Boundary Conditions

Initial conditions

- Steady-state problem -> completely determined by BC
- Limit-cycle oscillation -> completely determined by BC
- Transient computation of an initial-value problem is dependent on the initial conditions
- Initial conditions may be important for the convergence to steady state

Boundary flow field

- Supersonic inflow
  - All information from boundary to interior
- Subsonic inflow
  - Most information from boundary to interior
  - pressure related information from interior to boundary.
- Subsonic outflow
  - Only pressure related information from boundary to interior
- Supersonic outflow
  - No information from boundary to interior

- Dictated by numerical stability

Boundary influence

If interaction between the boundary and interior flow fields is a problem:

- Extend the boundaries for external flows
  - typically 10-50 times the size of the object
  - Less problem in 3D flows
- Include the stagnation chamber or the true inflow/outflow geometries for internal flows
- Make empirical/mathematical corrections on the boundaries
- Warning for recirculation (=inflow) at outflow boundaries

- **Be aware of the problem!!!**

Inflow conditions for turbulence

- At inflow boundaries the turbulence quantities must be prescribed for turbulent computations
- Inflow turbulence levels mostly not fully known
- Solution may be strongly dependent on the inflow turbulence levels, but mostly only minor dependencies
- Important to prescribe realistic values for solution accuracy and numerical stability

- If problems: move the inflow boundary sufficiently far from the region of interest.
- The turbulence levels at the inflow boundary are also applicable as initial conditions.

Turbulence level

- Turbulence level, Tu
  - $Tu < 0{,}3\%$ in external aerodynamic flows
  - $Tu \approx 1\%$ in wind tunnels
  - $Tu \approx 5 - 10\%$ in internal turbo machinery flows
  - $Tu < 2 - 3\%$ usually do not influence the mean flow field.
  - Turbulent kinetic energy related to Tu

$$K = \frac{3}{2}(Tu \cdot U_{\infty})^2$$

Turbulence length scale

- Turbulent length scale
  - External flows $\nu_T / \nu \approx 1 - 10$ is a reasonable guess
  - Internal flows: turbulent length scale related to geometry

$$L = \frac{K^{3/2}}{\varepsilon} = 1 - 10\% \text{ of geometrical scales}$$

  - Check also the length scale on which the advected turbulence changes. That should be in the order of, or larger than, typical geometrical scales.

$$\frac{K}{\varepsilon} U_\infty$$

Transition to turbulence

- The location of the transition point (or region)
  - Depends on surface roughness, free stream turbulence levels, noise, etc.
  - No general method to predict
  - Difficult to measure
- The flow may be dependent on the transition location
  - Try to get information from experiments
  - Try to estimate (specific empirical relations exist)
  - Compute the growth rate of disturbances (a subject as big as CFD)
  - Assume the flow fully turbulent (if transition is unimportant)
- Transition location prescribed in CFD by setting laminar or turbulent walls
  - Laminar: $Re < 10^3$
  - Turbulent: $Re > 10^6$