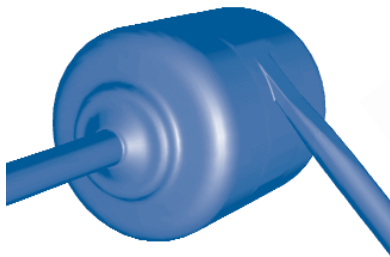
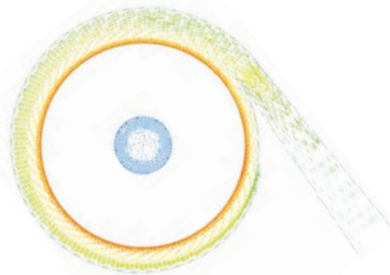


# Virtual Prototyping System for Blood Pump Design

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The blood pump housing, showing the inlet at left and outlet at right



Cross-section of the pump in the outlet plane, showing velocity vectors

Since the late 1990s, ABI (Advanced Bionics, Inc.) has used Fluent software on a regular basis in the development of proprietary bearing- and seal-free rotary pump technology. Blood pumps for medical applications are a major part of ABI's business. The traditional theory of centrifugal pumps, used for over 100 years, does not apply directly to small blood pumps with flow rates between 0.3 – 1.5 gal/min and differential pressures of 1.0 – 6.0 psi. To complicate the matter, small blood pumps use variable speed drives, and have unique optimization criteria. In addition to traditional pump characteristics, such as flow rate, pressure, and efficiency, blood-handling characteristics such as hemolysis and thrombosis are important for blood pumps. Hemolysis is the destruction of red blood cells and is correlated to shear stress and residence time. Thrombosis is clot formation, and is correlated to wall shear stress. Thus, operation of an optimum blood pump should not lead to too much shear stress (to have low hemolysis), and should simultaneously maintain a certain level of wall shear stress (to prevent thrombosis). ABI has developed an expertise in analyzing blood pump performance, and has used this capability as a virtual prototyping design tool with a number of variables representing the pump dimensions. A number of actual blood pump tests

have shown that the computational and experimental results are very closely correlated.

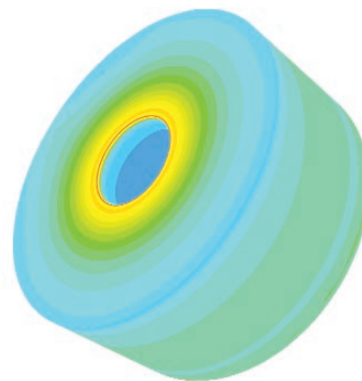
To perform an accurate analysis, the whole pump, and often a substantial portion of the outlet region, needs to be meshed. GAMBIT is used to build 3D grids with sliding, often non-conformal interfaces around the rotor region. This kind of flexibility allows accurate meshing for the blades, which have complex geometry. A typical mesh size for the calculations is about 300,000 cells. Journal files for GAMBIT provide an opportunity to make small changes in the geometry and automatically rebuild the computational grid. This means that the mesh generation time for each design change is significantly reduced. This parametric approach allows fast virtual prototyping of many variants from the predetermined matrix of geometric parameters.

The parametric approach is also applied in FLUENT, where journal files are used during the solution stage and for postprocessing. The performance of each variant is tested at different operating conditions. Journal files allow automatic preparation of the case and data file for each regime from a prescribed set of rotation speed and flow rate boundary conditions. For solutions in the turbulent regime, the standard k-ε turbulence model is used. FLUENT's enhanced wall-func-

tions allow accurate prediction of near-wall regions without a significant increase in the mesh size. For unsteady calculations, the "frozen rotor" solution, computed from the multiple reference frames (MRF) model, is used as an initial condition.

Postprocessing of the CFD results includes a quantitative assessment of the pump design performance through predictions of pressure rise in the pump, rotor torque, forces, and stresses. Vector plots provide detailed pictures of the flow patterns, and contour plots show the locations of regions where the maximum potential blood damage would most likely occur. Journal files are used during postprocessing to prepare comprehensive reports on the computational results.

If desired, special procedures are written using Scheme files, which can be read by FLUENT. These procedures allow for complex cyclical operations during solver execution and postprocessing that expand the capabilities of the code. Only after the optimal virtual design has been identified is the actual prototype built. The highly efficient virtual prototyping system that has been developed at ABI has significantly reduced design time and development costs. ■



Contours of the wall shear stress on the rotor wall of a Tesla-type pump; half of the pump rotor is shown