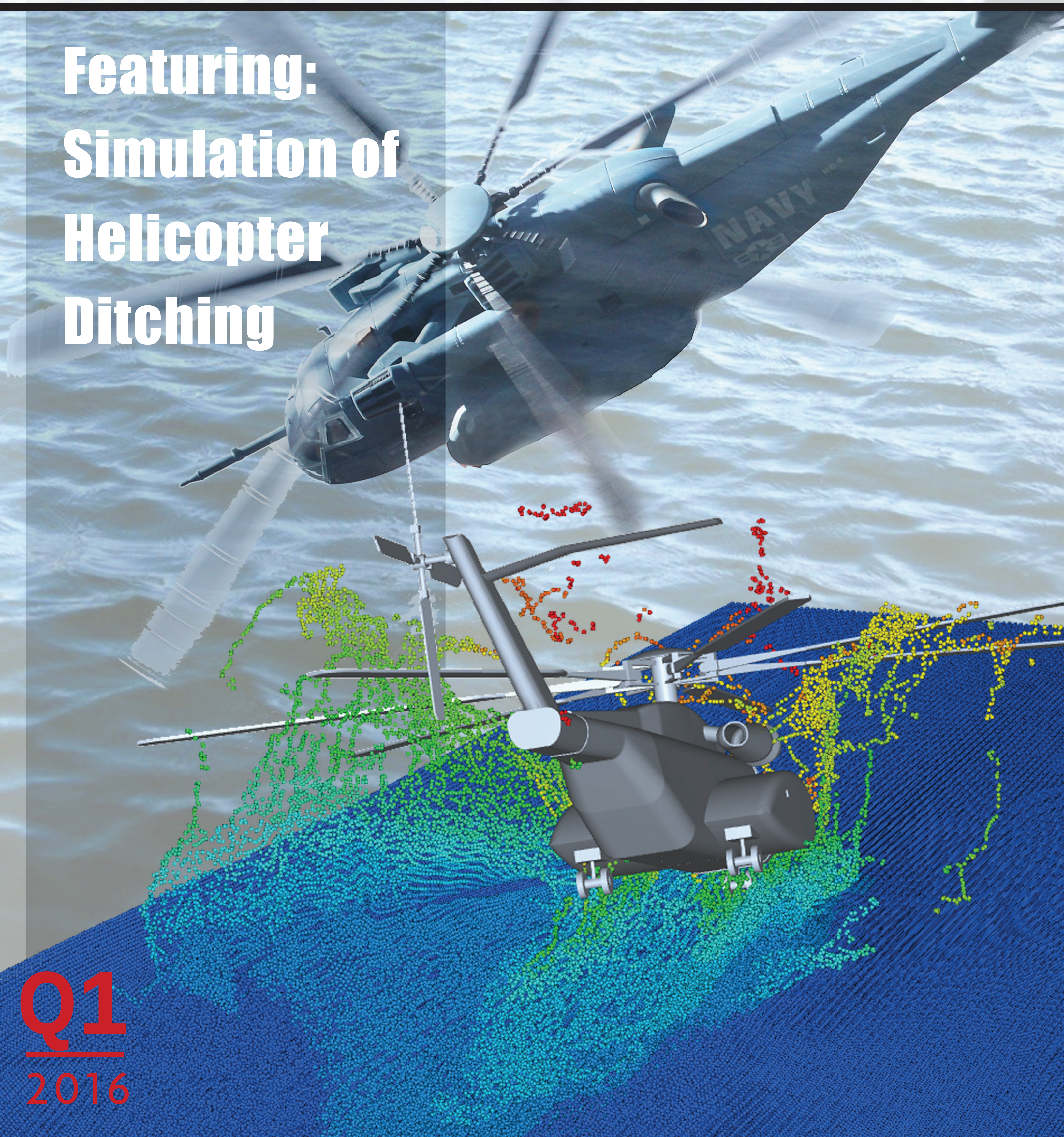
the CertaSim SOLUTION™

Featuring: Simulation of Helicopter Ditching



Q1

2016

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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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News and Events

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 3.0.1801. 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:

* Modeling of rebars. This can be done with *COMPONENT_REBAR which automatically generates a grid of rebars to embed in the concrete material. The rebars can be elasto-plastic and a failure criteria applied with *MAT_REBAR.

* MAT_CONCRETE is a material model developed by IMPETUS to have a different failure in compression and tension which represents concrete very well.

* MAT_LIBRARY makes it possible to use a material from the built-in Material Library in the Assemble Mode of the IMPETUS Afea Solver GUI as described in the article at the end of this Journal.

* CONTACT_SUPER makes it possible to now run the contact on the GPU. It is a very accurate and robust contact. It includes automatic contact checking features which would normally be computationally expensive but is only possible due to the speed gain by utilizing GPU Technology.

* Directional dependent damage with the new *PROP_DAMAGE_CL_ANISOTROPIC.

* PBLAST_DETONATION to allow for use of multiple buried mines to be detonated in the same simulation.

The 3.0.1801 executable can be obtained by contacting support@certasim.com.

GPU Technology Conference (GTC) 2016

The IMPETUS Afea Solver® utilizes GPU Technology for parallelization. Each year NVIDIA holds their GTC Conference where the latest GPU technology is showcased to thousands of attendees. To be on the edge of technology, CertaSIM every year attends the conference and 2016 is no exception. The conference is in San Jose, California April 4-7, 2016. Dr. Wayne Mindle from CertaSIM, will present a paper titled, "Simulation of Hypervelocity Impact of a Whipple Shield". The paper focuses on the benefits of GPU Technology for modeling Hypervelocity in IMPETUS ADVANCED. Let us know if you will be there so we can take the opportunity to meet in person! Information about the conference can be found at: http://www.gputechconf.com/

