OMNIS™ - Addressing today's and tomorrow's multiphysics simulation challenges

A focus on Automotive

The automotive industry has been using CFD tools in the design and optimization processes of all parts of the vehicle, from external aerodynamics to noise reduction to thermal management to internal combustion etc. Most often within the design process, all of the above are combined together in what is called a virtual prototype to allow optimizing the vehicle as a system.
The physics behind the various applications are however quite often very different, which translates into the need of having dedicated technology for each specific application. As a consequence the designers, scientists or engineers are often using a large number of various CAE codes and software tools with different interfaces (GUIs), data set-up, structures and formats, each of them focusing on their specific discipline, with no or poor connection between them. A more global approach to the whole CAE workflow for a multidisciplinary design and optimization loop has become an absolute necessity for these users.

This is where OMNIS™ comes in: an end-to-end CAE environment with dedicated tools to solve each step of the simulation process quickly and efficiently. OMNIS™ gives global approach to the whole CAE workflow from design to results analysis, driven by the user through an ultra slick user-interface, or controlled automatically with the Python API or even by the optimization module. Its unified user-interface reduces the user's learning process and its consistent datastructure avoids slow file conversion and annoying corruption errors. The unique OMNIS™ framework enables tools to communicate with each other within one workflow, while its multiple solvers give access to a broad range of technologies for solving any fluid/acoustic flow problem, with the added flexibility of being able to plug in in-house or opensource solvers and tools via the API.

This article shows how OMNIS™, with its breadth of CFD technology behind, solves the most complex fluid flow challenges for automotive design, while at the same time reducing engineering and solving time, in a fully streamlined easy-to-use collaborative workflow.

The example of Figure 1 illustrates various applications such as: underhood thermal management, external aerodynamics, power-train, acoustics and underhood components like turbochargers. The challenge? Very different physics, different departments involved and tough constraints on throughput time.
OMNIS™ responds ...

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FIGURE 1 : Automotive fluid flow application overview

Simulation preparation

Setting up a successful simulation starts with preparing the geometry model for the simulation. In addition to creating the design directly in OMNIS™, an external geometry can be imported by directly opening the most popular file formats such as ACIS, IGES, STEP, STL, Parasolid, CATIA, Pro/ENGINEER or SolidEdge.

In OMNIS™, the geometry is preserved throughout the simulation process, ensuring lossless transfer between the modules and consistency of the analysis. To ensure maximal reliability of the initial design, the OMNIS™ data structure points directly to the CAD data.

All material, physical and numerical properties are linked to the CAD model entities. Identical CAD naming and hierarchies will guarantee consistency of the simulation set-up and will minimize user input within automated workflows.

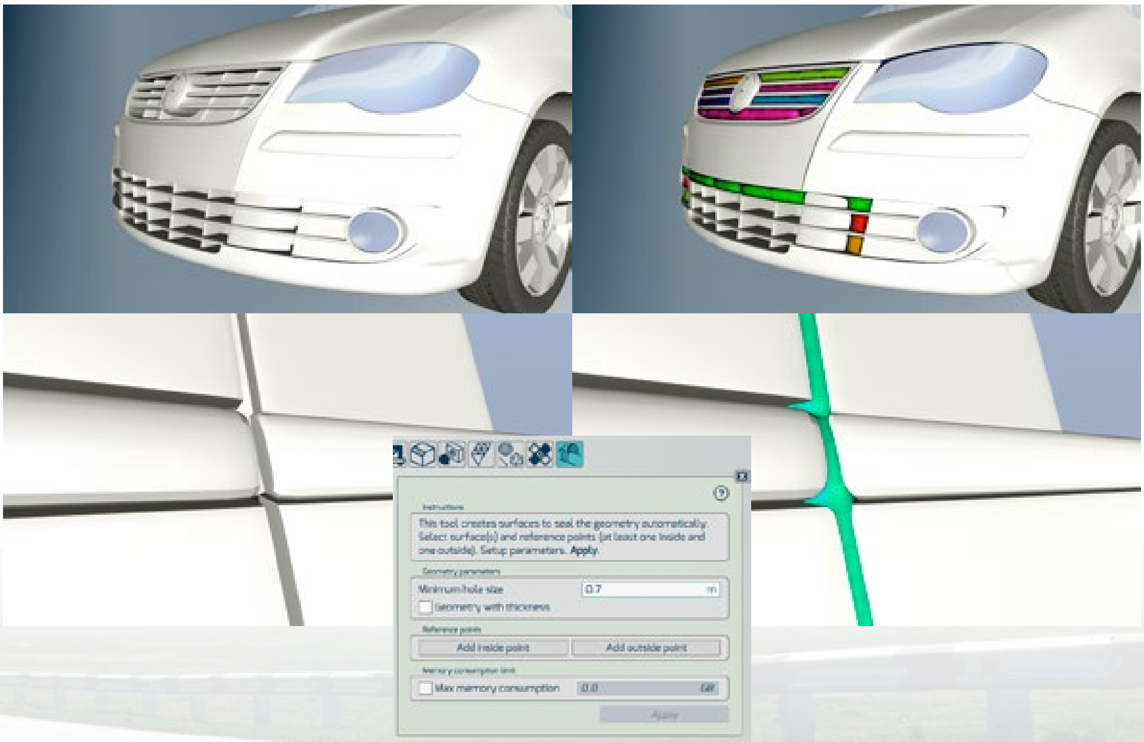
Production-level geometries can contain gaps, interferences, fasteners, and very small features. These features are often necessary for manufacturing, but add unnecessary complexity for simulation. Edit design tools become necessary to prepare the geometry for the simulation in the most automated way possible.

