FocalPoint The Newsletter for Gridgen® Users

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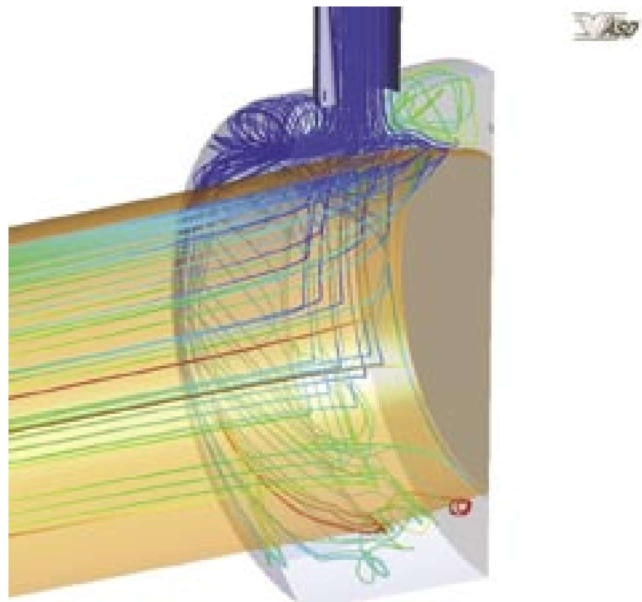
# CFD and FEM for Medical Applications Using Gridgen Meshes

Article by S. Kühne and A. Geltmeier, ASD Advanced Simulation & Design GmbH Rostock, Germany

ASD Advanced Simulation & Design GmbH provides expert numerical simulation services in the field of medical technology by assisting manufacturers in product development and design processes. Both flow simulations and structural mechanical analyses are performed using several commercial simulation software packages. For these often very different applications, ASD uses Gridgen as the favored mesh generator because of its ability to create structured, unstructured and hybrid meshes and its interfacing to many software packages.

Simulations are performed over a wide range of very different applications including dental, orthopedic and traumatologic implants, blood pumps, oxygenators and dialyzers. Specific expertise is provided with modelling non-Newtonian blood behavior, including clotting, and mechanical damage processes or the highly non-linear and anisotropic mechanical properties of living bone and tissue by translating related models into CFD and FEM software.

As an example, ASD developed a virtual dialyzer. With a virtual dialyzer, not only can the blood and dialysate flow behavior be investigated, but also the convective and diffusive mass transfer across the membrane. In general, a dialyzer consists of a fibers bundle with up to 10,000 fibers with an outer diameter of about 0.38 mm and a fiber length of 200 mm. The large amount of fibers and the small dimension of a single fiber compared to the size of the dialyzer housing makes it impossible to simulate simultaneously both the mass transfer across the membrane and the global flow in only one geometrical model. Therefore, the virtual dialyzer model consists of a global and a local model.



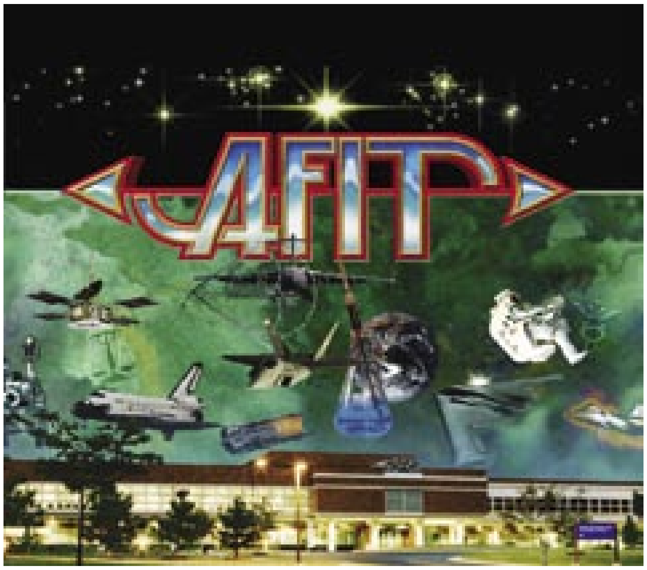
Streak lines of the dialysate inflow into the fiber bundle (the orange cylinder represents the fiber bundle).