2nd Annual BMES/FDA Frontiers in Medical Device Conference

The "Frontiers in Medical Device Conference" is a medical device conference sponsored by the Biomedical Engineering Society (BMES) and the Federal Drug Administration (FDA). The conference is in Washington DC, May 23-25. The IMPETUS Afea Solver® has been successfully applied to various areas in the Biomedical Industry as well as in the Medical Device Industry. CertaSIM, LLC will have a booth at the conference, together with csimsoft, the developer of Trelis and Bolt (http://www.csimsoft.com). csimsoft is a CertaSIM partner and their suite of pre-processors are world known for building quality solid element meshes. csimsoft and CertaSIM are currently working together on a project for generating optimal meshing for medical devices and biomedical parts to be modeled in the IMPETUS Afea Solver®. Please come and visit us at our booth to see our results. Read more about the conference:
http://www.bmes.org/meddevicesconference

International Crashworthiness Symposium

"Novel Lightweight Automotive Materials and Structures for Advanced Crashworthiness"

German DLR Institute of Vehicle Concepts, University of Windsor and University of Waterloo co-host this symposium at University of Windsor, Ontario, Canada, April 11th, 2016. Dr. Morten Rikard Jensen, CertaSIM LLC will give a presentation entitled, "Anisotropic material behavior of AA6061-T6 extrusions during large deformation and modeling of such phenomena". This covers numerical and experimental work in the area of predicting deformation and failure in extruded aluminum profiles.
It is a part of a collaboration project between Doctoral student Matthew Bondy, Professor William Altenhof, Department of Mechanical, Automotive and Materials Engineering, University of Windsor and CertaSIM's R&D Department.

ICILSM 2016
1st International Conference on Impact Loading of Structures and Materials

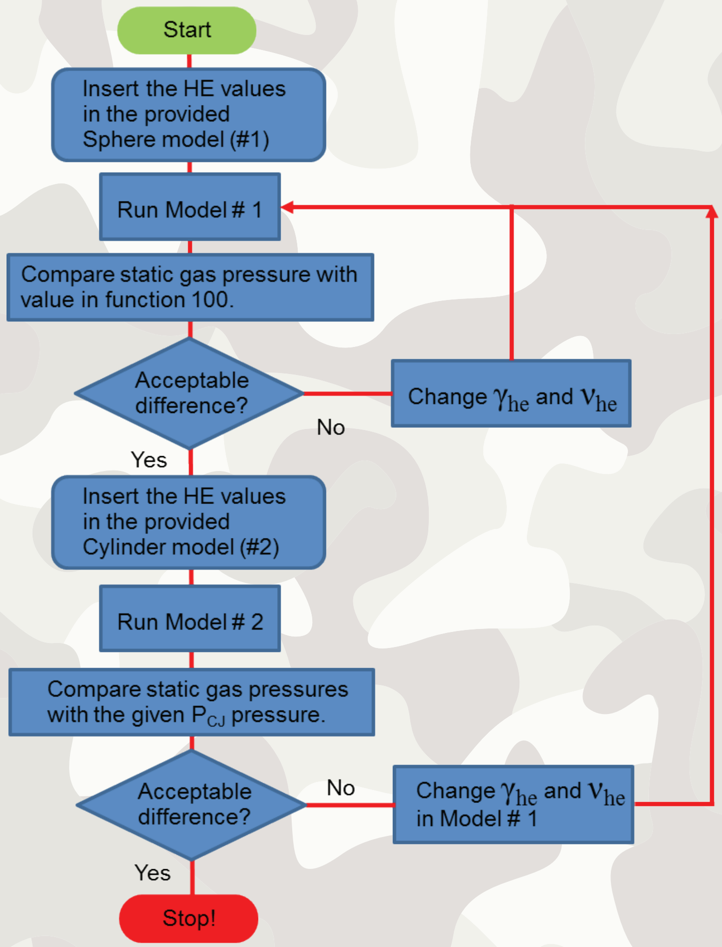
University of Windsor has used IMPETUS to simulate cutting deformation of AA6061-T6 tubes and compared the results with experimentally obtained data. The preliminary results for this effort will be presented at the ICILSM 2016 conference in Turin, Italy, 22-26 of May, 2016. Doctoral student Matthew Bondy, Mechanical, Automotive, and Materials Engineering, University of Windsor, Ontario, Canada will present the paper. Professor William Altenhof and Dr. Morten Rikard Jensen, CertaSIM, LLC are co-authors of the article. The conference information can be seen at:
http://www.icilsm2016.org/index.php

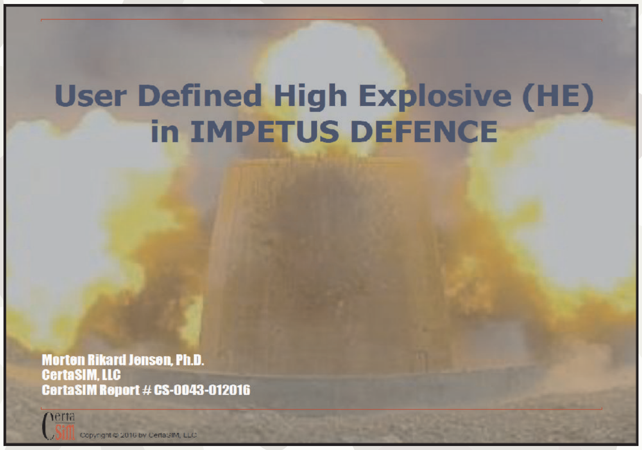
The International Crashworthiness Symposium is a great opportunity for Industry and Academia to connect and exchange ideas. The symposium is free to attend but registration is required. Some of the interesting topics that will be presented involve crashworthiness of aluminum, steel and composites. There will be presentations from major corporations and academic institutions. For a complete listing of the confirmed speakers, the topic of their presentation and their organization, please make reference to the URL below to learn more about the symposium. To register for this free event, simply send an e-mail to crash@uwindsor.ca indicating your interest to attend, your complete contact information, as well as your title and the organization you represent.