FIGURE 2 : Native bi-directional CAD import

In particular, one of the main time-consuming operations consists in closing the topological holes and gaps such as the gap between the car door and the passenger compartment, or the holes left after removing the screw bolts that join the two parts of the turbocharger volute. In this respect, the innovative AutoSeal outperforms all other standard edit and repair geometry tools.

Repairing a non-watertight non-conformal arbitrary geometry in one-click, cutting down the engineering time from days to a couple of hours, is now possible. Honda, for example, reported that a skilled engineer typically needed one full week to close all the holes of a cabin space before. Now this whole process has been brought down to just about one hour with AutoSeal.[1]

FIGURE 3 : AutoSeal gaps and hole closing for external aerodynamics



[1] For more details, check out the article "Honda demonstrates a major breakthrough in CAD preparation and meshing speed on page 6-9.

Pre-Processing

There is no single mesh generation technique available today - or seemingly in the foreseeable future - that answers all applications' requirements as they largely differ by size, shape, complexity and relevant physics. The solution necessarily comes from combining mesh generation techniques. The OMNIS™ mesh generation strategy is twofold: enhancing all mesh techniques to their best, and combining the most appropriate within the computational domain.

Unstructured mesh generation offers more flexibility to handle geometry complexity. When it comes to flexibility, OMNIS™/Hexpress users can choose between full hexahedral meshes with hanging nodes, or mixed element conformal meshes, "not-so-clean" geometry tolerant volume-to-surface approach, or surface-to-volume approach, inflation, deformation or extrusion boundary layers inflation techniques, and much more. Engineers at Honda for example, perform and analyze CFD aero-thermal computations of the underhood: radiator fans, flow around engine bay/peripherals, exhaust system, etc. Their pre-processing phase used to be time-consuming and cumbersome. When they switched to OMNIS™/Hexpress, they managed to divide their CPU time by 3 and their engineering time dropped to 30 mins/ mesh instead of weeks.[2]

FIGURE 4 : Hybrid Hex-dominant mesh of the full underbody incl. engine (top) and zoom of the cooling fans of a Honda CR-V (bottom)