In the global model, the fiber bundle is assumed as a porous object considering the anisotropy of the radial and axial permeability factors. From the resulting global velocity and pressure distributions, the boundary conditions for the local model are generated. This local model contains a representative segment of the entire fiber bundle geometrically resolving the membrane and the intra- and extraluminal space. Using this model, the mass transfer across the membrane can be predicted by considering the diffusive and convective transport of different substances solved in the blood. The virtual dialyzer was validated with experimental data and was successfully applied to the design. For manufacturers this offers the chance for assessing and optimizing existing designs or designing new devices very fast and cost-effectively. ■

## INSIDE THIS ISSUE

# CFD Grid Generation at the Air Force Institute of Technology

Article Courtesy of Lt. Col. Raymond Maple, Department of Aeronautics and Astronautics, Air Force Institute of Technology




The US Air Force relies heavily on a highly educated officer and enlisted force to maintain its technical superiority. The mission of the Air Force Institute of Technology (AFIT), located at Wright Patterson AFB, OH, is to ensure that this force is on hand when needed. The AFIT Graduate School of Engineering and Management awards approximately 450 Master's and 25 PhD degrees each year in many diverse areas, including aeronautical engineering. In recent years, computational fluid dynamics (CFD) has been a steadily growing part of the aero engineering program, with an increasing number of students choosing to study CFD in depth or apply it as a tool in their thesis research.

The CFD curriculum at AFIT consists of four classes. Three of these classes form a "traditional" tightly integrated sequence that begins with the mathematical foundations of CFD and culminates in the writing and application of a 2-D viscous code. The fourth class was recently added to fulfill a need for a more applications-focused presentation. Basic theory and implementation are covered at a high level, but the emphasis is on the application of CFD as a process and a tool used to solve real-world problems. Not surprisingly, a large portion of the syllabus is devoted to grid generation.

Lectures covering the theory and application of grid generation techniques are supported by grid generation lab assignments that provide the students with a "hands-on" understanding of the subject. In these labs, students are encouraged to experiment with different approaches and discover what works and what doesn't. Though students have access to a number of commercial, government, and academic grid generation tools for these labs, Gridgen is used almost exclusively. The build-up approach to grid generation employed by Gridgen closely parallels the classroom discussion, from geometry definition and domain decomposition to node distribution and surface/volume meshing. Gridgen allows the students to learn fundamentals that can then be applied with any grid generation tool.

For thesis research, students are encouraged to investigate the capabilities of all the available grid generation tools and choose the one that best fits their needs. Many students choose to use Gridgen for their thesis research. Two examples of grids generated by students are described below. In his research, the student looked at computed combustion product densities for several different geometries. This required him to generate the geometries in a solid modeling tool, import IGES files, and generate the grids, taking particular care to preserve rotational symmetry.

In the second example, the student needed to model a micro air vehicle (MAV) in a wind tunnel at multiple angles-of-attack. The presence of the tunnel walls required that the MAV geometry be physically rotated and the volume mesh rebuilt for each angle of attack. Using the Glyph scripting language included in Gridgen, the student was able to automate this process and quickly generate the required volume meshes for a variety of different MAV surface mesh densities.

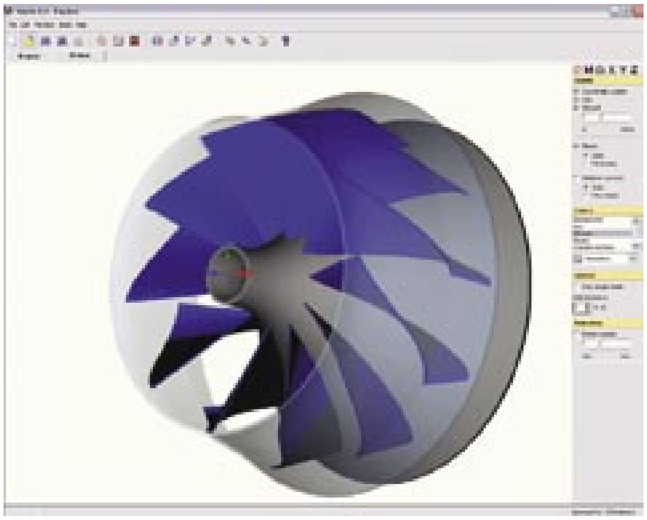
As the CFD program at AFIT has grown and evolved, the need for powerful grid generation tools has increased, both in and out of the classroom. Gridgen has proven to be a powerful tool for educational grid generation.

*The views expressed in this article are those of the author and do not reflect the official policy or position of the United States Air Force, the Department of Defense, or the U.S. Government.* ■

**Interested in our Gridgen Teaching Partnership?**

Recognized academic institutions already having at least two Gridgen academic licenses, can add ten additional licenses for the duration of a class at no additional charge. For more information about our teaching licenses, please contact Heather McCoy at hlmccoy@pointwise.com.