Learn more about the symposium:
http://files.certasim.com/download/file/tech-info/conferences/Crash_symposium_Windsor.pdf

How to apply User Defined High Explosive to a Simulation with IMPETUS DEFENSE

CertaSIM's R&D Group has just released a new non-classified report describing how to apply user defined High Explosive (HE) in an IMPETUS simulation. The IMPETUS Afea Solver® models both soil and HE with particles using the Discrete Particle Method which is a very efficient and accurate method to model mine blast and warhead penetration. There are four pre-defined high explosives in IMPETUS DEFENSE: TNT, C4, PETN and M46. These are calibrated and ready to use by only specifying the physical geometry of the HE charge. However, in some cases other types of HE need to be applied, e.g., HMX, Comp B or LX 17. This can be done with the user defined HE. The specification requires the density, HE energy per unit volume, HE fraction (γ_{he}) between C_p and C_v, HE co-volume (ν_{he}), detonation point and velocity. All parameters can be found in the literature or from experiments except for ν_{he} and γ_{he} which are determined by numerical calibration, also known as reverse engineering. This is done by specifying the density and the JWL EOS parameters for the user HE and then comparing the numerical results against the JWL pressure equation. The γ_{he} and ν_{he} parameters are then adjusted to match the JWL results. After this calibration, a second model is carried out where the pressure in different locations are compared to the Chapman-Jouget pressure for the desired HE.

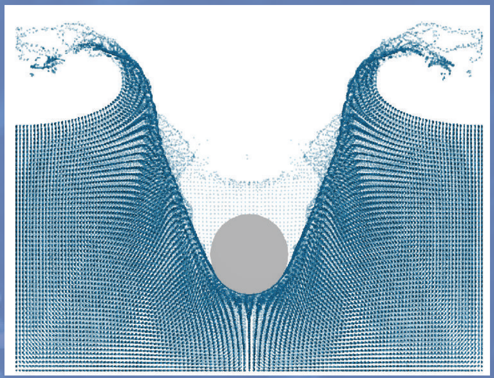




The details on the procedure and an example can be found in the report. It is entittled "User Defined High Explosive (HE) in IMPETUS DEFENCE", M. R. Jensen, # CS-0043-012016, 29 pages. Both the report and the corresponding command files are available to CertaSIM's customers by contacting sales@certasim.com.

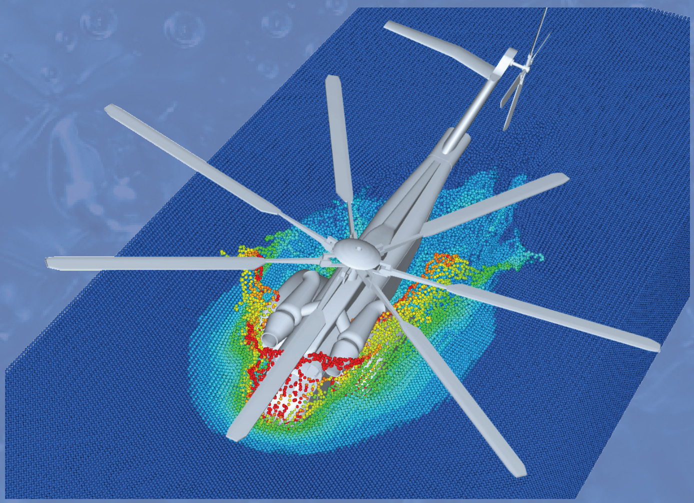
Modeling of Water Entry and Helicopter Ditching

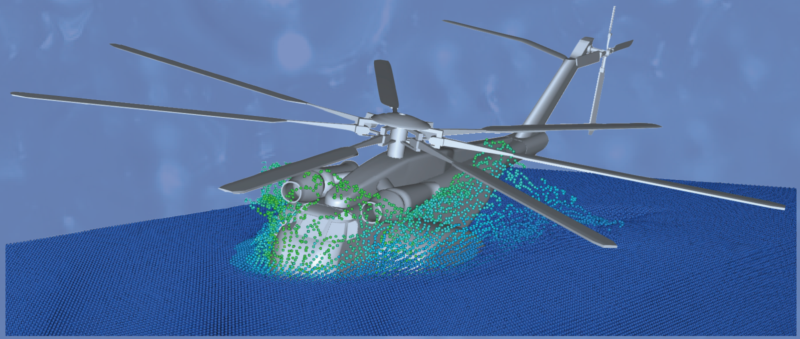
CertaSIM, LLC continues its effort to further demonstrate the use of the Water Entry Lab command option, this time to simulate Helicopter Ditching. A large effort has already been dedicated towards validation of the γSPH Solver available in IMPETUS ADVANCED. The use of the *SPH_WATER_ENTRY_LAB command has been validated by three different experimental set-ups from three different sources, showing very good agreement between numerical and experimental results. The validation work covers dropping of deformable objects and structures with complex shapes. Verification examples of a water entry of a rigid Lifeboat and a deformable Hull model have also been investigated. The status of the current work is documented in a public CertaSIM report, see [1].



A project is now underway to demonstrate simulations of a deformable helicopter. The Sikorsky MH-53E Sea Dragon, the largest helicopter in the United States Military, was chosen for the simulations. It is used by the military as a mine-sweeper.

A Water Ditching scenario of an oblique impact was used with a roll angle of 10° and a downward pitch angle of 5°. Both horizontal and vertical initial velocities were specified as input. The bottom part of the helicopter, which is referred to as the "wet surface" because it is in contact with the water, is specified as deformable (elasto-plastic), the upper portion is modeled as rigid. The deformable parts are quadratic hexahedron elements and the rigid parts are linear elements. In order to affectively study the water impact and it's effect on the structure a 5 sec simulation time was used. The model takes advantages of the new subcycling option in γSPH, which saves significant computational time.





Much shorter termination time could have been used in order to study the initial impact, e.g. running for 80 msec as done in [2]. The initial numerical results for this model are very promising, showing realistic tilting and motion of the helicopter during the impact.

The next step in the project is to model Wave Generation and for this purpose a new functionality has been added to the *SPH_WATER_ENTRY_LAB. The feature generates the initial conditions (wave, velocity, pressure) based on an analytical solution for each particle. The specification follows the standard IMPETUS philosophy of simplified input. One gives simply the wave type, wave height and position. The wave type can be selected as Laitone, Boussinesq or given as a general function. The feature has been tested on a rigid model of the Hughes OH06 Cayuse helicopter [3]. Future work includes modeling of the Sikorsky MH-53E Sea Dragon helicopter in a Sea State 4 Condition.

