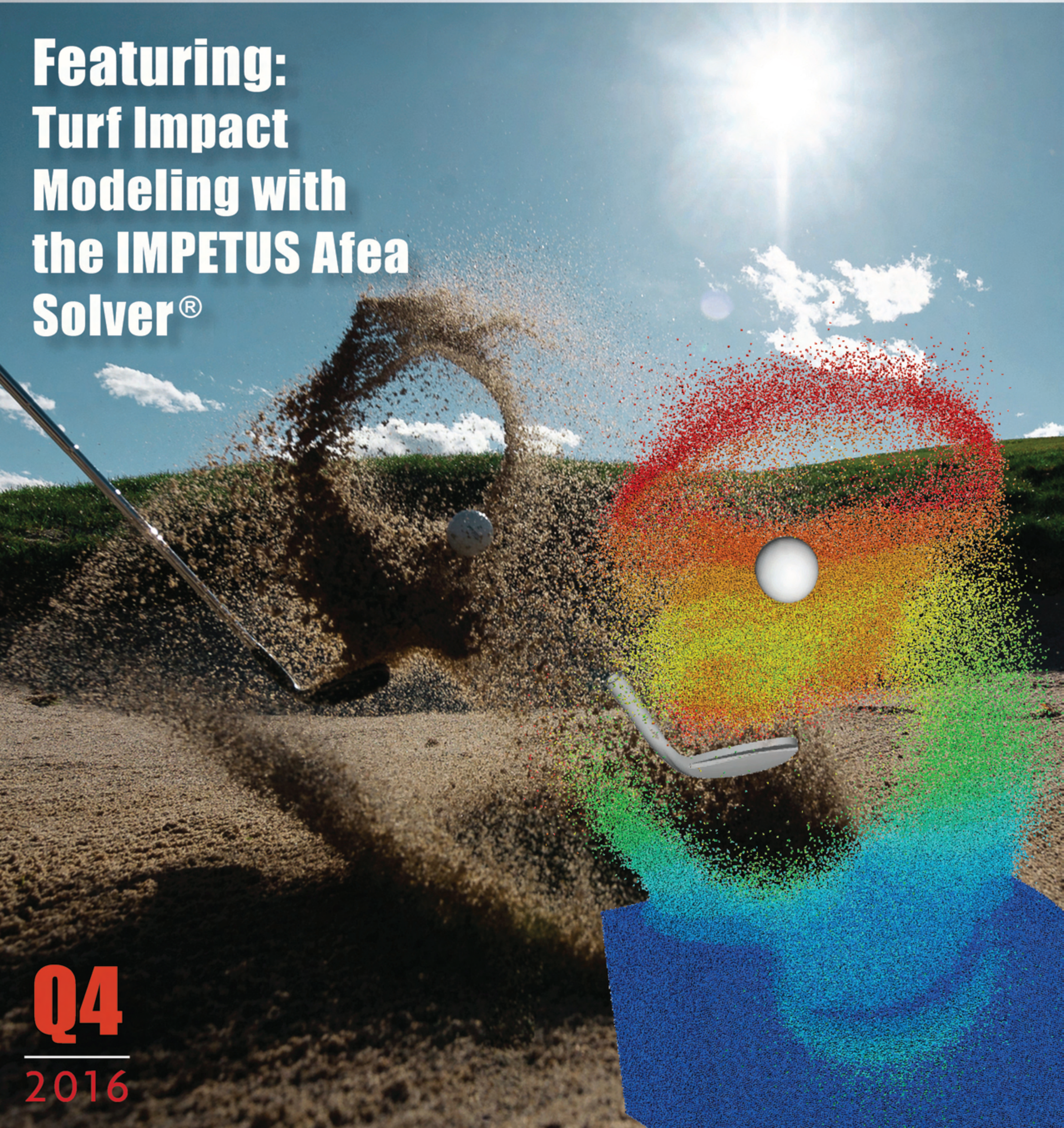
the CertaSim SOLUTION™

Featuring: Turf Impact Modeling with the IMPETUS Afea Solver®



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CertaSIM, LLC is the official distributor of the IMPETUS Afea Solver® in North, Central and South America and provides technical support and training for the IMPETUS suite of software.

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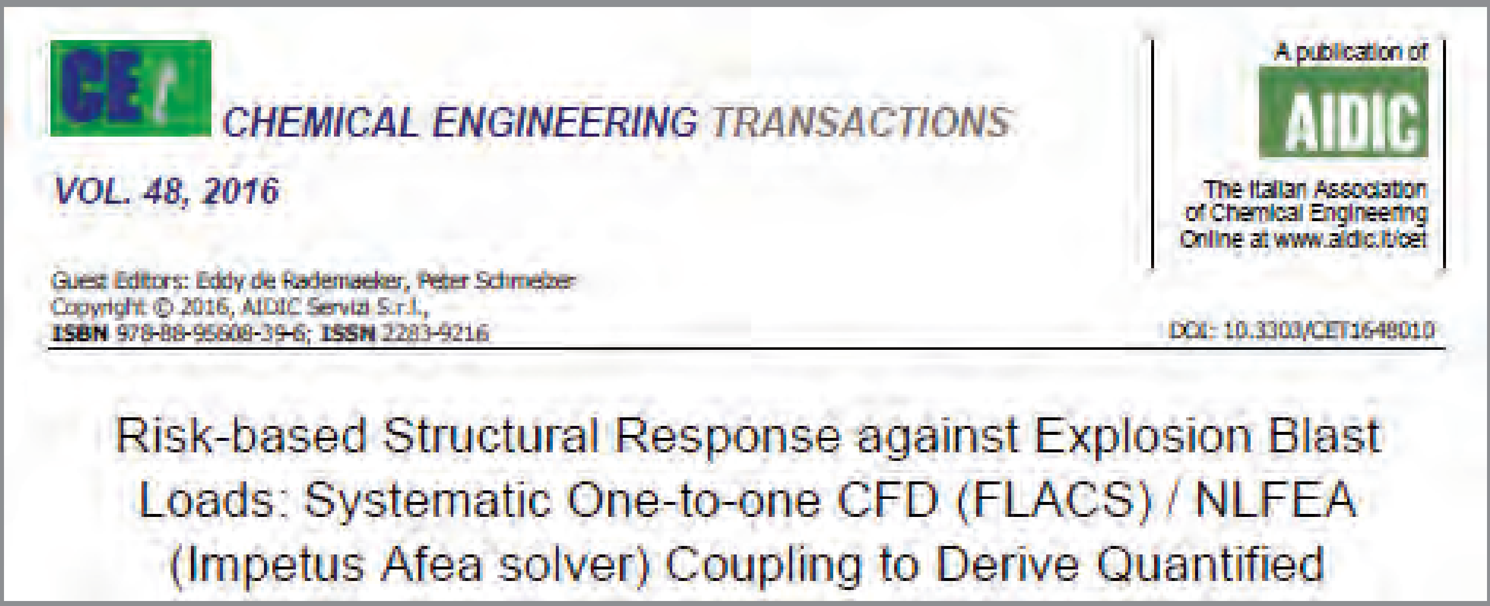
Coupled Solution for Modeling Explosive Impact on a Structure

The IMPETUS Afea Solver® has been coupled with FLACS to model explosion on offshore structures. It is a full spatial mapping of the transient overpressure obtained in CFD (FLACS) to a Non-linear Finite Element model (The IMPETUS Afea Solver®). Recent published work by Statoil ASA, GexCon AS and IMPETUS Afea AS show that using this new innovative coupling, more accurate results are obtained and as an example is shown a firewall where the computed deformation was reduced by 50% compared with Legacy methods, showing that the old methods are "very conservative."