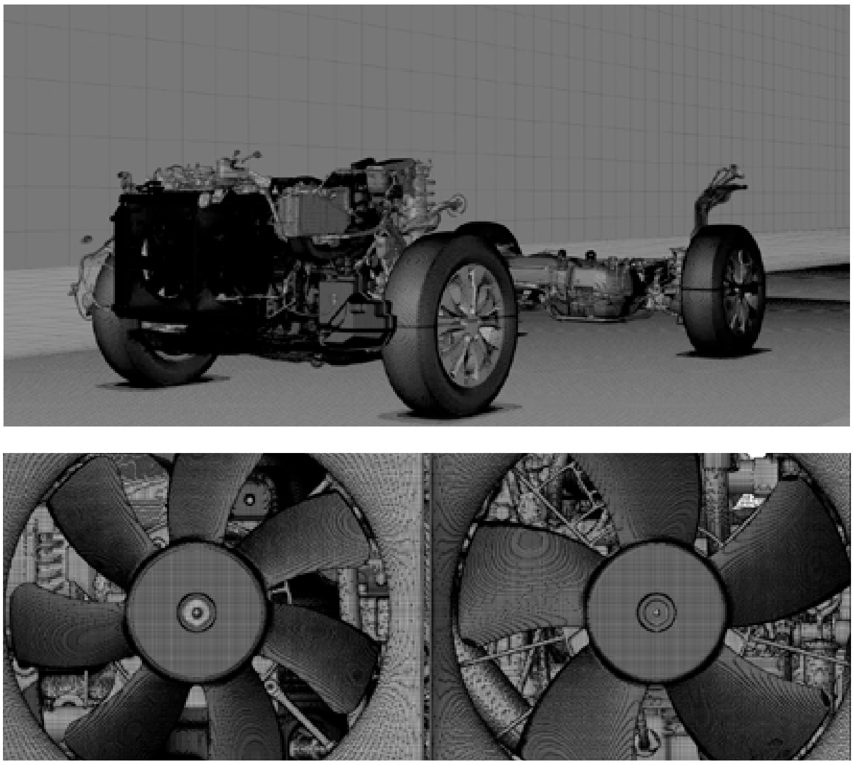
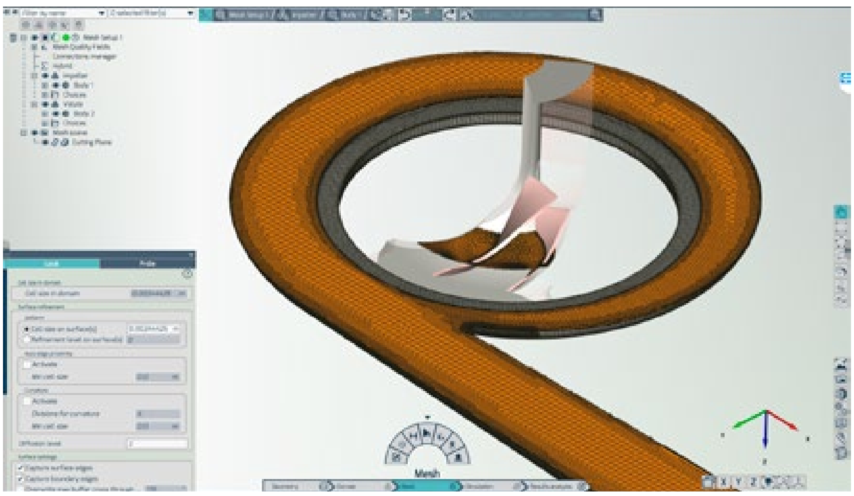


FIGURE 5 : Combined structured mesh impeller (AutoGrid5™) and unstructured mesh volute (HEXPRESS™) of a turbocharger



Fully automated multi-block structured mesh generation has been a goal for many years, because of superior mesh quality and reduced cell count. In that domain AutoGrid5™ is the undisputed worldwide reference in the Propulsion, Energy and Engine industries. Through its wizard-based application-dedicated workflow, it guides users with a few clicks to generate 100M+ high-quality cells in a few minutes for a broad range of turbomachinery applications.

2 For more details, check out the article Honda Automobile explains how they save CPU time with HEXPRESS™/Hybrid on the NUMECA website.