References:

[1] "Modeling Water Entry with IMPETUS ADVANCED", M. R. Jensen, #CS-0045-021516.

[2] "Crashworthiness of Helicopters on Water: Test and Simulation of a Full-scale WG30 Impacting on Water", N. Pentecôte and A. Vigliotti, IJCrash 2003, Vol. 8 No. 6 pp. 559-572.

[3] "Modeling Wave Generation in IMPETUS ADVANCED", M. R. Jensen, #CS-0046-042016.

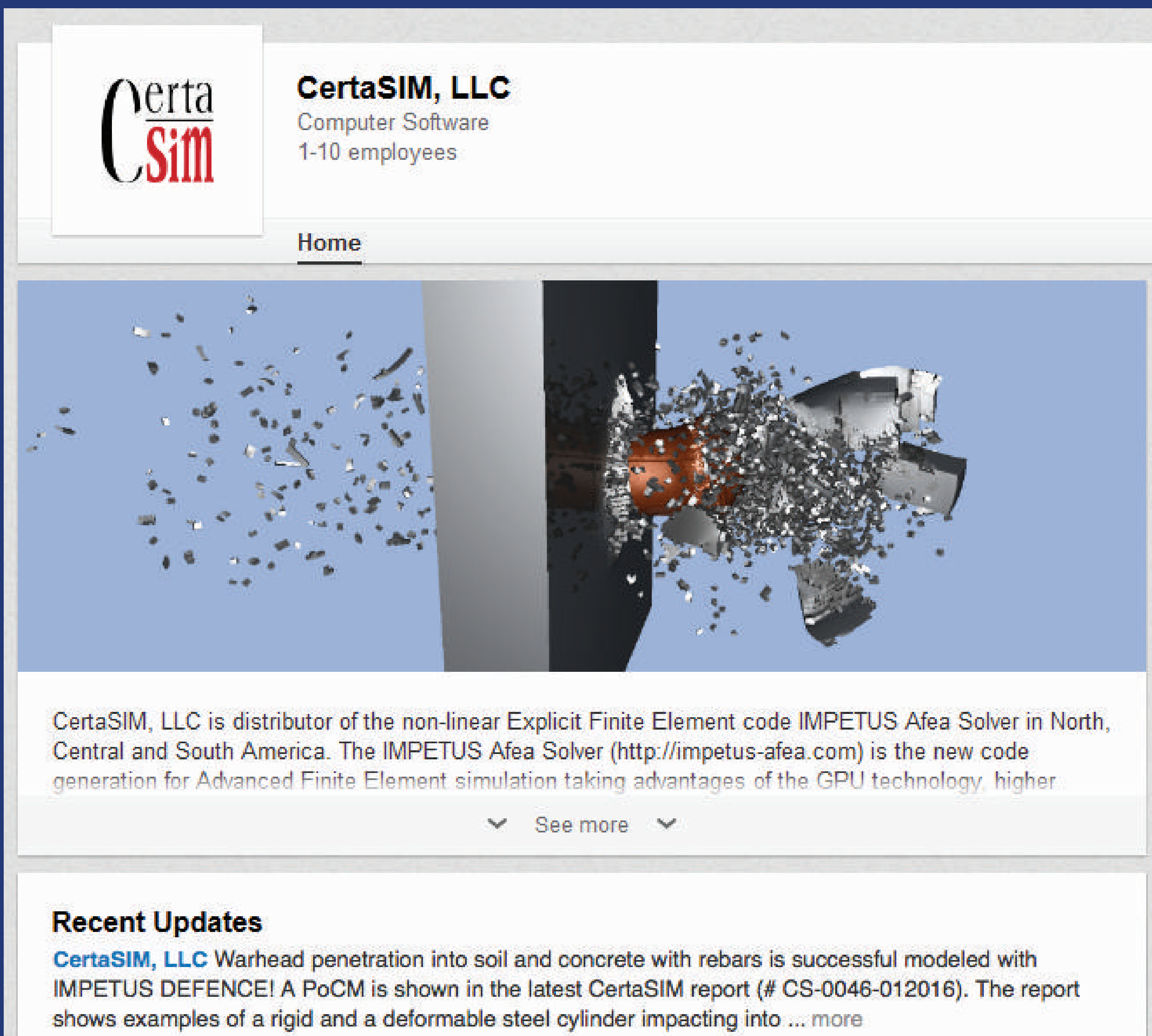
Acknowledgement:

The meshing of the Sikorsky helicopter model and development of the initial model was done by MDG Solutions, Inc. under contract with CertaSIM, LLC.

CertaSIM, LLC Company Page on LinkedIn

New options are added to the IMPETUS Afea Solver® when they are tested and have passed a QA test suite controlled by the IMPETUS Verifier as mentioned elsewhere in this issue. It is beneficial for IMPETUS users to know about these new features. CertaSIM provides this in a quick accessible format by postings on LinkedIn using the CertaSIM, LLC company page. It is strongly recommended for IMPETUS users to follow this Page to obtain the latest news. Also published on the page is news about any new articles or CertaSIM documentation reports, links to application videos, etc. One can then request a copy of the reports and stay updated.

To follow the Page, search for CertaSIM, LLC and click Follow.
We look forward to welcoming you to our community!



Michelle D. Gasbarro - President of MDG Solutions Inc.

Michelle D. Gasbarro is the president of MDG Solutions Inc. which is located in Raleigh, North Carolina. She has been with MDG Solutions since the beginning in 1997. She is an expert in military survivability including blast, ballistics and fragmentation threats. Her educational background is a Bachelor of Science degree in civil/structural engineering and a Master of Science degree in Biomedical Engineering. Besides that she has worked extensively within the area of metal forming covering thin sheet metal forming, extrusion hydro-forming and stretch-bending etc. We asked her to describe the main reasons that made MDG Solutions Inc. change from a Legacy Code to the Next Generation Solver, the IMPETUS Afea Solver®.