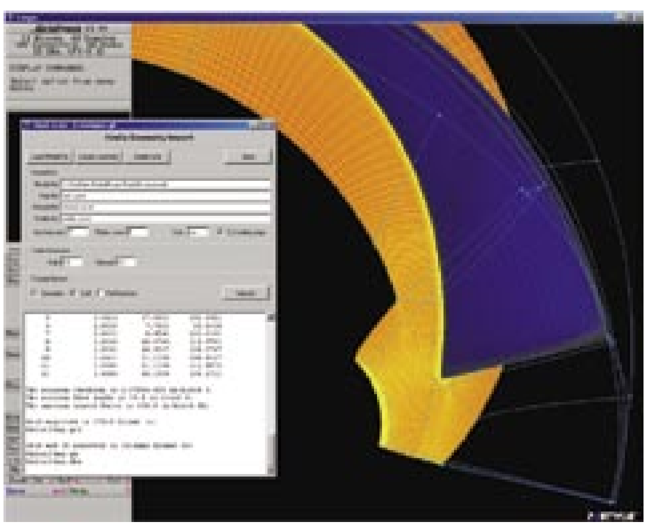
# Design and Analyze Pumps with Kreila and Gridgen



Pump designed in Kreila.

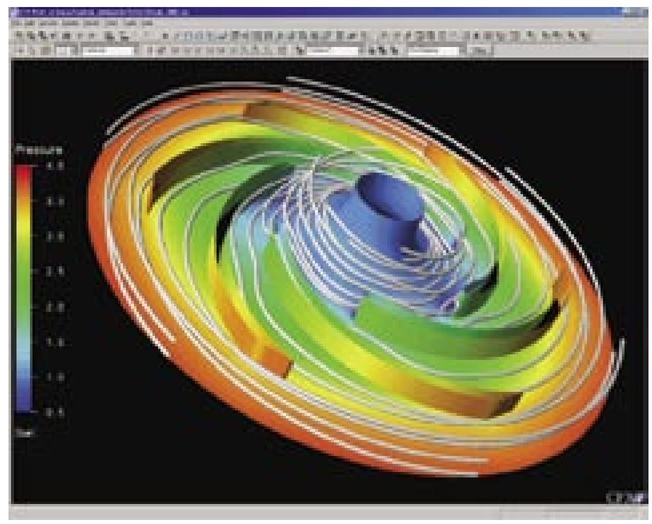
Pointwise and CFDnetwork Engineering have recently collaborated to develop a system for designing and analyzing pumps. The system, based on CFDnetwork's Kreila pump design software and Pointwise's Gridgen, automates the process of designing pumps and preparing them for CFD performance analysis.

Kreila is powerful, yet easy to use, pump design software that can be used to design pumps from scratch or to redesign existing impellers. The engineer tells it the desired flow rate, head, RPM, and any (optional) pre-swirl, and Kreila automatically generates a pump design. Users can accept the automatic design or can go back and change details of the design with Kreila's guidance. This easy, but flexible, approach to pump design saves time and still lets engineers get exactly the pump they want.



CFD model prepared in Gridgen.

Gridgen's custom Kreila interface reads Kreila geometry files directly and automatically grids them with a hexahedral mesh. Once the pump design is complete in Kreila, a high-quality grid is built and made ready for CFD analysis with the simple push of a button. Gridgen exports the grid in the native format of many CFD solvers, including Fluent, STAR-CD and CFX. Gridgen provides the flexibility to add more portions of the flowpath if desired.

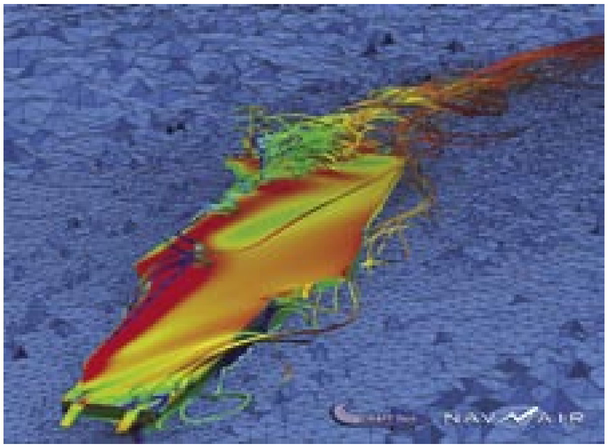


CFD solution from CFX.

