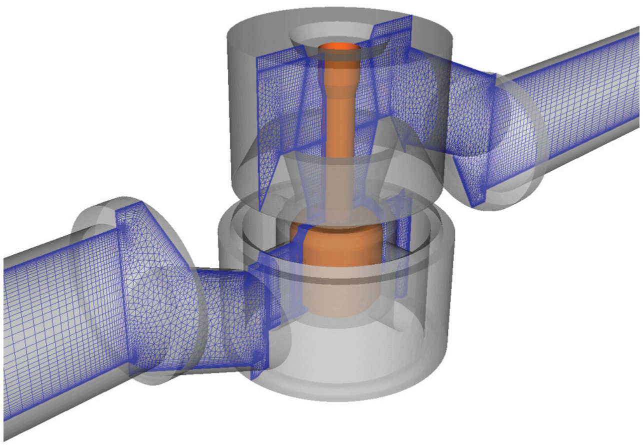
Gridgen Hybrid Meshes for High Fidelity, Efficient Simulations



Pressure regulator valve geometry with the hybrid grid (shown along the symmetry plane) used to mesh the valve flowpath.

Researchers at Combustion Research and Flow Technology, Inc. (CRAFT Tech) have been using Gridgen in conjunction with the multi-element unstructured flow solver CRUNCH CFD® in studies of flowfields that involve both complex geometries and physics. For such cases, a purely structured or purely unstructured approach can be insufficient to satisfy both the complexity of the geometry and the high fidelity required to resolve local physics in an efficient manner. By using a multi-element approach, an optimal combination of structured and unstructured blocks can suit both the geometrical and physical characteristics of the system.

This strategy has proven to work very efficiently for simulations of a variety of systems, including aircraft/aero-propulsive simulations and turbomachinery/fluid handling systems such as pumps, compressors, and valves. In this article, the multi-element approach is demonstrated for a pressure-regulating valve found in the feed systems of liquid rocket test stands at NASA Stennis Space Center. As shown in the figure, this valve has a very complex flowpath that consists of complicated pipe junctions and multiple channels feeding a chamber that contains a variable area poppet with tight clearances in the valve seat region. Traditional structured grids are very difficult to generate for such a complex geometry, which for a purely hexahedral grid forces an awkward block topology with highly skewed and irregular cells. For a contiguous multi-block structured grid, severe constraints on grid resolution are placed on critical regions of the flow domain such as the seat region of the valve where the flow sharply accelerates. Conversely, a grid comprising only tetrahedral and prism elements is cumbersome to build because of difficulties with prism extrusion in the concave corners and tight clearances associated with certain regions of the geometry. These shortcomings are overcome in the multi-element approach wherein high quality grids are efficiently generated in all regions of the valve geometry.

A cross-section of the multi-element grid is depicted in the picture. In the axisymmetric portions of the geometry, namely the seat region and the areas around the poppet, hexahedral blocks are created by rotationally extruding structured domains around the valve body axis. The high aspect ratio hexahedral cells are ideally suited for resolving the high pressure and velocity gradients near the valve seat and enabling boundary layer clustering on the enclosed walls that exist on all sides of the domain. The remaining portions of the valve body comprise non-axisymmetric regions with complex pipe junctions and ports. Prism layers are extruded from triangular surface grids in these areas to resolve the boundary layers associated with these complex-shaped surfaces. Straight sections of the geometry such as the inlet/discharge ducts and the four ports channeling flow into the valve body are meshed with high aspect ratio hexahedral cells along the walls and a core of prisms through the center. The remaining portions of the volume are then filled with tetrahedral cells that connect the disparate topologies in different regions of the valve.

Both steady and unsteady CFD simulations were performed using CRUNCH CFD® with the aim of investigating the chatter-like behavior obsessed when the valve is operating. The hybrid grid topology allowed this to be done in an efficient manner.

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213 South Jennings Avenue Fort Worth, Texas 76104-1107 Toll-free 888-GRIDGEN
Tel (817) 377-2807 Fax (817) 377-2799 gridgen@pointwise.com www.pointwise.com

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