"MDG Solutions, Inc. is an engineering consulting firm specializing in advanced computational mechanics and computer simulation techniques to effectively help clients engineer their products and manufacturing processes. Following a 12-year career as an automotive engineer, MDG Solutions was incorporated in January, 1997 and remains viable today, thus culminating into more than 30 years' experience in FEA-based product development. Expert-level Non-Linear FEA, Material Science, and Structural Dynamics are the core competencies behind accurate simulations of complex, real-world problems. What sets MDG Solutions apart from the majority of FEA houses is the ability to apply virtual engineering to advanced applications where structural and material responses are extreme due to harsh loading events. Examples include structural impact such as automotive crashworthiness, or manufacturing operations such as bending, forming, and stamping, all of which involve excessive metal deformation.

However, the last decade has seen a particular focus on engineering developments for military vehicle survivability and fortification against the ever-increasing threats coming from ballistics, high explosives, and fragmentation events. Uniquely complex in these types of simulations, extreme material deformation, damage, and fracture are the hallmark responses in this class of problems, and a true challenge for the explicit FEA software and computing hardware being employed.

During the early years, MDG Solutions was heavily involved with developments in metal forming and automotive crashworthiness, where simulations were carried out using the explicit Legacy Solvers developed nearly 40 years ago. Since these solvers were initially developed with these types of applications in mind, the element technology, various contact algorithms, boundary and loading conditions defined in the simulations were fairly robust and stable. In addition, these types of simulations could routinely be executed on stand-alone workstations, bringing the entire prospect of FEA-based consulting within reach of small and independent consulting firms. But after the events of 9/11, a significant reduction in "out-sourcing" to consulting firms took place that made it quite difficult to survive in these traditional arenas. And not surprisingly, 9/11 created a renewed surge within the engineering communities to advance our Military and Homeland Security frontiers. As a result, MDG Solutions underwent a shift in focus to now include engineering developments in the survivability and fortification arenas for military vehicle development. Developing ground vehicle structural frames, sub-systems, armor systems, and responsive interior structural systems became the new norm.

Clearly the class of problems involving blast, ballistics, and fragmentation within the framework of simulation can inherently be characterized as having more complex physics and material science aspects when compared to the metal forming industries. In addition to the necessary knowledge and fundamental mechanics relating to material damage and fracture, a deep understanding of blast and ballistic physics is required - especially as it pertains to understanding soil cratering, ejecta formation, and eventual impact with vehicle structures during blast, and the complicated penetration mechanics inherent in ballistics and fragmentation. Lastly, simulating this class of problems for a small consulting firm now introduces significant challenges in terms of hardware availability.

The more common practice for simulating high explosive events in earlier decades was to use simplified, empirically-based techniques for defining the pressure loading on the structure from the soil impact, such as CONWEP or WESTINE. But it has been well documented in the literature that these approaches are too rudimentary and can only deliver a simultaneous pressure loading that is not time-dependent, but that is a critical characteristic of the streaming soil ejecta formation and impact with the vehicle. The more accurate and robust alternative is using the Arbitrary-Lagrangian-Eulerian (ALE) Fluid-Structure-Interaction (FSI) simulation technique which is available in the dominating Legacy Solvers. The downside, however, is this approach requires extensive computing capability, most notably a large cluster of computing cores chained together to create a massively paralleled computing system. In addition, it is very complex and most times impossible to run simulations that require arbitrary explosive shapes, or obstacles in the soil bed such as rocks or stones since the shape of the explosive or object has to be “carved” out of the ALE domain mesh. Furthering the list of challenges with ALE-FSI simulations, the numerical advection process which is responsible for the handshake between the Eulerian soil mass fluxing through the ALE mesh after detonation and then impacting the Lagrangian structural mesh for the vehicle is prone to “leakage” at the soil-structure interface. As a result, considerable run time and knob turning is required to limit the effects of FSI leaking. Lastly, while the ALE-FSI technique when done correctly can reliably and accurately capture the blast physics and its effects on the soil bed which subsequently drives the loading on the structure, the simulation run time must be measured in days and weeks, not hours. Herein lies the paradigm challenges for the small consulting firms that cannot afford or manage such large computing systems.

