Boundary conditions

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What do we mean by boundary conditions?

$$\frac{\partial}{\partial t}\int_V \rho\,\phi\, dV + \oint_A \rho\,\phi\,\vec{v}\cdot d\vec{A} = \oint_A (\vec{S}_A + \Gamma\nabla\phi)\cdot d\vec{A} + \int_V S_V\, dV$$

Fluxes and surface sources must be defined at the domain bounday.
The generic conservation equation in differential form:

$$\frac{\partial\rho\phi}{\partial t} + \nabla\cdot(\rho\,\phi\,\vec{v}) = \nabla\cdot\vec{S}_A + \nabla\cdot(\Gamma\,\nabla\phi) + S_v$$

It is second order in space due to this term

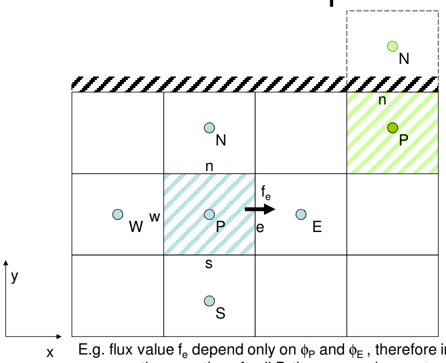
Three types of boundary are possible for such PDEs:

1. BC of first kind: value of ϕ is given at the boundary;
2. BC of second kind: normal derivative of ϕ is given;
3. Mixed BC: linear combination of ϕ and it's normal derivative is given.

$$\frac{\partial\phi}{\partial n} = \nabla\phi\big|_n$$

Boundary conditions for each conservation equations cannot be independently defined (E.g. we cannot use BC of 1-st kind for every velocity components along with BC of 1-st kind for pressure.)
Therefore FLUENT provides only boundary condition "packages" of well defined physical meaning.

Numerical interpretation



BC of 1-st kind:

$\phi_n = 0$:

$\phi_N = -\phi_P$

BC of 2-nd kind:

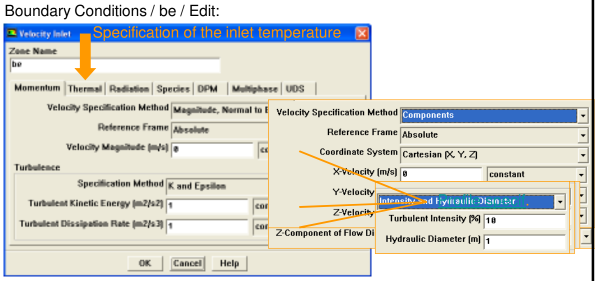
$\partial\phi_n / \partial y = 0$:

$\phi_N = \phi_P$

E.g. flux value f_e depend only on ϕ_P and ϕ_E , therefore in the discrete form of conservation equation of cell P, there are unknown ϕ values only from the neighboring cells (E,W,N,S).

Parameterization of BCs in FLUENT

Boundary Conditions / be / Edit:



Inlet and outlet BC packages

i : incompressible *c* : compressible

Velocity-inlet	*i*	Inflow (or outflow, if negative) of given velocity. BC of second kind for the pressure. First kind BC for every other field variable.
Mass-flow-inlet	*i*+*c*	Inflow at given mass-flow-rate or mass flux (ρv) profile. It is a BC of second kind for the pressure.
Pressure-inlet	*i*+*c*	Inflow with a given pressure profile. Flow direction must be specified. BC of 2nd kind for the velocity magnitude. BC of 1st kind for every othe scalar quantity.
Pressure-outlet	*i*+*c*	Outflow with a given static pressure profile. BC of 2nd kind for the velocity and other field variables. Target mass-flow-rate can be spec.
Outflow	*i*	Outflow with a given share of flow rate. BC of 2nd kind for every quantity. Non-reflective. Only outflow is allowed!
Pressure-far-field	*c*	In- or outflow with given far-field characteristics. Flow direction and Mach number can be specified. Non-reflective.
Inlet-vent	*i*+*c*	Pressure-inlet + ζ(v) loss coeff. E.g. an intake with a filter of grid.
Intake-fan	*i*+*c*	Pressure-inlet + Δp(v) pressure rise. (Characteristic curve.)
Outlet-vent	*i*+*c*	Pressure-outlet + ζ(v) loss coeff. Outlet with a filter or grid.
Exhaust-fan	*i*+*c*	Pressure-outlet + Δp(v) pressure rise.