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Risk-based Structural Response against Explosion Blast Loads: Systematic One-to-one CFD (FLACS) / NLFEA (Impetus Afea solver) Coupling to Derive Quantified

Latest Official Release of the IMPETUS Afea Solver

A new official QA verified version of the IMPETUS Afea Solver® has just been released. It is version 3.0.1996. The version includes many exciting new features many of which were beta tested by CertaSIM's users and found to be very powerful.
Some of the features are:

- *PBLAST: Extended library of built in high explosives and added functionality to model water.
- *CONTACT: Optimized and improved search algorithm.
- *MAT_BERGSTROM_BOYCE: Added alternative viscous damping law.
- *PARTICLE_DOMAIN: More flexible input structure for discrete particles/SPH.
- *PARTICLE_DOMAIN: GPU implementation added.
- *PARTICLE_DOMAIN: Opened up for user defined HE and SOIL.
- *MAT_FORMING_R: Added damage softening option.
- *OUTPUT_SENSOR: Option for displacement output relative local/global coordinate system.
- *MAT_HOEK_BROWN: New material model for rock masses.
- *MAT_JC: Extended thermal softening law.
- Performance benchmark feature added to GUI.

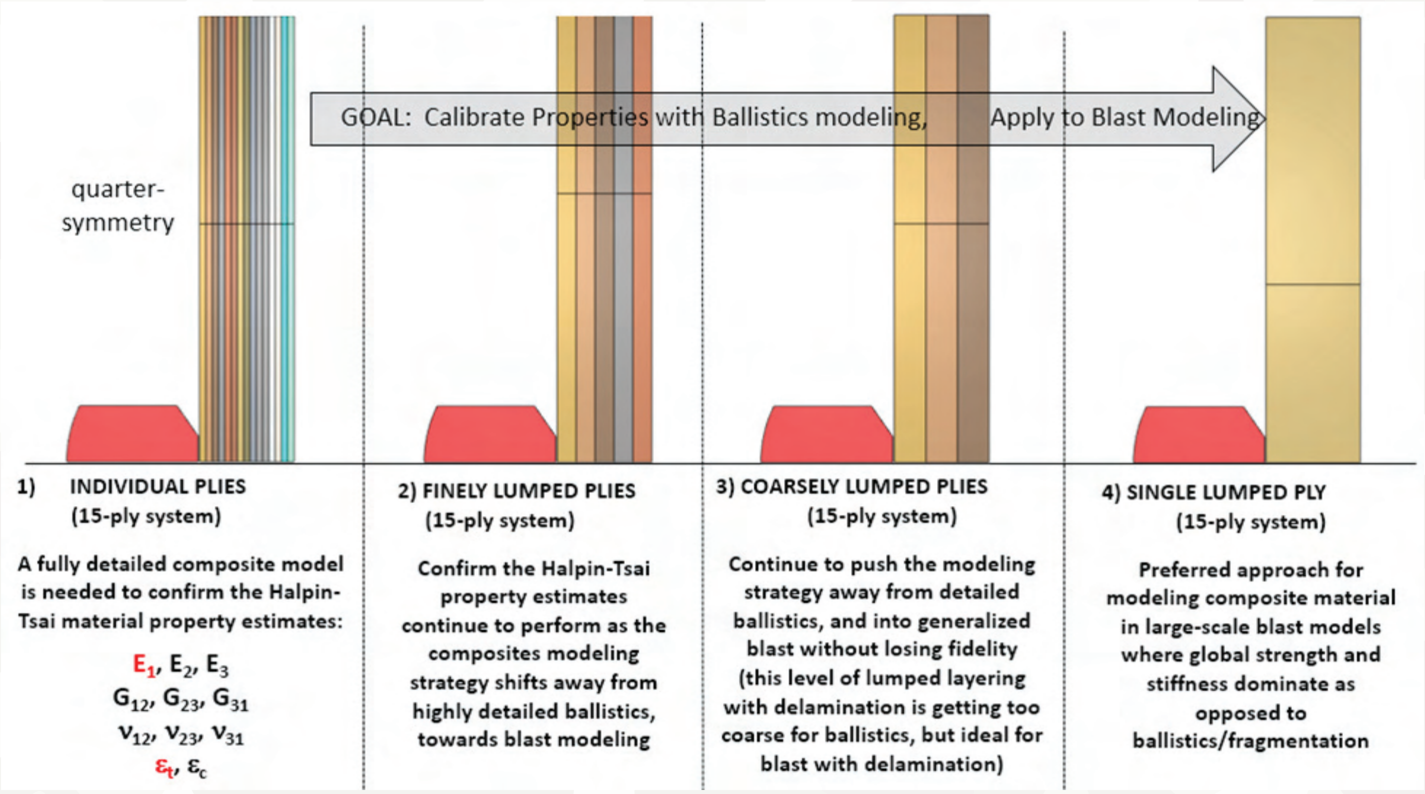
The 3.0.1996 executable can be obtained by contacting support@certasim.com

Identification of Lightweight Materials for Lower Hull Blast Protection

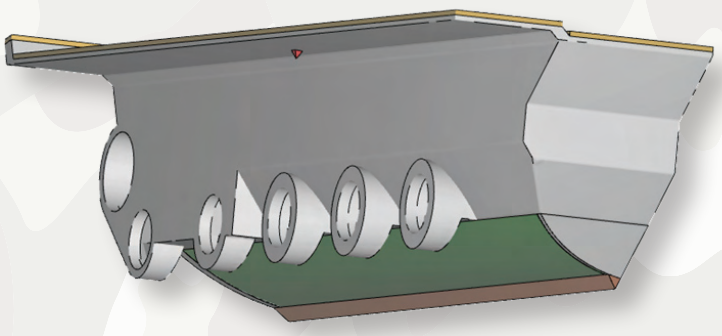
MDG Solutions, Inc., and SAIC collaborated on the TARDEC Lightweight Hull Material Program. The program was initiated to investigate if advanced materials could improve blast performance, decrease the weight and lower the cost for blast protection of military vehicles. The numerical analysis portion of the project utilized the IMPETUS Afea Solver® which included both ballistic and blast simulations. Results were presented at the GVSTS 2016 conference at Fort Benning, Georgia [1].

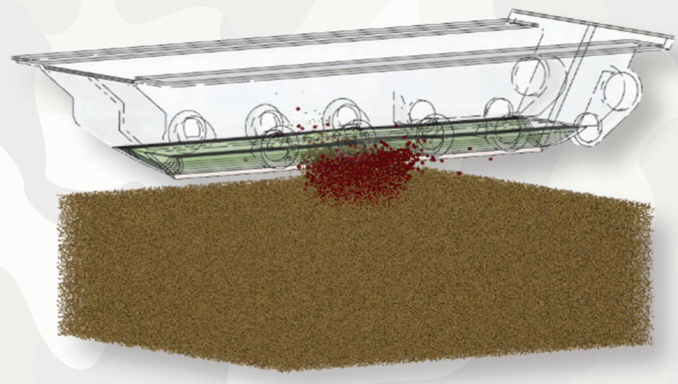
Glass-fiber reinforced thermoplastic polyethylene terephthalate was used as skin for the composite sandwich structure which consisted of a core, a lower and an upper skin plate. Different materials were then used for the core of the composite, among them was a core of 30 wt% discontinuous glass fiber reinforced polypropylene (PP/GF30).

In order to compare the response from the various composites, a Baseline was selected. It was chosen to be an armor aluminum 5083-H116. Experimental tests were performed to obtain the material parameters, which included tensile and compression tests, Flyer Plate tests and Taylor bar tests. Ballistic tests were performed to verify the material parameters. As part of modeling the ballistic behavior the team investigated how to simplify modeling of the structure so that a full scale model of a hull could be included in simulating a blast event. They concluded that reducing the number of plies significantly reduced the computation time.



There was good correlation of the ballistic modeling with the experimental data. A hull from a military vehicle was provided by TARDEC and used in the blast tests. This event was modeled with the IMPETUS Discrete Particle method (iDPM) and again good results were obtained.





The paper concluded that the goals for the Lightweight Hull Material program were obtained since the work successfully improved the survivability, obtained a lighter structure and in fact reduced the cost to manufacture the hull.

Any questions regarding this work can be addressed to support@certasim.com as well as any questions about modeling composite materials with the IMPETUS Solver.

MATERIALS FOR LIGHTWEGHT LOWER HULL BLAST PROTECTION

Michelle D. Gasbarro, MDG Solutions, Inc. /Michael Foley, US Army TARDEC

Wilford Smith, SAIC /James Northrup, SAIC /David Milner, SAIC

1. Abstract

This paper presents the results of a study to design, develop, and characterize materials for vehicle underbody and lower hull blast protection systems. We used static and dynamic materials testing with high-resolution finite element analysis (FEA) to estimate the performance of thermoplastic composites as underbody blast shields. The FEA simulations were baselined to high-strain rate ballistic experiments; constituent matrix and fiber properties were extracted from the testing and used to estimate the full scale survivability performance of thermoplastic-based glass fiber reinforced composites. In the paper we describe our simulation methodology and approach to developing a composite blast shield using commodity materials that results in roughly a 25% weight reduction over its aluminum counterpart, while reducing cost.

Acknowledgement. All pictures shown in this article are courtesy of the authors [1].

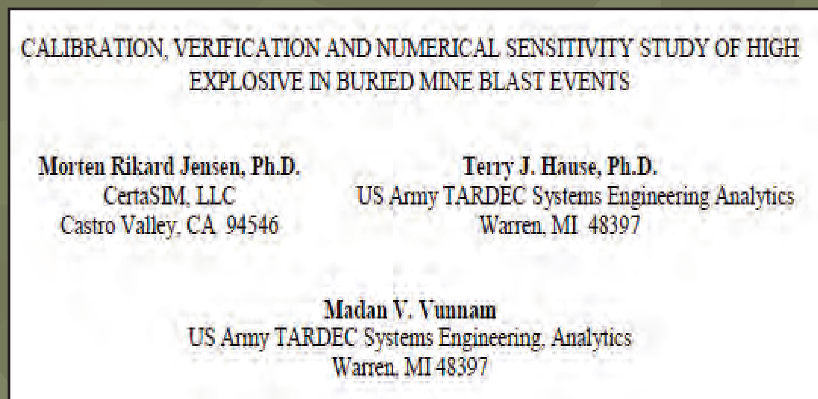
References:

[1] M. D. Gasbarro, M. Foley, W. Smith, J. Northrup and D. Milner, "Materials for Lightweight Lower Hull Blast Protection", 2016 Ground Vehicle Survivability Training Symposium (GVSTS), Ft. Benning's Maneuver Battle Lab in Columbus, Georgia, November 15-17th, 2016.

Calibration, Verification and Numerical Sensitivity Study of High Explosive in Buried Mine Blast Events

TARDEC and CertaSIM, LLC just finished a joint project which focused on user defined High Explosive (HE). CertaSIM has been involved in extensive research to show how to correctly and accurately model the soil bed in buried mine blast events [1-3]. This research combined with our customer's successfully applying the same techniques has led to confidence in applying the IMPETUS Afea Solver's iDPM method to represent the soil. We can now move on to investigate other aspects of the mine blast event which includes modeling the HE. The IMPETUS solver includes calibrated models of several commonly used HE. However, there can be variations in the HE or other HE's that one might want to include in a simulation. This means that in order to model the HE one will have to specify a user defined HE. This was the basis for a joint study carried out by TARDEC and CertaSIM. The results of the work are shown in [4] and it was presented at the 2016 Ground Vehicle Survivability Training Symposium (GVSTS), Ft. Benning's Maneuver Battle Lab in Columbus, Georgia, November 15-17th, 2016.

The procedure for determining the HE parameters was divided into two steps which included calibrating the HE model and then verification of the model. The first step involved reverse engineering to determine the value of the co-volume that matched the value obtained with the JWL EOS. This was done using a controlled expansion of a sphere. Next, verify the HE parameters which was done by modeling a cylindrical charge and comparing the computed pressure with experimental results for the Chapman-Jouguet pressure.


CALIBRATION, VERIFICATION AND NUMERICAL SENSITIVITY STUDY OF HIGH EXPLOSIVE IN BURIED MINE BLAST EVENTS

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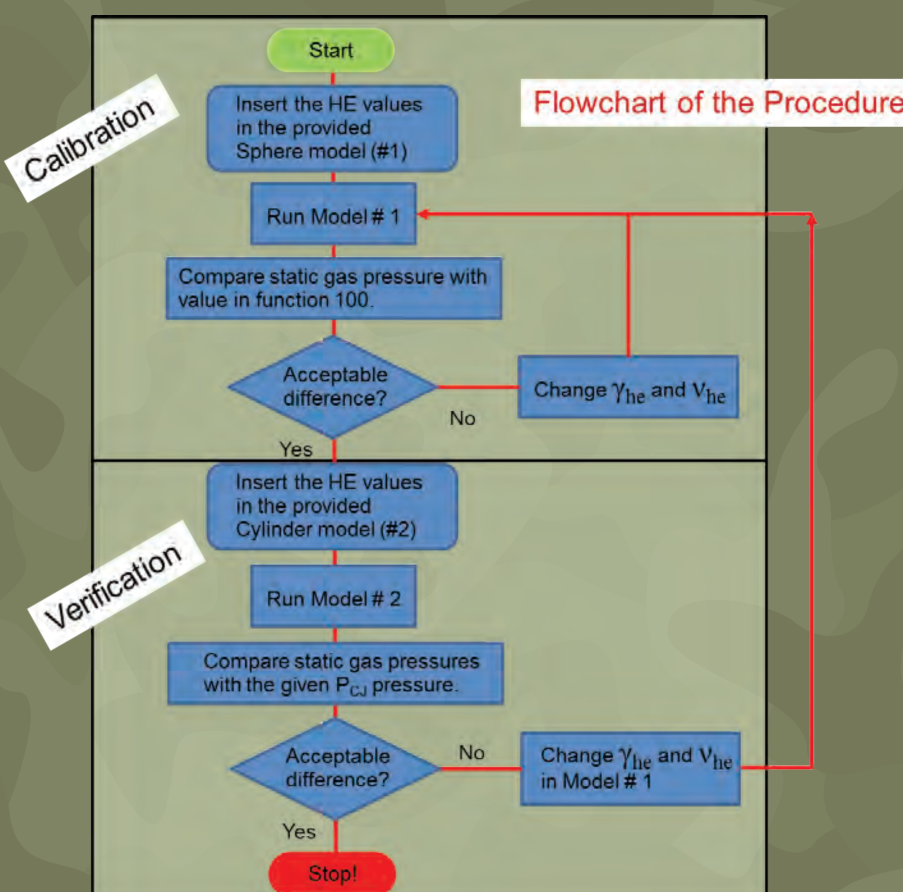
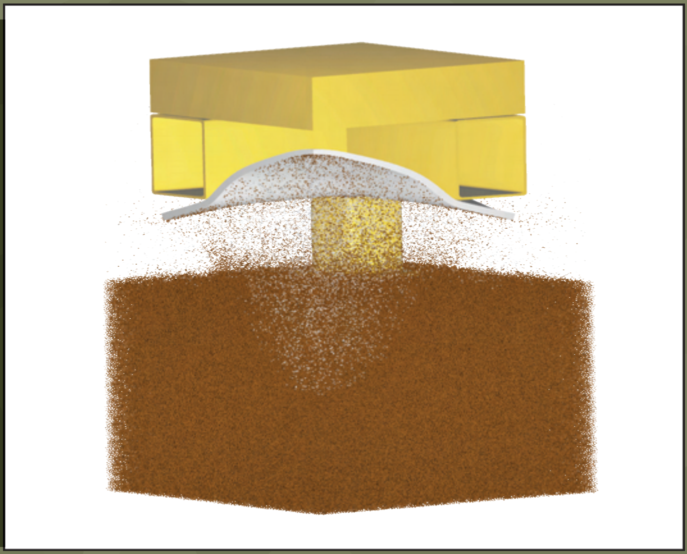
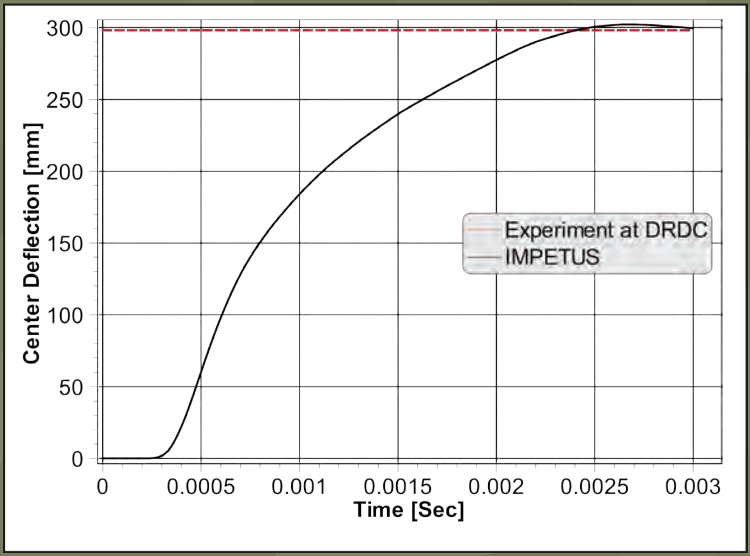
As described in [4] this was successfully done for a C-4 compound and it was used as a Baseline in a larger numerical sensitivity study. The model in this study was the cylindrical charge model and the response parameter was the pressure in the sensor located closes to the detonation point. Five parameters were used in the sensitivity study and it was found that the γ value (c_p/c_v) was the most sensitive parameter, followed by the HE energy per unit volume. To verify the C-4 compound against experiments, a real blast test event was modeled. It was based on the work at DRDC [5] and very good agreement was shown between the experiment and numerical results from the IMPETUS model.







Any questions regarding this work can be addressed to support@certasim.com as well as a detailed class notes on the topic [6].

Acknowledgement:

All pictures shown in this article were courtesy of the authors [4].

References:

[1] W. L. Mindle et. al., “The Discrete Particle Approach to Modeling Air, Soil and HE for Blast Simulations”, 2014 NDIA Ground Vehicle Systems Engineering and Technology Symposium, August 12-14, 2014, Novi, Michigan, USA.

[2] Smith, W. and M. R. Jensen, “Discrete Particle Method is a Predictive Tool for Simulation of Mine Blast - A Parameter Study of the Process and Approach”, 2015 NDIA Ground Vehicle Systems Engineering and Technology Symposium, 4-5 August 2015, Novi, MI.

[3] J. G. Rasico et al., “Modeling Fragmentation of a 155mm Artillery Shell IED in a Buried Mine Blast Event”, Proceedings of the 2016 NDIA Ground Vehicle Systems Engineering and Technology Symposium (GVSETS), August 2-4, 2016, Novi, Michigan.

[4] T. J. Hause et al., “Calibration, Verification and Numerical Sensitivity Study of High Explosive in Buried Mine Blast Events”, 2016 Ground Vehicle Survivability Training Symposium (GVSTS), Ft. Benning’s Maneuver Battle Lab in Columbus, Georgia, November 15-17th, 2016.

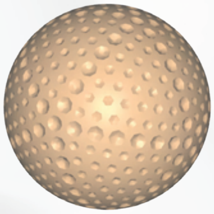
[5] K. Williams et al., “A Numerical Analysis of Mine Blast Effects on Simplified Target Geometries - Validation of Loading Models”, DRDC-TM-2002-260 (2003), Report from Deference Research Establishment Valcartier, Québec, Canada.

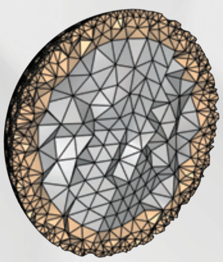
[6] M. R. Jensen, “User Defined High Explosive (HE) in IMPETUS DEFENCE”, # CS-0043-012016, 29 pages.

Modeling Golf Equipment with the IMPETUS Afea Solver®

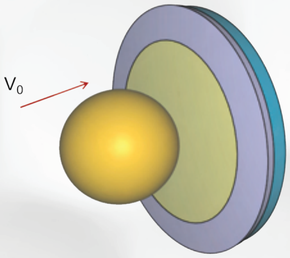
Golf is a very popular game worldwide but especially in the US where 24 million Americans played the game in 2016 [1]. Numerical simulation plays a huge role in research and development of new clubs and balls. The sport is characterized by highly non-linear time dependent impact with high deformation and large rotation which is well suited for an Explicit Non-Linear Transient Finite Element Solver such as the IMPETUS Afea Solver®. In addition the shape of the club head can make traditional hexahedron meshing time consuming and difficult in an industry where reducing design time is critical. This necessary and tedious step in the simulation process is made easier with the accurate high order tetrahedral elements available in the IMPETUS solver. The ASET™ Solid Element Technology provides tetrahedron elements that perform very well adding a new dimension to the modeling of the club head which results in a significant increase in productivity. In fact IMPETUS has been used for modeling Golf applications since 2012 and the first class on the application was taught in early 2014 [2]. Many different areas have been investigated such as ball impact, material characteristics, spinning, etc. Modeling soil impact using the IMPETUS iDPM method has also been done but will be discussed in a separate article.

There are very strict rules regarding the weight of the ball, see [3] and it was seen that by using mesh smoothing of high order elements to better capture the curvature of the ball changed the mass by 1.68% and the result was a much closer value to the real weight of the ball. Furthermore, it is very easy to make a three layered ball even with dimples with the tetrahedron elements.

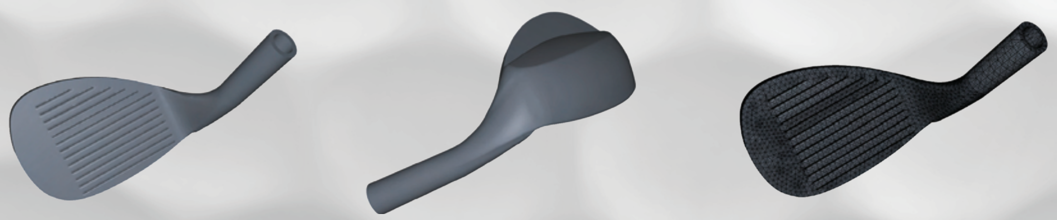




If hexahedron elements are used, the meshing can simply be done with *COMPONENT_SPHERE and the element order changed to quadratic or cubic with the *CHANGE_P-ORDER command. A common issue in the golf engineering community is how to model the constitutive law for the golf ball, considering the fact that the ball is heavily deformed under the impact load. In IMPETUS the ball is typically modeled as Hyper-Elastic using *MAT_MOONEY_RIVLIN. In addition to the traditional M-R model the IMPETUS formulation includes the option of adding viscous effects. A model of the USGA impact plate set-up [4] was published to provide a standard for testing the ball response.

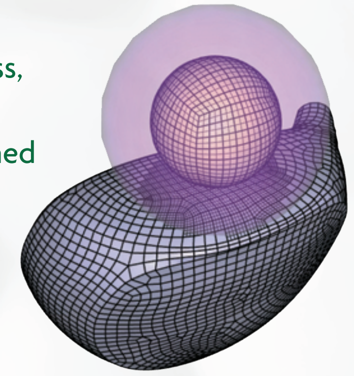


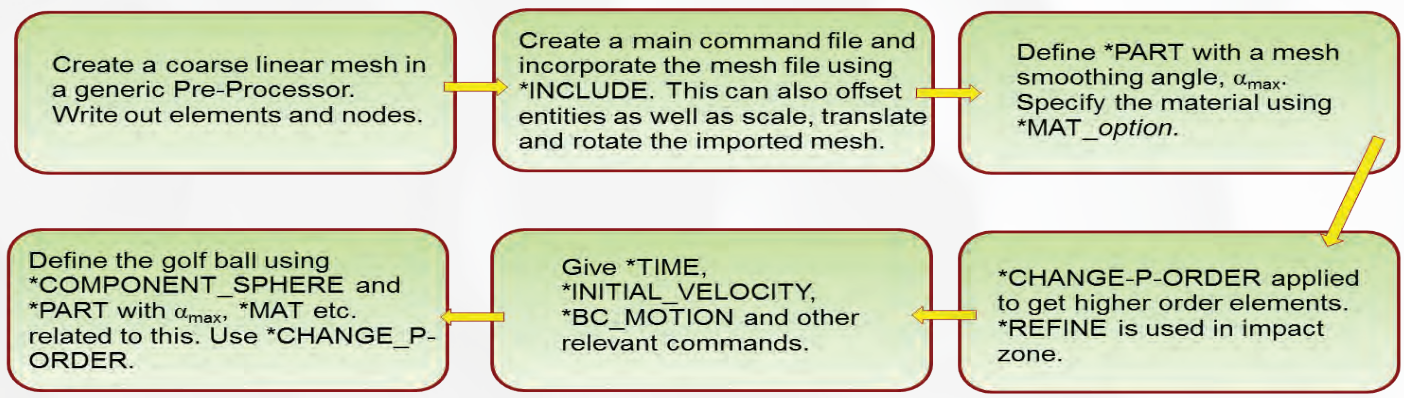
The turn-around time for product development of a new club head is very short which requires that the team of engineers have to be able to perform their analysis quickly. This leads to the obvious advantage of using accurate tetrahedron elements. The higher order tetrahedron elements in IMPETUS have successfully been applied for meshing club heads.

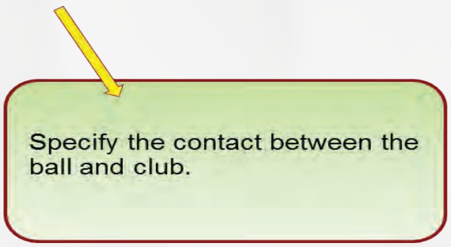


The meshing strategy in IMPETUS is in general to model coarse with linear elements in the pre-processor, turn the elements into higher order in places where accuracy is needed and even use Shadow Refinement in areas of importance. This is also what is recommended for the simulations where a golf ball impacts the club head. Design requirements include modeling impact at various locations on the club head to evaluate the location of the largest von Mises stress. To visualize the results for a large number of impacts the engineers require a contour plot of the highest stress for each scenario. To make this a simple task for the engineering analyst the IMPETUS Solver GUI includes an option to automatically extract the largest stress from each simulation performed and then create a single "Multi-Simulation Contour Plot". In such a case where the impact zone varied, it is very beneficial to use the *GEOMETRY_option command to define the impact location where mesh order and refinement are required. Since this is done by the solver at runtime the engineer does not need to manually remesh the club head for each scenario. To illustrate the procedure consider the following example that uses the *GEOMETRY_SPHERE command to modify the mesh. Note all elements inside the sphere will be changed to cubic elements.

To gather the necessary information, velocity, stress, strain, etc., at the various locations sensors are defined which are independent of the mesh. The sensors are defined by using the *OUTPUT_SENSOR command.







To illustrate the flow in a Golf Simulation using IMPETUS consider the following: First generate a coarse linear mesh of the club, then define parts, smoothing angles, materials, change the elements to higher order and define the boundary conditions. The ball model is generated in the same manner and contact is specified between the two entities.

The details for modeling golf equipment and the generic club and ball models are available for CertaSIM customers and can be obtained by contacting sales@certasim.com

References

[1] D. Heiter, "The State of the Golf Industry in 2016", Forbes/SportsMoney, May 8, 2016.

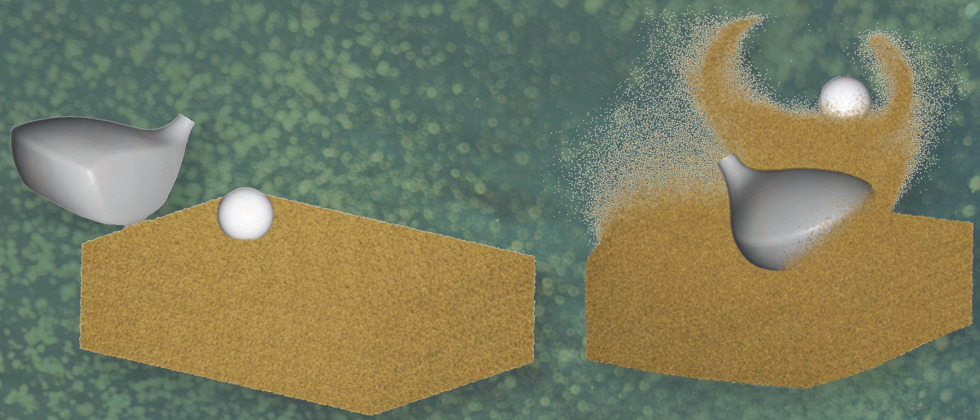
[2] M. R. Jensen, "Modeling Golf Equipment with the IMPETUS Afea Solver®", CertaSIM Report # CS-0018-011514.2, Livermore, 2014.

[3] R&A Rules Limited, "A Guide on the Rules on Clubs and Balls", January 2016, Edition 5.

[4] R&A Rules Limited and United States Golf Association, "Interim Procedure for Measuring the Coefficient of Restitution of an Iron Clubhead Relative to a Baseline Plate", January 1, 2006, Revision 1.3.

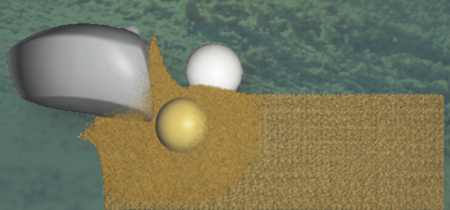
Turf Impact Modeling with the IMPETUS Afea Solver®

Not all golf shots are off the "tee", the club head is constantly impacting the turf (grass and soil). Modeling the turf with a Lagrangian or Arbitrary Lagrangian-Eulerian (ALE) formulation is very difficult to set up and potentially very compute intensive to obtain an accurate solution. There are many scenarios based upon impact angle and soil characteristics, just the modeling effort can be a major task let alone the computation cost. With IMPETUS the solution is simple because we use our Discrete Particle Method (iDPM) for modeling the soil in conjunction with GPU Technology for massively parallel processing. With iDPM the soil is treated as discrete particles not as a continuum which is more realistic and much easier to model. The technology has been successfully used for modeling missile penetration in soil [1] and bullet penetration in sand [2] and so it was natural to apply it to modeling turf. Modeling soil for impact has been implemented as a unique command, *PSOIL, and is available in the IMPETUS BASIC package. The *PSOIL command is simple to setup where the general domain is defined together with soil type, soil-structure friction, boundary conditions and the number of discrete particles. It is also possible to specify a user defined soil type which requires calibration of the soil parameters based on experimental results, similar to what is done for mine blast models.



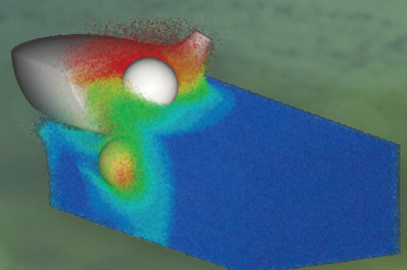
Standard output includes contour plots of soil velocity and displacement. History plots of the energies and momentum of the soil are easily visualized. For the club head the impulse from the soil can be plotted and differentiated to obtain the force on the structure.

An additional benefit of the iDPM method is the ability to embed objects in the soil. Imagine a rock below the surface, not a problem, IMPETUS will fill around it at runtime, just place it in the soil domain. This is probably not a standard scenario for golf course turf, but easily modeled anyway!



The velocity for the sand can displayed as a fringe plot and it is also possible to blank part of the soil to better visualize the impact on the structural parts embedded in the soil.

These models are available for CertaSIM customers and can be obtained by contacting sales@certasim.com.



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[1] M. R. Jensen, "Modeling Warhead Penetration with the IMPETUS Afea Solver®", CertaSIM Report # CS-0046-012016, Livermore, 2016.

[2] T. Borvik et. al., "Penetration of Granular Materials by Small-arms Bullets", Journal of Impact Engineering 75 (2015) 123-139.

Morten Rikard Jensen, Ph.D. - CTO, CertaSIM, LLC

As the year comes to an end and the next one begins, Dr. Morten Rikard Jensen, CTO of CertaSIM, LLC, reflects on the highlights of 2016 and what we look forward to in 2017. As CTO, Dr. Jensen manages customer support, training and research projects at CertaSIM and is responsible for the technical direction of the company.

"2016 was a fantastic and hectic year for CertaSIM! We funded the "Concept for Modeling Crashworthiness of Extruded Aluminum Profiles with the IMPETUS Afea Solver®" project at University of Windsor, Canada. The preliminary results from the experiments were presented at the International Crashworthiness Symposium in April and we are currently working on the numerical aspect of the project. We are convinced that based on the experimental data collected, a procedure to accurately model crash boxes will be developed. Based on the success with IMPETUS at Georgia Institute of Technology for modeling of a real heart valve that includes FSI using SPH for the fluid flow, we have moved into the biomechanics field which includes modeling of medical devices. We work closely with Computational Simulation Software "csimsoft" (www.csimsoft.com) which develops Next Generation Meshing Tools, BOLT & Trelis which complements our Next Generation Solver! We shared a booth at the BMES/FDA "Frontiers in Medical Devices Conference - Innovations in Modeling and Simulation - 2016" where we demonstrated a Stent Model.

Mine blast modeling for military vehicle design is an important application for the IMPETUS solver. To provide support for our customers, CertaSIM, LLC dedicated R&D funding for three days of blast testing of an ATD to gather our own data that will be used to develop a Blast Hybrid III 50th percentile Male ATD model. The tests were completed in July at the General Dynamics Edgefield Test Center. The staff was very professional and they follow a time tested procedure which leads to very consistent results. Witnessing the live tests was a real education that not many numerical analysts have the opportunity to experience. The data gathered will lead to an accurate and suitable Blast ATD for the IMPETUS Solver. We really enjoyed working with the GDLS staff both at Edgefield and their staff in Sterling Heights, Michigan. The calibration of the ATD for crash, following the SAE's standard requirements, is now done and we are soon ready with the calibration for blast experiments. On the numerical side we developed, together with Navistar Defense, an IED model of a M795 grenade including fragmentation, buried in soil, impact with a real vehicle structure including an ATD. It was a very good learning process about fragmentation, where the results were presented in August at the GVSETS 2016 conference held in Detroit. CertaSIM also worked with TARDEC on calibration and verification of user defined HE which is a very useful skill when the HE to be applied is not a standard compound and does not match the pre-defined HE provided by IMPETUS. A paper and presentation was given at GVSTS 2016 at Ft. Benning in November. MDG Solutions, Inc. was contracted to develop a HUMVEE model to be used for different scenarios like mobility, air drop, etc. They did a great job and we used the model to showcase among other things, mine blast in an uneven terrain.

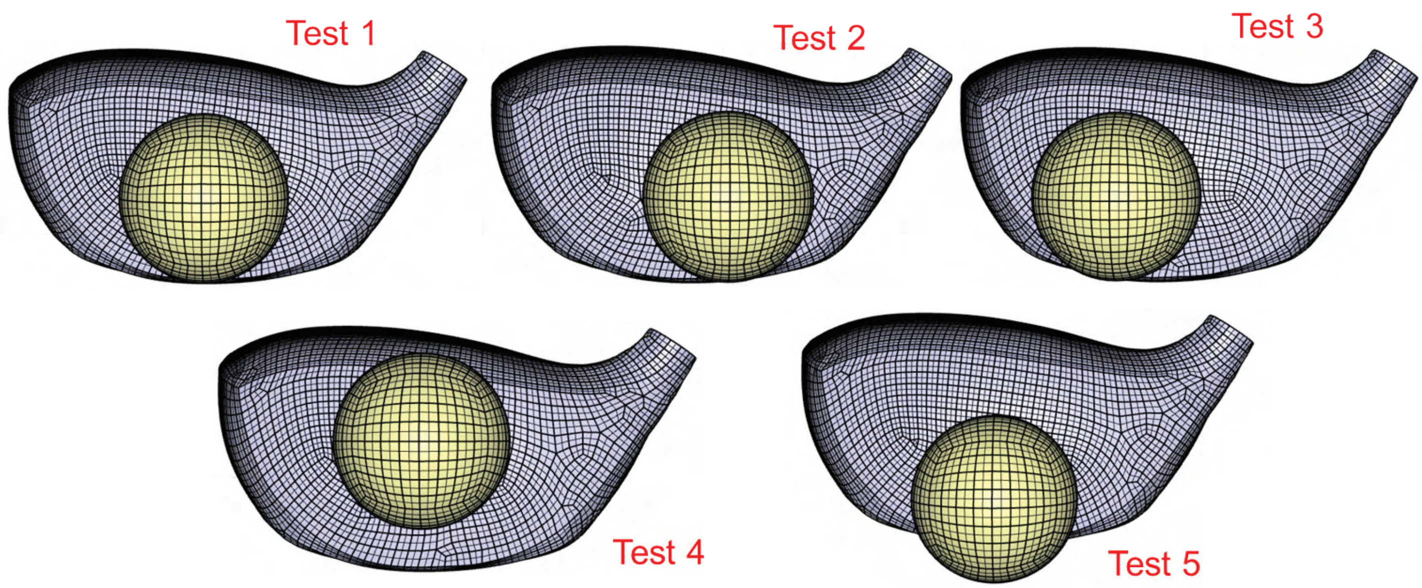
2016 was a busy year and I expect 2017 to be busier! We expect the dummy calibration for blast to be completed and hope to be able to start a new project modeling seats. Then we plan to model an "Armored Personnel Carrier" referred to as an APC, with multiple seats and ATDs and subject it to an IED impact.

In the past we have worked on ballistic projects and IMPETUS has been validated for this type of application, especially in Europe. It is our hope that we will be able to fund some ballistic experiments and again have our own reliable data as we now have for the mine blast event. Another defense application that we will focus on in 2017 is air blast, an area that we have not yet investigated thoroughly, but a new "fast implementation" is being developed by the IMPETUS Development Team in Sweden and it will be available for testing in 2017. A few Metal Forming projects are coming up, also some sports projects in the area of golf and baseball. Hopefully, some of the projects can be made public so CertaSIM's customers can request the IMPETUS models and the reports. I'm very excited to follow the development of the IMPETUS Afea Solver® in the coming year since there will be a lot of new very cool features that will benefit customer productivity! Furthermore, it will be extremely interesting to test the latest NVIDIA Tesla GPU processor, the "P100" which will be available in 2017. The new Pascal processor represents another major boost in performance: more memory, more cores, faster processors and faster memory access. It seems that every new version results in significant boost in performance and the form factor stays the same, which means a standard workstation is all that is necessary to solve the "big" problems."