The Kreila-Gridgen system was tested at Technical University Dresden for a sample pump design and analysis. They found the system to be more reliable than previously used grid generation systems due to the higher quality grids produced by Gridgen, the flexibility Gridgen gave to make modifications to the grid if the analyst felt they were necessary, and the ability of Gridgen to smoothly vary the grid distribution to put grid points where they were needed.

Contact Pointwise if you would like more information about the new Kreila interface. ■

**Partner Highlight**



CVN airwake flow solution courtesy of CRAFT Tech and NAVAIR. CFD grid generated with Gridgen from Pointwise, Inc.

## CRAFT Tech

If you have seen this image of an aircraft carrier (CVN) airwake on Pointwise's marketing collateral and are wondering where it came from, our friends at Combustion Research and Flow Technology (CRAFT Tech) produced this grid using Gridgen.

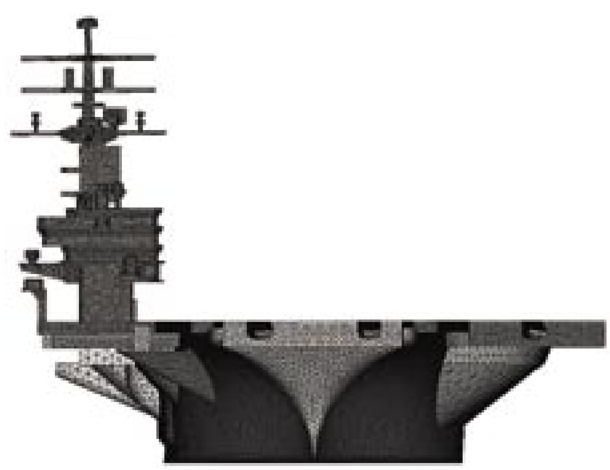
CRAFT Tech's specialty is the high-fidelity computational simulation of complex fluid dynamic and combustive problems on large-scale, parallel architecture computers. Technology sectors supported by CRAFT Tech include missiles, aircraft/rotorcraft, propulsion/turbomachinery, weapon systems and effects, and industrial problems. They also perform fundamental research in CFD, grid adaptation, aeroacoustics, turbulence, combustion and multi-phase flow.

Jeremy Shipman of CRAFT Tech says, "We have been using Gridgen for many years now in conjunction with our CRUNCH CFD multi-element flow solver in analyses that involve both complex geometry and the need for a high fidelity mesh. Gridgen allows the flexibility to generate grids comprising of tetrahedral, hexahedral, and prism elements providing a cell topology that can be tailored to both the geometric complexities and the physics of the flow."

CRAFT Tech built the CVN grids in order to study sensitivity of CFD simulations of the ship's airwake flowfield to the geometric complexity and boundary layer resolution used. The airwake is important because aircraft approaching the carrier for landing pass through the wake. Large-scale turbulence in the airwake affects the landing aircraft and makes it more difficult to successfully approach the ship. For safety's sake these effects must be studied for many different wind over deck conditions for each ship-aircraft combination the Navy plans to use. If the airwake can be modeled with sufficient fidelity using CFD, the results could be incorporated into a flight simulator, in which a pilot actually flies an aircraft through the fluctuating numerical airwake to determine the wind-over-deck performance envelope of the aircraft and ship, without risking danger to the pilot.

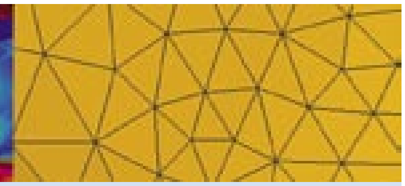
To construct the CVN grids in the project CRAFT Tech made heavy use of some of the newer features in Gridgen, such as automatic domain creation with the node/connector merge functions (very complex geometry in the IGES format with all the issues that come along with that), and baffle domains to control tetrahedral volume resolution for wake type flows.

CRAFT Tech was able to determine that the majority of the flow was dominated by bluff body shedding. High fidelity boundary layer resolution only affects the flow in the near deck region and immediately downstream of the ship's mast structures. Thus, lower boundary layer resolution could be used, saving time and money, without loss of too much accuracy in the simulations. As part of the on-going project, funded by an SBIR contract through the Naval Air Systems Command (NAVAIR), CRAFT Tech generated a high-fidelity unsteady solution of the CVN airwake that the Navy has incorporated into the Manned Flight Simulator at the Patuxent River NAWC. NAVAIR provided CRAFT Tech with the geometry of the CVN. ■



Triangular suface mesh on an aircraft carrier was used for airwake studies.

