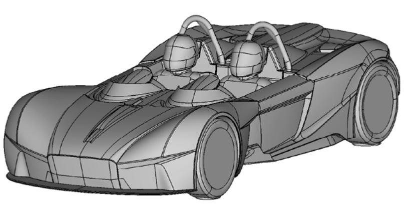
CASE STUDY: Imperial College London and ITI's CADfix Enable High-Order CFD Meshing for Elemental RP1 Racecar

"CADfix helped us simplify and prepare the CAD geometry to achieve the representation necessary and meet the required quality for CFD. The automatic features in CADfix made the job of cleaning up the geometry easier than it is with other systems."

- Dr. Joaquim Peiro,
Faculty of Engineering
Imperial College of London
Department of Aeronautics

"CADfix has a very clear purpose: to allow the clean-up of CAD geometry for downstream applications. For CAE engineers facing the challenge of translating and adapting general CAD definitions to something suitable for flow simulation, CADfix is the right tool to use."

- Michael Turner,
PhD Student
Imperial College of London
Department of Aeronautics



Elemental RP1 model geometry inside of CADfix, after processing

Overview

The Department of Aeronautics at Imperial College London conducts advanced research in fluid mechanics, aerospace materials, structures, and computational methods. Their work includes mesh generation and flow solutions for simulating complex geometries like aircraft structures and the Elemental RP1 racecar, a lightweight, street-legal track car producing over 500 bhp/ton and 500 kg of downforce at 150 mph.

The Elemental RP1 high-order CFD project, a collaboration between Imperial College and London Computational Solutions, Ltd., led by Mark Taylor, aimed to simulate complex flows around the racecar model using high-order meshing and CFD. The team, including Joaquim Peiro, David Moxey, and Michael Turner, sought to gain insights into flow physics to enhance the car's performance.

Challenges

Using their software NekMesh and supported by ITI's CADfix team for geometry handling and integration, the team successfully applied high-order CFD meshing to the entire car geometry model. This was a pioneering effort for a complete car geometry and one of the most complex high-order CFD simulations attempted.

Meshing involves dividing a domain into smaller elements that can be represented, stored, and manipulated by a computer program to model complex geometries and flows. The Imperial team's technology stands out due to its use of a high number of degrees of freedom within a single element, allowing for curved high-order elements and accurate representation of complex geometries and flows.

Solution

The NekMesh team, collaborating with Nektar++, a project led by Prof. Spencer Sherwin of Imperial College, developed a CFD analysis technique using high-order elements. Initially integrated with various geometry engines, the team faced challenges handling complex CAD geometry, leading them to adopt CADfix as the ideal solution for repairing and simplifying CAD models.

With ITI's assistance, the meshing system was reworked to use the CADfix geometry engine. This change enabled the generation of meshes directly from CADfix-prepared models, significantly increasing the complexity and number of CAD models they could manage.

The NekMesh team received CAD geometry from various industry systems. Detailed 3D CAD models, suitable for design and manufacturing, were often too complex for CFD analysis. The Elemental RP1's original CAD model consisted of around 2,500 surfaces, providing great detail but exceeding the limits for mesh generation tools and complicating geometry splitting.

Result

ITI's CADfix 3D CAD model translation, repair and simplification solution enabled the handling of geometry in a way that significantly reduced the amount of work and time required to simplify the model. Using CADfix, the team succeeded in repairing flaws in the geometry – such as gaps and overlaps that would not be acceptable for CFD – without deterioration of the representative analysis model.

"Typically, there is a quantum leap between the requirements of CAD geometry for visualization or manufacturing, versus requirements of CAD geometry for CFD. CADfix permitted the engineering team to pick up the supplied CAD files, repair defects in the geometry, clean the surfaces, and defeature the model to make it suitable for CFD," stated Michael Turner. "New techniques were used with CADfix to defeature surfaces more quickly than they could with a standard CAD system. Using CADfix, the 2,500 surfaces in the original CAD model were reduced by 40% to just 1,500. Using CADfix over more conventional CAD tools cut the amount of effort required from days to hours."

In addition to using the CADfix interactive product to handle the CAD model geometry for CFD analysis, the Imperial team also took advantage of the powerful functionality of the CADfix geometry engine and its extensive application programming interface (API).

The NekMesh high-order mesher needs to operate on a geometric model to apply discretization algorithms and generate the required high-order mesh for CFD simulation. Having experienced problems when attempting to integrate the mesher with one particular CAD library, the NekMesh team discovered that CADfix also had a very capable geometry engine with a fully functional API. A direct integration between the CADfix geometry engine and the meshing systems utilized by the Imperial team was rapidly developed. Access to the ITI CADfix developers, with their expertise and willingness to support the Imperial team, was highly beneficial and led to a very successful collaboration. Whereas alternative CAD API libraries can be complex in their approach, the CADfix API facilitates the necessary level of interaction in a simple and clean way.

The collaboration with ITI resulted in a robust cutting-edge high-order mesh generator capable of working with real world CAD geometry. "By using a higher degree of approximation we attained a more accurate representation of the flow, more efficiently, and at a lower cost," stated Dr. Peiro.

The NekMesh team at Imperial has worked with other organizations on related activities and sees an increased interest in this high-order methodology. As Dr. Peiro concludes, "The collaboration with ITI shows that it is feasible to set a marker for what can be achieved if the right elements of CAD, mesh generation, and flow solutions fit together strategically. I envision that over time this new technique that applies capabilities of CADfix and high-order elements could help break some of the bottlenecks that exist within traditional aerospace or automotive companies who aim to achieve efficient CFD. In the longer term, I believe this technique will become routine in industrial settings."