Important notes

- Outflow cannot be used in the presence of Pressure Inlet or Pressure Outlet;
- Back flow is not allowed through an Outflow (due to immediate convergence problems);
- Velocity Inlet provides unphysical results in compressible flow simulations (Mass Flow Inlet need to be used in these cases);
- Pressure Inlet is automatically changed to Pressure Outlet when back flow occurs (and the Pressure Outlet does similarly);
- In the case of supersonic flow, only upstream values are used at the boundary surfaces;
- There are three ways of branching the flow:
  - Outflow (with Flow Rate Weighting)
  - Multiple Pressure Outlets
  - Velocity Inlet with negative velocity (mathematically incorrect by works if proper care is taken)

Other BCs

Symmetry Face normal velocity is 0. BC of 2nd kind for every other field variable.

Wall BC of 1st kind for the velocity and 2nd kind for the pressure. Many options for thermal BCs. E.g. water surface can be modeled as a frictionless wall.

Axis Axis of an axisymmetric 2D model. Always along the x axis. v=0, w=0, BC of 2nd kind for every other field variable.

Periodic Flow quantities are matched in every point of the periodic surface pair. Requires identical mesh on both surface. Translational (eg. tube bundle) or rotational (eg. turbine blade) Pressure gradient or target mass-flow-rate can be specified.

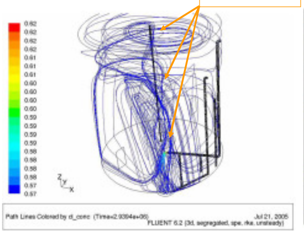
Interface Connects separate grids. It does not require matching nodes. Grids can slide on each other in every time step. There is an option for periodic BC.

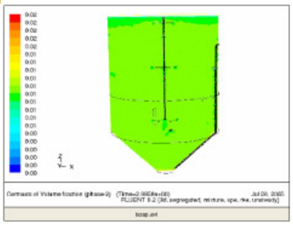
Modeling fluid machinery

1. Actuation disk - fan
2. Rotating frame - frozen rotor
3. Bidirectional averaging - mixing plane
4. Rotating zone - sliding mesh

1. Fan models

Fan surfaces



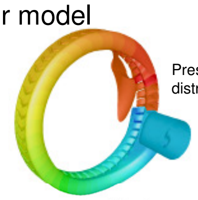


Mixers in sewage sludge fermentation tank at the Budapest Sewage Works.
Reduction of the number of elements. Potential for long term simulations.

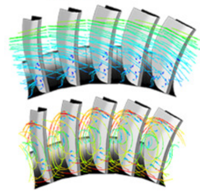
2. Frozen rotor model

Side channel pump

Appropriate if the num. of blades is high.



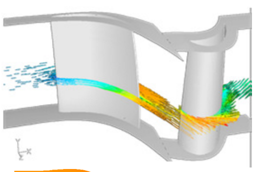
Pressure distribution

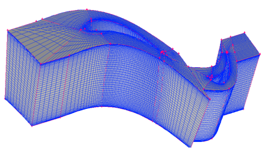


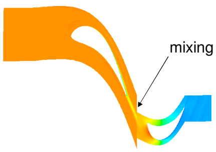
Periodicity can be exploited.

3. Mixing plane models

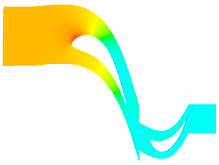
Kihasználható a lapátrács periodicitása





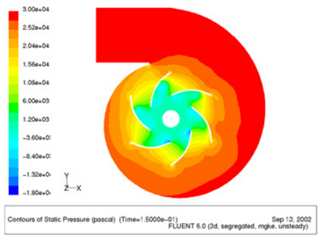


In absolute frame

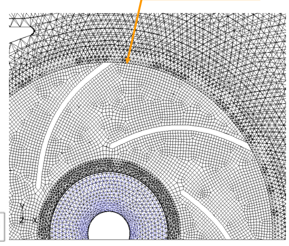


In co-moving frame

4. Sliding mesh models



sliding interface



Blades operate with fluctuating pressure load, when there is an uneven pressure in the scroll casing.
Local acceleration in the blade channels can be taken into account.
The sliding interface must be meshed with regular quad mesh.
Works also with axial flow impellers: