Lecture 10

BOUNDARY CONDITIONS

10.1 BOUNDARY CONDITIONS FOR FLOW PROBLEMS

Partial differential equations obtained from conservation laws are the same for a particular type of flow (compressible or incompressible) irrespective of the flow domain. The boundary conditions act as the constraints, and establish the uniqueness of the flow field for a specified problem. In numerical simulation, we come across two types of boundary conditions:

1. Physical boundary conditions which are imposed by the physical processes at the bounding surfaces of the flow domain, and
2. Artificial boundary conditions which are specified at the boundaries of computational domain which are not natural boundaries (sometimes referred to as the fluid boundaries).

The artificial boundaries arise from the approximation of physical problem domain for numerical simulation in both internal and external flows. For example, in simulation of flow over an aircraft, its solid surface represents the natural physical boundary. Flow is otherwise unbounded, i.e. flow domain is infinite. However, numerical simulation requires a finite computational domain. Thus, artificial external boundaries must be chosen, and appropriate values of flow parameters must be specified based on physical reasoning.

10.2 BOUNDARY CONDITIONS ON PHYSICAL BOUNDARIES

Boundary conditions on physical boundaries are straight forward. For viscous flows, relative velocity at the solid surface is zero: this is called no-slip boundary condition. For energy equation, a similar condition holds for the temperature (i.e. temperature of the fluid at the wall is same as that of the solid wall). However, the wall temperature may not be known, and instead heat flux may be specified. Thus, boundary conditions for viscous flow at solid wall are:

- $\mathbf{v} = \mathbf{v}_w$ where $\mathbf{v}_w$ is velocity of the solid surface (*no-slip condition*)
- $T = T_w$ (specified wall temperature T_w) or $q = q_w$ (specified heat flux q_w at the wall).

For inviscid flows, the fluid can freely slip over the surface. However, there can be no velocity component normal to the surface. This velocity boundary condition is called *free slip* condition, and is given by

- $\mathbf{v}_n = 0$ where $\mathbf{v}_n$ is velocity component normal to the solid surface.

10.3 BOUNDARY CONDITIONS ON ARTIFICIAL BOUNDARIES

Conditions on artificial or fluid boundaries can take variety of form: inlet, outflow, symmetry, cyclic or periodic are few of the popular types of boundary conditions specified on fluid boundaries. Details of these boundary conditions are:

- Inlet: specified pressure, velocity, temperature and density as a function of position.
- Outflow boundary condition: specified pressure, $\partial \mathbf{v}_n / \partial n = 0$, $\partial T / \partial n = 0$.
- Symmetry boundary condition: $\partial \phi / \partial n = 0$ for all flow variables ϕ.
- Periodic boundary condition: $\phi_1 = \phi_2$ for all flow variables ϕ where subscripts 1 and 2 denote the periodic boundaries.

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