

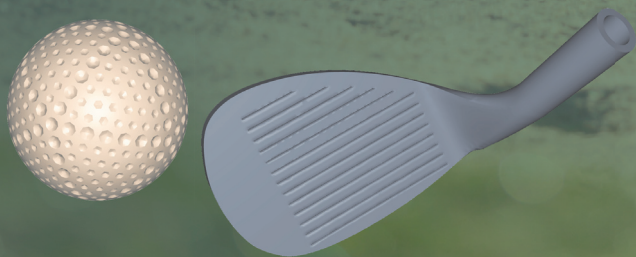
## The IMPETUS Afea Solver®

### Modeling Golf Equipment



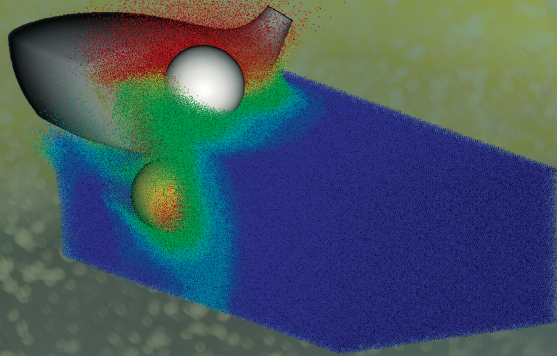
Golf is a very popular game worldwide but especially in the US where 24 million Americans played the game in 2016. Numerical simulation plays a huge role in research and development of new balls and clubs. The sport is characterized by highly non-linear time dependent impact with high deformation and large rotation which is well suited for Explicit Non-Linear Transient Finite Element solvers 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 tetrahedron 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. 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. Furthermore, it is very easy to make a three layered ball even with dimples using the tetrahedron elements.



There are very strict rules regarding the weight of the ball and it has been documented that using mesh smoothing of high order elements to better capture the curvature of the ball results in a much closer value to the real weight of the ball.





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. With IMPETUS the solution is simple because the Discrete Particle Method (iDPM) for modeling the soil is used 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. 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!

A common tool in the Golf industry is to visualize the results for a large number of impacts on the club head. This is done as 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”. This is just one of the tailored features for Golf club analysis that is available in the IMPETUS Afea Solver GUI.

#### Key Features and Benefits:

- Robust and fast contact for ball to club impact.
- Hyper-Elastic material with viscous effects for modeling the ball.
- Accurate high order elements using ASET™ Element Technology.
- Practical and useable high order tetrahedron elements for quick club turn around.
- iDPM for accurately modeling turf impact using discrete particles.
- Simple set-up of the iDPM models with automatic particle and contact generation.
- Built-in calibrated soil models for wet and dry soil for turf modeling.
- GPU Technology for computational efficiency leading to reduced runtimes.
- Tailored state-of-the-art post-processor for the Golf Industry.
- Intuitive GUI interface and Solver commands which are easily mastered.
- Overall productivity increase due to ease of use and smart technology.



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