OMNIS™ combines high-quality structured meshes in the bladed part with a full hexahedral unstructured mesh in the volute allowing the flow solver to converge in typically 30 minutes to 2 hours per million nodes and per core (Figure 5). Ford testifies that with a dozen cores, the aero-analysis of a new design at 3-4 operating conditions can be done in 2 hours! An impressive result compared to standard commercial solvers that need an entire day for this.[3]

A breadth of solver technology

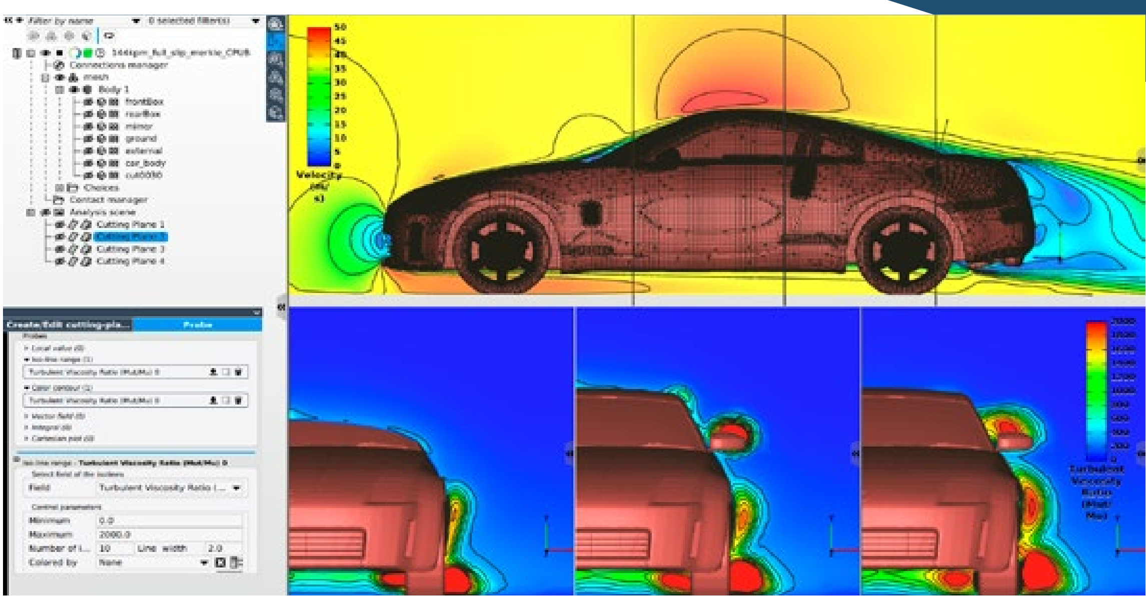
The use of multiple solvers to resolve complex engineering simulation tasks is current practice nowadays. Such an approach is extensively used for multiphysics simulations in which solvers designed for a particular physics are combined to analyze the influence and interaction of different physics phenomena on the global behavior of the geometry under analysis. From fluid-structure interaction simulations to aero-acoustics analysis and various complex flow physics such as multiphase and multispecies flows as well as the connections to an optimization framework. OMNIS™ offers a wide range of powerful solvers with FINE™/Turbo, FINE™/Open, OMNIS™/LB, FINE™/Marine, FINE™/Acoustics and FINE™/FSI-Oofelie, as well as a Python API to external and open-sources tools and solvers.

The main focus for car external aerodynamics for example is the accuracy in predicting drag and lift forces that measure the design performances. While these simulations are often heavy, the numerical algorithms must be efficient and validated, the simulation workflow must be robust and user-independent.

To achieve these objectives, OMNIS™/Open provides the automotive aerodynamics template with the best mesh, numerical and physical settings preset for maximum speed and robustness, and close-to-zero user intervention.

> "Engineers at Honda perform aero-thermal computations of the underhood. Their pre-processing phase used to be time-consuming and cumbersome. When they switched to OMNIS™/Hexpress, they managed to divide their CPU time by 3 and their engineering time dropped to 30min/mesh instead of weeks."