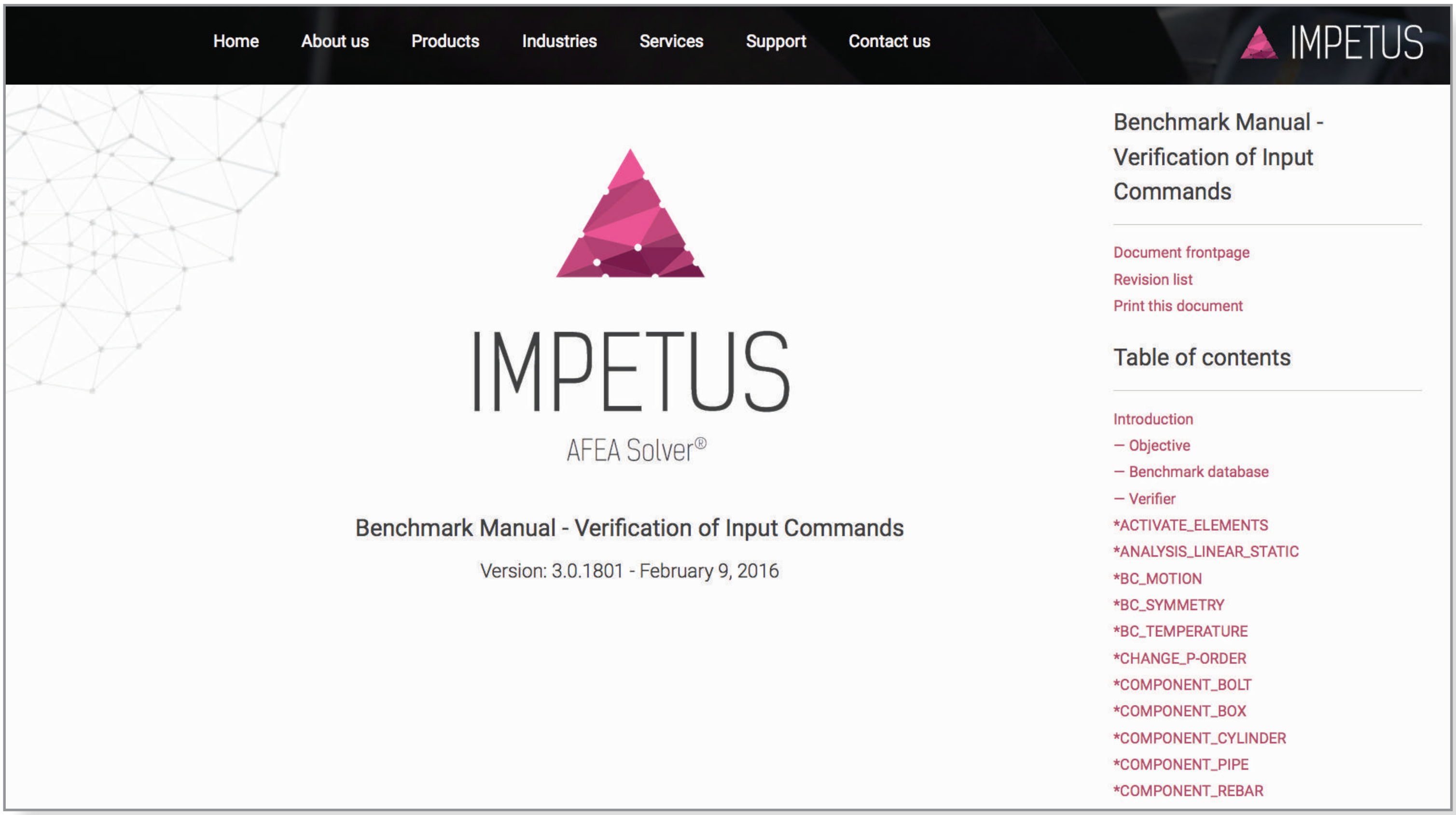
While MDG Solutions did engage in some limited ALE-FSI buried mine blast simulations for armor system development, the primary approach was to rely on the simplified empirically-based techniques. But over time, and when correlating simulation results with client blast test results, it became clear that not only was “verification” FEA not consistent and accurate, but repeatable and “predictive” FEA was simply unobtainable with these simplified techniques. Engineers and Program Managers must be able to rely on the fidelity and validity of the FEA in order to make critical design decisions throughout the development cycle. Still wanting to contribute in the engineering field of military vehicle and armor system development because of the common good behind that purpose, and to earnestly help develop products that protect the war-fighter as best we can, MDG Solutions was faced with a serious strategic decision on how to adapt to these ever-increasing technical challenges, coupled with ever-increasing software and hardware demands.

The answer came in February, 2011 when a new explicit FE Solver was introduced to the US, the IMPETUS Afea Solver®. Developed by a team in Norway and Sweden in the late-2000s led by Dr. Lars Olovsson, the purpose was to create a paradigm advancement in FEA technology over classical finite element formulations and techniques. The IMPETUS Afea Solver® can be thought of as the Next Generation Explicit Solver, built for the engineering simulation challenges of *today's era*. Not only has an all-new element technology been developed that now makes possible the routine use of 2nd- and 3rd-order accuracy in deformation, plasticity, and fracture predictions, but the core kernel languages the code was written in takes advantage of GPU Technology for parallelization. The end result is a very accurate FE Solver that now runs on a stand-alone desktop computer with exceptionally fast run times, thus giving power back to the smaller consulting firms to remain relevant in industry, and continue to contribute in the more complex fields of FEA-based product development - especially Defense applications. And to answer to the shortcomings of the legacy approaches for simulating high explosive events, a newly-developed technique called Discrete Particle Method (DPM) is at the core of the IMPETUS Afea Solver®. DPM allows the analyst to easily define representative soil beds containing buried or surface-laid explosives. Upon detonation, accurate soil physics drive the soil ejecta formation and ultimate contact with the target structure, and across accurate time scales, with no interface leakage between the soil and structures. And with ease, the analyst can define arbitrary shapes to the explosives, or even multiple explosives detonating in sequence if necessary. Even scenarios where the IED is known to be a filled oil can, gas can, or a specific artillery or mortar shell, the model preparation and analysis set-up is refreshingly easy.

By coupling the new solid element technology in the IMEPUTS Afea Solver®, otherwise known as the Aset™ family of higher-order elements, with the Discrete Particle Method for capturing soil physics in the presence of detonations, and the GPU Technology for computing hardware, full-vehicle blast simulations involving extensive damage and fracture can be reduced to over-night runs on a single desktop workstation. While it is recognized that change is not easy, especially when talking about changing the primary simulation techniques that have been in play for many decades in the engineering communities and within companies, switching to the IMPETUS Afea Solver® explicit software has been a mission-critical success story for MDG Solutions. It has made possible the opportunity to continue to contribute as an experienced engineer in a small consulting firm, with a wealth of knowledge, to the very necessary and important engineering endeavors of protecting our war-fighters against increasingly dangerous threats to the best of our abilities - a cornerstone principle here at MDG Solutions, Inc."

IMPETUS Afea Verifier - A Novel QA System

Software Quality Assurance (QA) is important and is necessary for all software. The IMEPTUS Afea Solver® is no different and the developers at IMPETUS Afea take this very seriously. They have developed an automated procedure that includes a database of benchmark problems to test for reliability of the software. The database consists of both Verification and Validation models.



For a detailed explanation between the two types of models see [1], but to give a simple explanation they refer to:

"Verification" - Solving the equations correctly

"Validation" - Solving the right equations

In the IMPETUS QA system this is done by: [www.impetus-afea.com]

Verification models are quick models where the objective is to ensure that algorithms are implemented correctly.

Validation models make sure that the Solver represents the real-world behavior.

Comparing results with results from earlier versions and with experiments can be a long tedious job if performed by hand. The automated system runs all models in the Benchmark Database and compares pre-defined Response Parameters with numerical values from previously carried out simulations and with experimental data. It further generates graphs, tables and reports for the QA team to investigate for suspicious results. The software is called the Verifier and the process of running the test cases is Version Control. If the Version Control fails an executable is not released before the bug is identified and fixed. This strict QA policy insures that the IMEPTUS Afea Solver® is trust worthy and has made the Solver extremely stable. All input commands are checked as well as all materials in the Material Library. However, users should always verify their results to ensure against user error.

