Meshing

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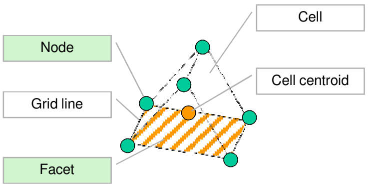
Mesh elements



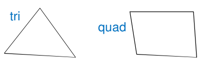
Mesh file contains:
-Node positions;
-Faces: references to corner nodes.

Field variables are stored in cell centers in FLUENT system;
Grid lines are straight sections.

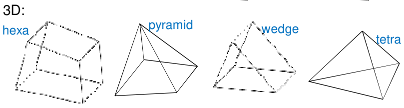
Symmetry options:
- 2D axisymmetric,
- 2D axisymmetric with swirl,
- 2D slab symmetric,
- 3D.

Regular elements:

in 2D:



in 3D:

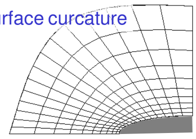


Polyhedral elements:
can be created in FLUENT by:
- adapting;
- creating a dual mesh;
- applying non/conformal interfaces.

Mesh sizing (1)

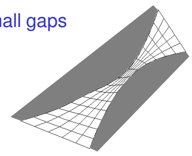
Extreme local values of the numerical errors should be avoided, therefore the mesh must be refined in the area of large gradients.

Surface curcature



If the flow follows the surface curvature, pressure and velocity rapidly changes towards the centre of the osculating circuit.

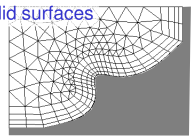
Small gaps



At least 4 layers of cells are necessary in small gaps for the proper resolution of the velocity profile.

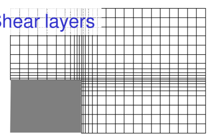
Mesh sizing (2)

Solid surfaces



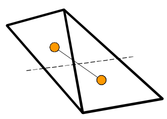
Boundary layers on solid walls are characterized by a large gradient of the wall parallel velocity component. Generally, wall functions are applied in the wall-adjacent layer of cells. The size of this layer can have a significant impact on the solution.

Shear layers

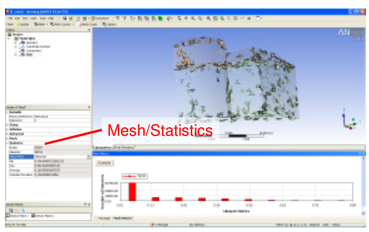


Velocity and turbulent quantities changes rapidly in the direction normal to the shear layer, furthermore, also in parallel direction close to the separation point.

Skewness



Conductive fluxes are poorly approximated if the section connecting center of the neighboring points enclose a large angle with the normal vector of the face. Flat cells are often distorted.

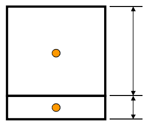


Skewness:

Max. 0.85 for hexa elements.

Max. 0.95 for tetra elements.

Size jumps



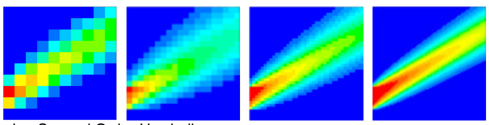
Numerical fluxes perform best on equidistant mesh. If the cell size is increased too rapidly, the formal accuracy (e.g. Second Order Upwinding) cannot be achieved.

Size increment below 30% is recommended.
Size jumps above 100% should be eliminated.

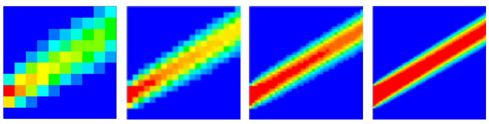
Numerical diffusion (1)

One of the major sources of inaccuracy.

By using First Order Upwinding:



By using Second Order Upwinding:



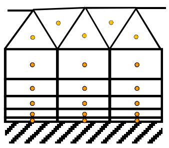
Numerical diffusion (2)

This error causes an false viscosity in the momentum equation which is usually much higher than the physical viscosity.

To eliminate this:

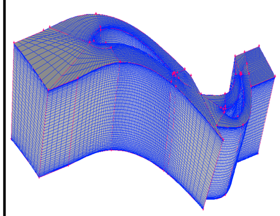
- Use Second Order Upwinding (or another high order numerical flux) if it is possible;
- In sensitive regions (e.g. in boundary layers on solid walls or in free shear layers) use prismatic layers of cells aligned with the flow direction, because the diffusion error is eliminated on streamlined meshes.

Wall layers



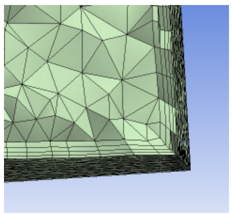
- Prismatic layers (hexa or wedge elements);
- The wall-adjacent layer is usually flat (cell centers reach the logarithmic layer);
- At least 3 or (better 5) layers;
- Gradual size increment (max. 50% increase from one layer to the next);
- Smooth transition to the inner mesh (as shown from the picture).