FIGURE 6 : OMNIS™ Automotive aerodynamics template, with results shown on a Nissan 370Z



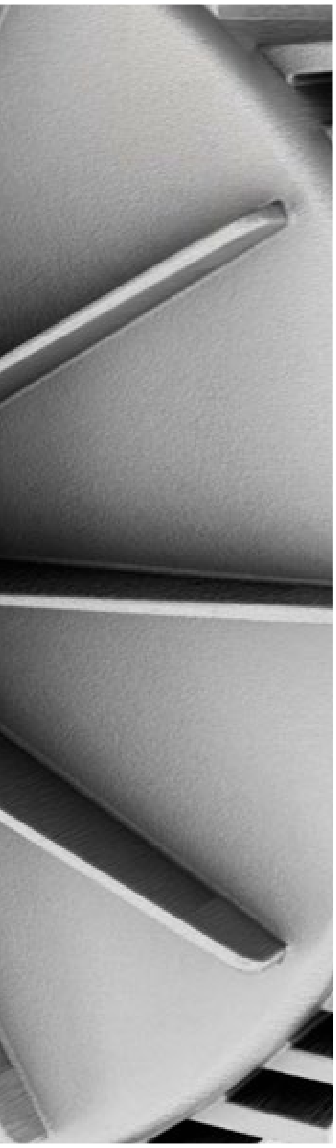
3 For more details, check out the article "Multidisciplinary Optimization of a FORD Turbocharger Compressor Design" on the NUMECA website.

FIGURE 7 : Electric Vehicle gearbox simulation performed with OMNIS™/LB

Rotating machinery peripherals such as the turbocharger or water pump can benefit significantly from the structured approach using FINE™/Turbo, as also put forward in the previous section, boasting significant speed and precision benefits versus other technologies on the market with a speed-up of 10x-20x! When using the power of HPC combining CPU's with GPU's, as shown in Figure 7, the speed advantage is increased even more. On a centrifugal compressor a further speed up of 3 to 5 can be obtained.

On the other hand the analysis of gearbox lubrication is out of the reach of conventional flow solvers, because of moving parts and body-to-body contact. OMNIS™/LB is capable of handling complex geometries on a mesoscopic scale without the burden of having to set-up and fine-tune a mesh. The solution provides an LES-level representation allowing to capture complex phenomena such as splashing, dripping, sloshing, etc.

And thanks to an open architecture, OMNIS™ also allows for in-house solver integration based on the powerful Solver Plugin API. The C/C++, Python or Fortran APIs provide all the building blocks, which are then put together to couple an external solver, giving it access to all the capabilities described above.

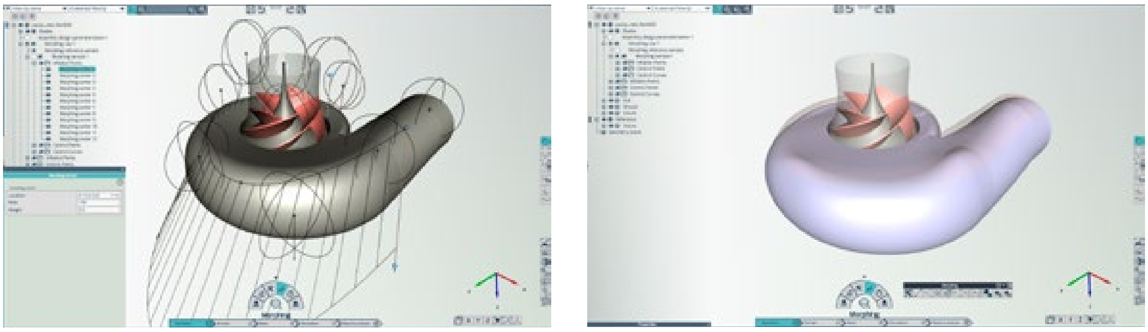


Design Exploration

Running a single scenario is often just the first step in the simulation process. In most cases, engineers want to study design alternatives and compare their results. OMNIS™ offers multiple options to vary the designs. They can be parametrically imported from the CAD system thanks to the OMNIS™ bidirectional CAD gateway, or generated with the OMNIS™ Agile parametric blade modeler for rotating machinery, or even deformed from the original geometry with the OMNIS™ morphing tool as shown in Figure 8.

Either way, OMNIS™ defines multi-design setups to automatically apply the same mesh and simulation process for each unique design variation, providing an automatic way to create, analyze, and update your designs.

FIGURE 8 : OMNIS™/Morphing of a turbocharger volute. Inflation points or Morphing curves driven (left) and Morphed geometry (right)



> "Ford declares that with a dozen cores the aero-analysis of a new design at 3-4 operating conditions can be done in 2 hours. An impressive result compared to standard commercial solvers that need an entire day for this."