## Gridgen Product News



Gridgen Version 15.07, the latest production release, has a couple of brand new geometry modeling capabilities that let Gridgen do more for all of your engineering analyses. The ability to create trimmed surfaces and add or remove edges from trimmed surfaces has been added. The trimming that is sometimes lost during CAD file import can now be recovered easily by simply re-trimming the surface. Trimmed surface creation uses an algorithm similar to the one used in Coons surface creation so that you have a great deal of flexibility in trimming. Those of you creating geometry models directly inside Gridgen will now be able to create more complex and realistic models using trimmed surfaces. The ability to project database curves onto database surfaces was added to support trimmed surface creation.

IGES file export lets you import geometry into Gridgen from a variety of sources (Native CAD Files, IGES, STEP, geometry created in Gridgen), clean it up (delete, disable, name, and layer), and write a new IGES file. Obviously, this IGES file can be used not just in Gridgen, but in all your CAE software that requires an analysis-ready model. Gridgen can also export structured (quad) surface grids to an IGES file so that if you've been changing the grid's shape to optimize your analysis, you can send the grid back to the designers as the new geometry.

A Native CAD Reader for CATIA V5 is now available, adding to the NCR suite that includes STEP, Pro/E, UG, and CATIA V4.

Since the last issue of Focal Point, we also released Gridgen Version 15.06. That release featured support for Mac OS X. In only a couple of months of production use, it has already become the 4th most popular Gridgen platform. The other new features in V15.06 relate to grid extrusion: the ability to simultaneously extrude hexes and prisms and an extrusion boundary condition that matches an existing grid.

Work on the next two Gridgen releases is well underway. For structured grid fans, a multi-grid algorithm is being added to the elliptic PDE solver for both surface and volume grids to accelerate convergence for large grids. And more geometry modeling work is being done in the area of solid modeling – importing, assembling, and meshing solid geometry. Imagine being able to work with a wing as a single, contiguous entity, rather than a collection of hundreds of surfaces.

Don't hesitate to send your suggestions for new features to gridgen@pointwise.com.

## Meet Our Newest Employees...

John Deur joins Pointwise as Manager of Customer Support. John oversees direct customer support, Gridgen training, quality assurance, and consulting. John has decades of CFD and grid generation experience including serving as a supervisor for NYMA, Inc. at NASA Lewis Research Center and Manager of Combustion Technology at CD-adapco. Most recently, John was Columbian Chemical's Combustion Scientist in Marietta, Georgia.

Scott Powers joins the company as a programmer in our Gridgen Development Team. Prior to joining Pointwise, Scott was the technical and website lead at Concept Keys in Fort Worth. He was in charge of GUI development at Raindrop Geomagic in Research Triangle Park, North Carolina for 5 years before that. He also has 3 years of experience at the National Center for Supercomputing Applications in Champaign, IL where he worked on X/Mosaic and HTTPd. ■

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FocalPoint is a publication of Pointwise, Inc. It is for Gridgen users and people interested in learning more about Gridgen and numerical grid generation. It includes information about the latest release of Gridgen, future development plans, and tips on how to get the most out of Gridgen while saving time in grid generation. 

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## Calling All Gridgen Experts

Are you a Gridgen Expert? Well then it is time for you to show us your stuff. Log on to our support page at www.pointwise.com/support and enter your answers to Gridgen Quiz #1. If you send in your answers before August 15, 2005 and get all the answers correct, we will send you a prize.

### Gridgen Quiz #1

1. What is the main difference between Hilgenstock-White and Steger-Sorenson foreground control functions?

2. An engineer is running the elliptic solver with default settings on a database constrained structured domain. Several grid points keep oscillating with a pretty significant amplitude on each iteration. What is the first thing she should do to try to correct this?

3. Which of the following will cause a connector's distribution function to turn into type General?
   a. Projection
   b. Translating a database constrained connector
   c. Translating a non-database constrained connector
   d. Splitting
   e. Scaling
   f. Using it as floating boundary in the elliptic solver
   g. Using –3 as the constraint value in the Set Δ command

4. What is wrong with the following script? Correct it.

```
set npts 35
set pt1 0 0 0
set pt2 3 3 3
gg::conBegin
  gg::segBegin -type 3D_LINE
    gg::segAddControlPt $pt1
    gg::segAddControlPt $pt2
  gg::segEnd
set thisCon [gg::conEnd]
gg::conDim $thisCon $npts
```

The answers to these questions will be available on our support page after August 15. ■