A subset of the generated documentation is published on the IMPETUS Afea Website (www.impetus-afea.com). They are the Recommended Modeling Practices (RMP) reports and the Verification Manual. The later shows for each command the specification, model description, target results and if the version passed. It is easy to navigate through the Manual since there is a navigation bar to the right, listing the commands. The documents can be found under the Support Menu at the IMPETUS Afea Website. The section is labelled Verifier Documentation.

Verifier documentation

Each released version of IMPETUS Afea Solver's computational modules (FE and DP) is subjected to version control based on a benchmark database. We test all our input commands to verify if they work correctly. For some applications, Recommended Modelling Practices (RMP) have been developed. The RMPs contain validation tests in combination with a recommended modelling methodology. All of the following documents are updated based on the latest version control:

- Verification of Input Commands
- RMP001 - Material Failure Prediction Of Large-Scale Steel Structures
- RMP002 - High Explosive Blast Loading
- RMP003 - Recomputing DNV-RP-C208
- RMP004 - DOCOL Steels
- RMP005 - Perforation Resistance of Four Different High-strength Steel Plates

For further information about Verification and Validation of the IMPETUS Afea Solver®, please contact CertaSIM, LLC.

[1] P. J. Roache, "Fundamentals of Verification and Validation", Hermosa Publishers, 2009, ISBN 978-0-913478-12-7.

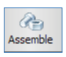
NEW FEATURES

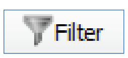
IMPETUS Afea Solver GUI

One of the most critical modeling choices for any Finite Element Model is the selection of the material data. The user needs to select the appropriate constitutive model to accurately capture the behavior of the material. Material parameters should then be determined from experiments carried out for the specific material used. However, often there are no resources for experimental material identification and users need to find the material by a literature study and hope to find something that can be translated into a numerical model. To ease this process and provide realistic material parameters, IMPETUS Afea has developed a Material Library which currently consists of 28 individual materials and more are constantly being added. Different types can be selected; high strength steel, aluminum, stainless steel, etc. These are all obtained from published references. The name for the material in the command file is *MAT_LIBRARY and a unique name is then given.

```
*MAT_LIBRARY
"material name", mid
```

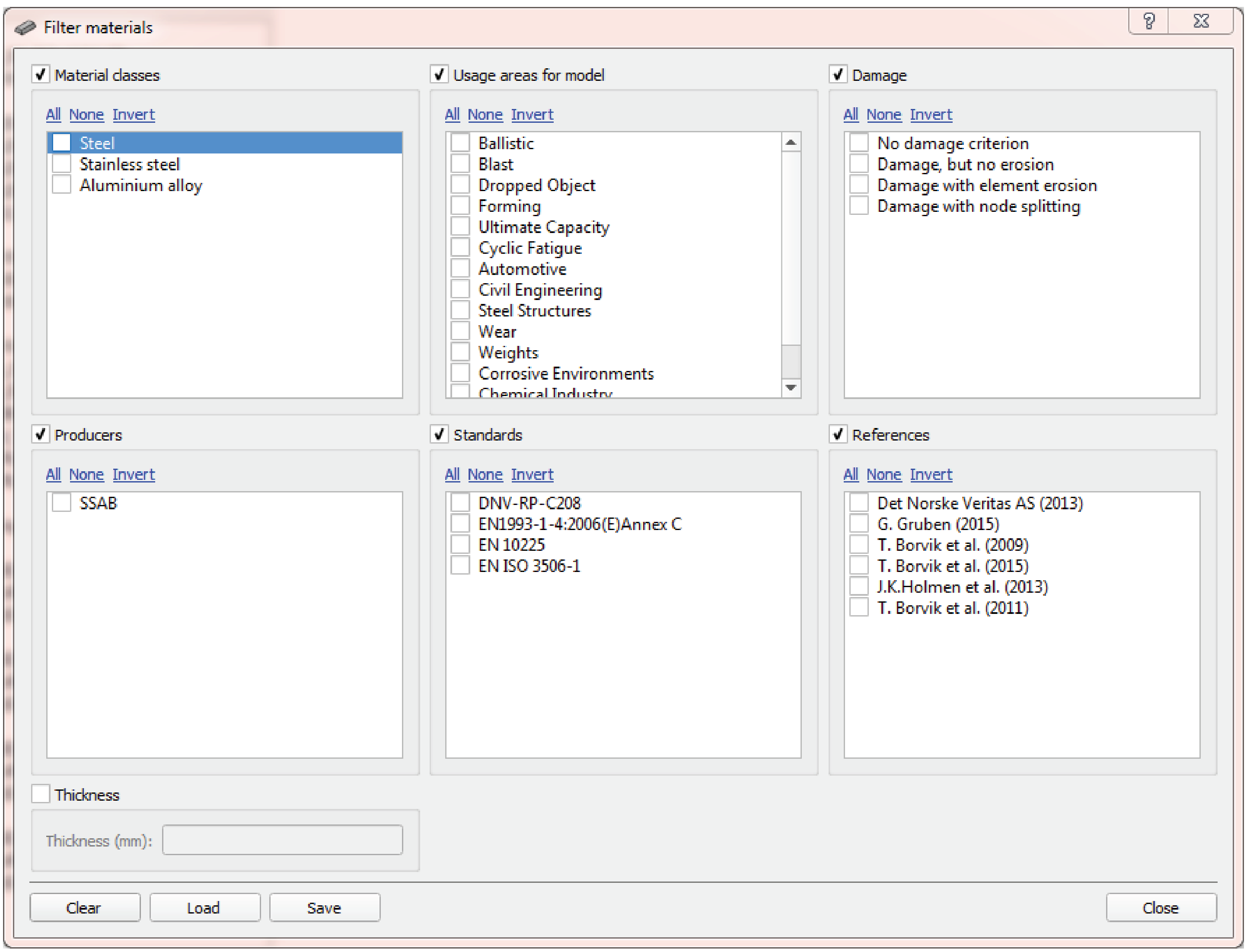
Here *material name* is a unique name of the material which is found and selected in the Assemble Mode of the IMPETUS Afea Solver GUI as shown in the following. The *mid* is the material ID that is used in *PART.

In Assemble mode 

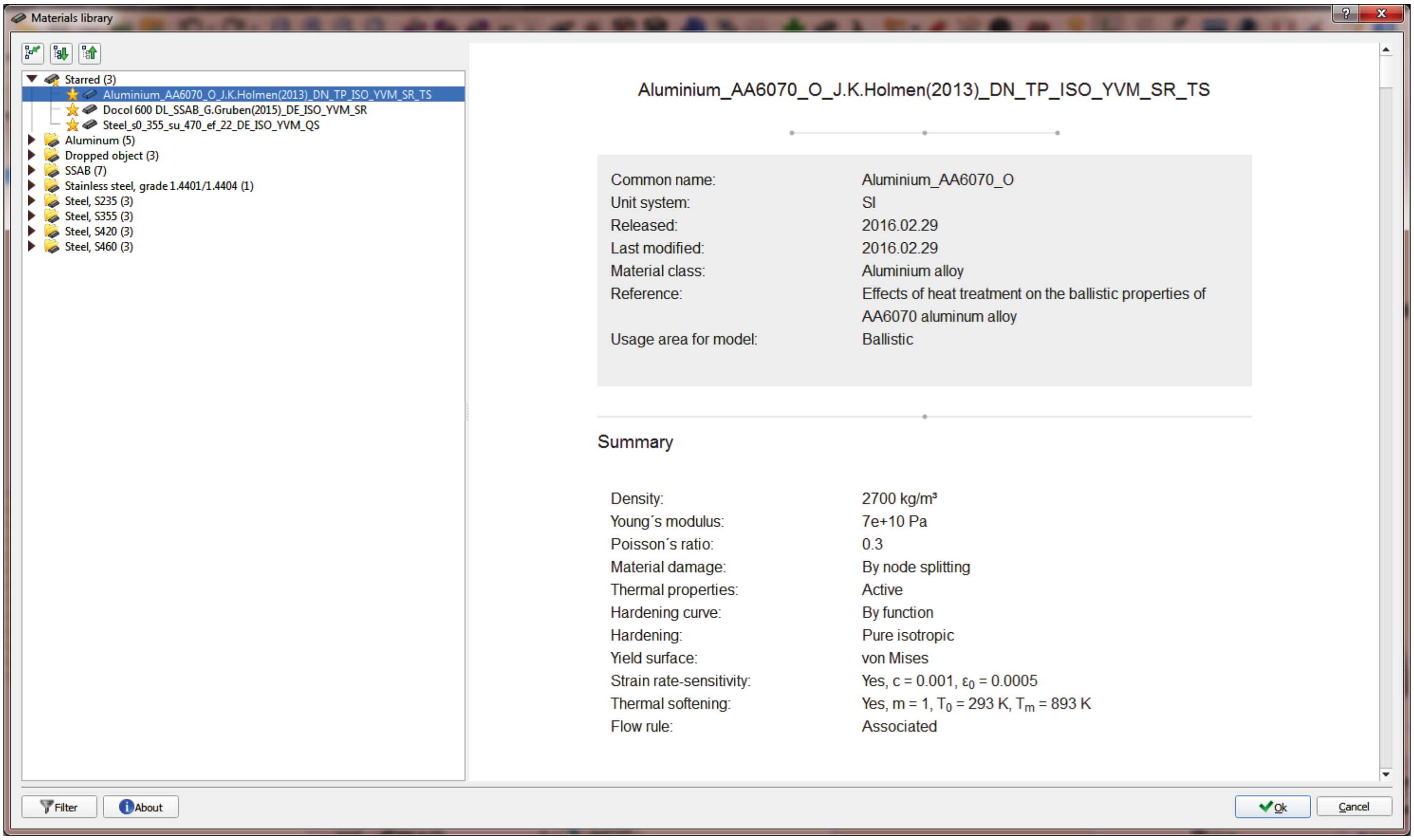
there are a couple of different ways to use the Material Library. One can click on the icon  for adding material from the library. Notice that in the lower left corner of the dialog box, the filter option 

allows one to filter to a specific search for a material, e.g. for the usage area, standards, etc. The about button 

lists the information about the current version of the Material Library.



The material that best represents the material is selected and OK is clicked. The material is added to the Object Tree to the left and automatically assigned a material ID, *mid*, which is one more than the highest *mid* in the current command file.



The material model can now be assigned to a part by using the Editor Mode. The command file can also be processed in a text editor or in any pre-processor that supports the IMPETUS Afea Solver® format. Notice that the name of the material is according to the reference used for the material parameters and that the applied material parameters are listed in the dialog box for the Material Library. For each material, there is:

Summary: Highlights the main features, e.g. type of yield surface, material damage option, etc.

General Description: Information about the testing used to determine the material parameters, and a general description of the use for the material model including limitations of the model.

Material Modeling: In this section are listed the equations and the command that is applied in the IMPETUS command file. All material parameters for the strength, damage and thermal equations are listed as well. They are listed in table form in order to easily identify what is used for the selected material.

Verification: Describes the numerical models used for verification of the material model and verifies that the material model is operating correctly.

Validation: The numerical results obtained with the applied material data and model is validated against experiments. It is done at a detailed level and references are given for the user to study the experimental work in more detail.

The large amount of documentation for each of the implemented material models helps the user to understand the material and the parameters as well as illustrates the confidence level at which the Material Library can be used. **However, it is the user's responsibility to verify that their simulation results are correct when using the provided material parameters.**

Another way to assign a material is to right click on a Part in the object tree, while still in Assemble Mode, and then either choose an existing material or select one from the Material Library. The procedure is as before but now the material is assigned to a part, the selected one. When the command file is saved, the material commands are written to the file. This is the case in both methods for creating the material.

```
*MAT_LIBRARY
"Aluminium_AA6070_O_J. K. Holmen (2013)_DN_TP_ISO_YVM_SR_TS", 3
```