Hexa mesh



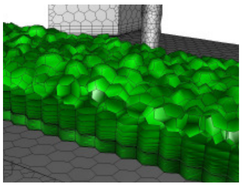
- In general cases, the same accuracy can be achieved with 30 to 50% less cells, as that of the tetra mesh. (Provided that the grid quality is good.)
- Allows anisotropic refinement: ideal for meshing boundary layers, shear layers and gaps.
- 3D (multi-direction) refinement requires complex grid topology. Best mesh quality can be achieved by block-structured mesh. (ICEM mesher can be recommended.) This is especially important in the analyses of streamlined bodies with possible separations, such as pumps, fans or aircrafts.

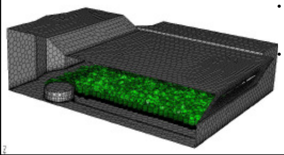
Tetra mesh



- Allows 3D refinement but the anisotropic refinement leads to grid distortion (thus it is not possible).
- It can be connected with hexahedral mesh excepting the case when flat hexa layers must be meshed around with tetras.
- Good automated methods exist which can combine tetra mesh with inflation layers (e.g. on wall boundaries).
- Less cells are introduced when adapted, than that of hexa meshes.

Dual (polyhedral) meshes



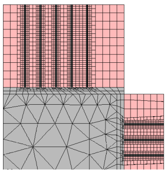


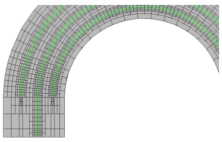
- Tetra mesh can be converted into polyhedral mesh in FLUENT: Mesh/Polyhedra
  Nodes and cell centers are swapped.
- Patch Conforming mesher should be preferred.
- Can be applied to the whole mesh or in smaller regions.
- Reduces the number of cells by some 60%, but it does not change the number of faces.
- Computing time of one iteration step will not change, but a much faster convergence can be achieved (less iterations are necessary).
- High quality dual mesh can be created even from a very skewed tetra mesh. It is an efficient way for improving grid quality.
- Significantly reduces the effective spatial resolution without decreasing the memory demand, therefore local application is usually preferred.

Preparation for meshing

- Geometry can be sliced for helping the meshing process. E.g sweepable bodies can be created.
- Short edges and narrow faces can be filtered before meshing:
  - Model/Insert Virtual Topology
  - Mesh/Pinch (global)
  - Mesh/Insert Pinch (local)
- Mesh sizing:
  - Mesh/Sizing (global)
  - Mesh/Insert Sizing (local)
- Inflation layers (prismatic layers of increasing thickness):
  - Mesh/Inflation (global)
  - Mesh/Insert Inlaltion (local)

Adapted meshes

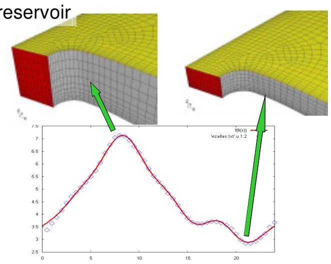




- Mesh can be refined (also locally) in FLUENT: Adapt menu.
- A new node is inserted in each cell centers.
- Useful for refining mesh in some hard zones or for creating solution adaptive meshes.
- Creates too large (100%) jumps in the cell size, therefore should be avoided if a reasonable alternative exists.

Deforming mesh

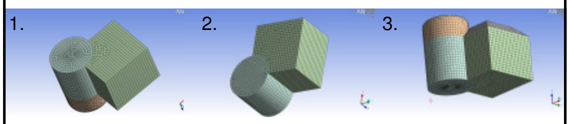
Example 1: Water reservoir

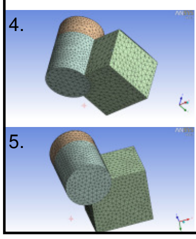


Example 2: Butterfly walve

Meshing methods

in Workbench Mesher





1. Sweep
   Mesh of the Source Face is extruded ito the domain.
2. Multi zone
   Creates quality mesh. Cannot mesh complex topology and cannot be combined with other methods.
3. Hex dominant
   Starts from the boundary and paves inward with hexa elements. Sometimes uses one or two tetra elements.
4. Patch Conforming tetra
   First meshes the boundary, then marches inward.
5. Patch Independent tetra
   Creates tetra from a regular hexa mesh, then it refines close to the surface. Very tolerant with geometrical errors. Cannot be combined with other methods.

Compressible models

	Incompressible	**Compressible**
Density depends on p:	no	yes
Density model:	ρ=const. Boussinesq Inkomp.Id Gas	Ideal Gas
Solver:	Pressure Based	Density Based
Definition of the stagnation pressure:	$p_{tot} = p + \frac{\rho}{2} v^2$	$p_{tot} = p\left(1+\frac{\kappa-1}{2}M^2\right)^{\frac{\kappa}{\kappa-1}}$
Maximum time step (Courrant criterion)	$\Delta t = C \left.\frac{\Delta x}{v_\perp}\right\|_{min}$	$\Delta t = C \left.\frac{\Delta x}{a+\|\vec{v}\|}\right\|_{min}$