Some Recent Developments and Applications Related to Overset Mesh Aspects of CFD++

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Abstract

CFD++ has many useful attributes that are helpful in simulating steady and unsteady flows over complex geometries including bodies in relative motion using the overset mesh approach. CFD++ is based on an internal unstructured book-keeping method that is very flexible and can permit the use of many cell types (hexahedral, tetrahedral, triangular prisms and pyramids in 3D) within the same grid. Grids that are assimilated into CFD++ can be both structured or unstructured. CFD++ also allows for multiple blocks of grids, e.g. multiple unstructured grids. In situations with relative motion between two geometries, such an approach allows the use of unstructured overlapping grids as well as patched grids.

CFD++ uses an integrated approach in dealing with overset meshes. The cutting/blanking operations and the interpolation operations are all performed within CFD++ and can be performed every time step for transient simulations. The movement of grids can be connected to the rigid body motion of one or more bodies. CFD++ includes an integrated rigid body dynamics (RBD) capability with a six-degree-of-freedom (6DOF) module. Forces and moments are computed about the center of gravity (or a given constrained center of rotation) and Quaternions are used to update the angular orientation and angular velocities and the linear position and velocity are simultaneously updated as well using the 6DOF module.

In order to perform the cutting/blanking operations, CFD++ employs the following procedure. First, the cutter boundary families (boundary faces which do the cutting) are specified by the user. The intersection between these cutter facets and (nonattached) cells defines the set of cut cells. The concept of flow region of interest is established by identifying one or more boundaries defining boundary sets from which adjacent cells are in the "live" region of interest. From such "live" boundaries, adjacent cells, and their adjacent neighbors, and then their neighbors, and so on, are marked as live cells until cut cells are encountered. This marking process is stopped at the cut cells. If the cut cells completely enclose a set of cells, such cells are not reachable through the adjacency process from live boundaries and therefore not marked as live. Such non-live cells are marked as orphan or "void" cells and marked as cells on which the solution need not be

updated. There is an option to include the cut cells in either the live set of cells or the void set of cells. Typically, the cut cells are excluded from the live set when the cutting is done by body boundaries. The cut cells are included in the live set when the cutting is done by outer boundaries of one grid or the other, in order to permit a small overlap between two grids. Multiple overlaps (between more than two grids) can exist and cause no trouble. At the boundary between live and void cells, new zonal interfaces (new "zonal" boundary conditions) are defined. At these boundaries, the simulation process automatically utilizes an interpolation of the solution on all the proximal live cells from all grids in the vicinity. Since CFD++ uses a multidimensional least-squares approach everywhere, the treatment of the new zonal boundary families is really no different that what is done elsewhere in the grid. It is just that the collection of cells used in the least-squares interpolation process includes topological neighbors in most of the grid, but includes "proximal" neighbors at zonal boundaries.

When bodies have relative motion, grids attached to those bodies are permitted to move with their bodies. When grids are allowed to move, the cutting and voiding process is performed every time step. Once void cells may reappear as live in a new time step. The solution in such nascent cells is initialized from the set of previously live cells in the vicinity.

CFD++ has many advanced features related to overset meshes. Three of them are: a) sequential cutting (where the cutting and blanking processes can be organized as an ordered set of operations); b) “super-sequential” cutting to reduce overlapped cell count to a minimum; c) perfect flux balance using “flux-stitching”. Furthermore, the overset mesh capabilities in CFD++ apply to all the solution modes available in CFD++ for compressible gases and liquids, incompressible fluids, density based and pressure based approaches, etc.

The overset mesh capabilities of CFD++ have been used in the following application areas: stage separation, store separation, canopy separation, sabot separation, silo flyout, thrust vector control, shroud release, helicopter rotors, turbomachinery, valve movement, ball valve movement, parametric studies using substituted components, etc. The applicable techniques will be illustrated in the presentation using generic examples.