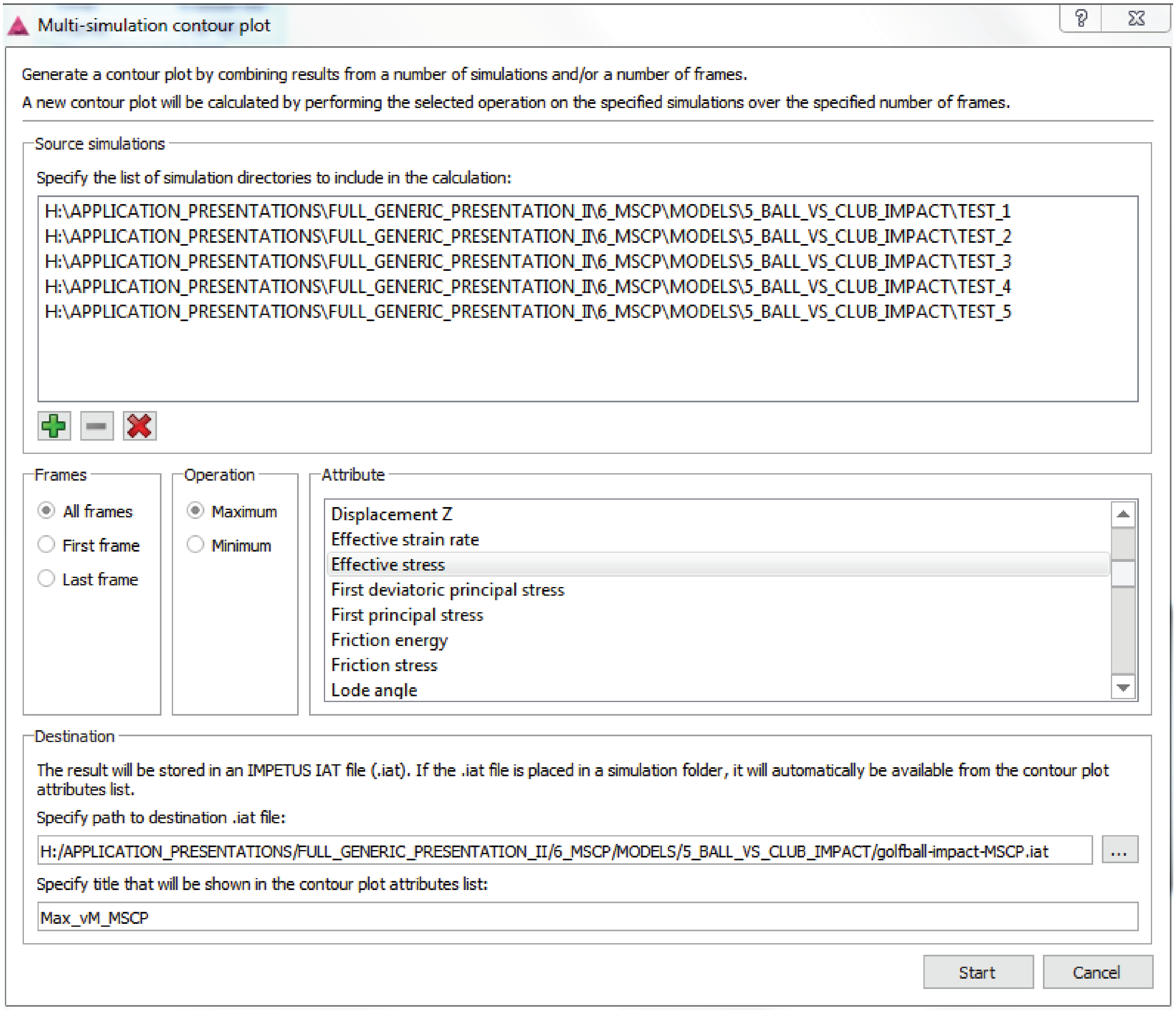
New Features in IMPETUS Afea Solver GUI

One of the typical investigations in the golf industry is to plot a single contour map on the golf club with the max values for a given output component as a result of a golf ball impacting the club head. This component can be stress, displacement, etc. The plot is generated from a user specified number of simulations. The value displayed is the maximum value over all runs for a given location. Generating such a plot is a tedious task and so the process has been automated in the IMPETUS Solver GUI as the Multi-Simulation Contour Plot (MSCP). The MSCP interface is located under the Contour Plot section in the top menu. From the Contour Plot one selects (Create) and clicks on the Multi-simulation.

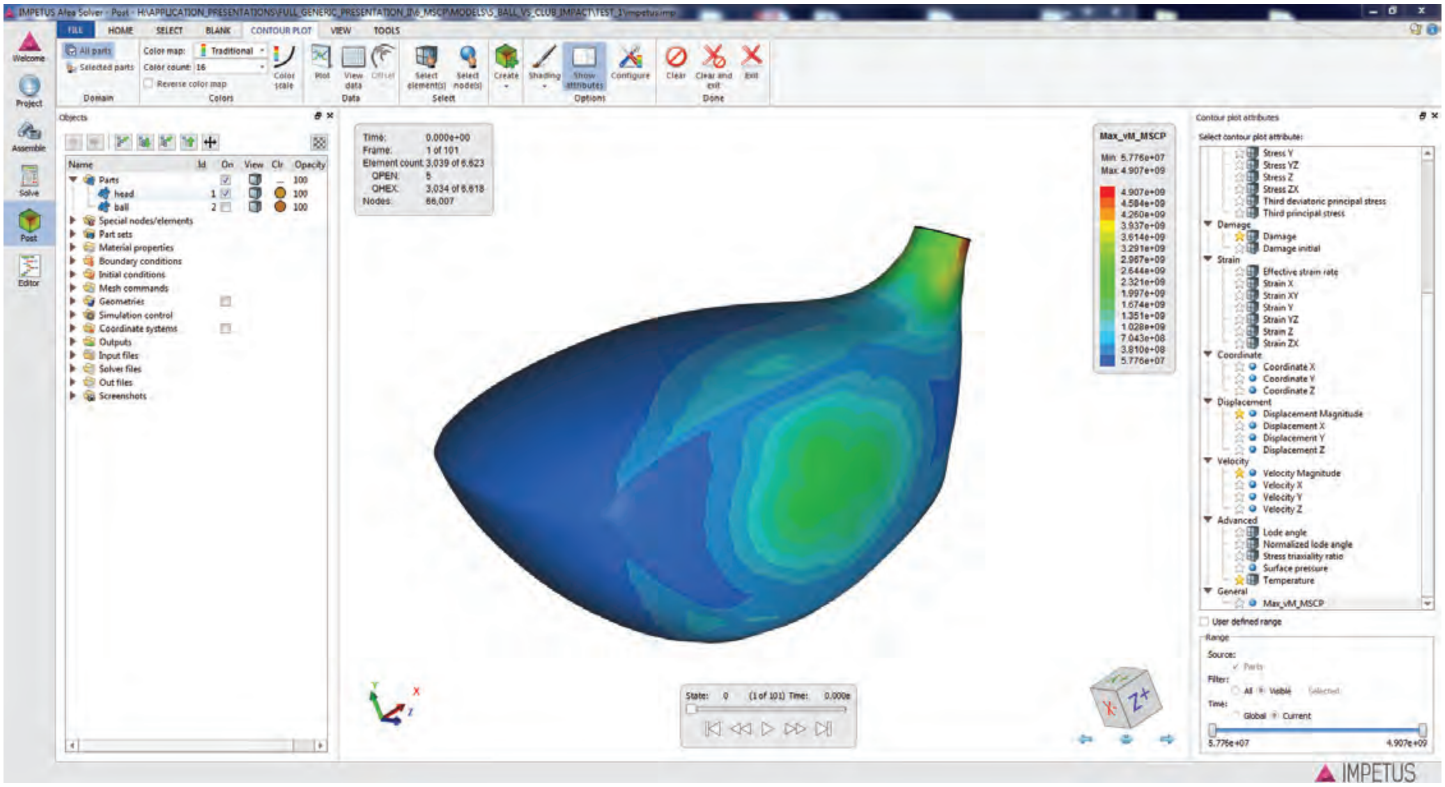
As an example consider a generic golf club model of a driver impacted by a golf ball. Five different simulations were run by varying the impact location. The maximum von Mises stress is selected as the component of interest.



The MSCP menu allows the user to select a series of directories that contains the runs, in this example there are five. One can then select what frame(s) to consider for the calculation, in this example all frames should be used to find the maximum von Mises stress, thus "Maximum" operation is selected. After the attribute is selected click the Start button. This generates *.iat binary files with the root name defined by the user. A title is specified as well which will be shown as a Contour Plot component. The progress of the calculation is updated in the lower left corner.



The *.iat files should be copied to the test directory and the component will be visible as an option in the Contour Plot when loading the model data, impetus.imp file.



This automated process removes the burden from the analyst to create their own software to extract data to produce a MSCP. Productivity is the key and engineers have enough to do without having to validate their own software to make sure results are consistent. By implementing this process in the GUI it now becomes a simple, fast and worry free task.