SNS COLLEGE OF TECHNOLOGY

Coimbatore-35
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DEPARTMENT OF AEROSPACE ENGINEERING

19ASB304 – COMPUTATIONAL FLUID DYNAMICS FOR AEROSPACE APPLICATIONS

III YEAR VI SEM

UNIT-I FUNDAMENTAL CONCEPTS

TOPIC: Mathematical properties of Fluid Dynamics Equations - Elliptic, Parabolic and Hyperbolic equations

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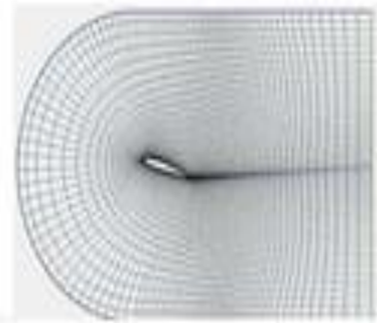
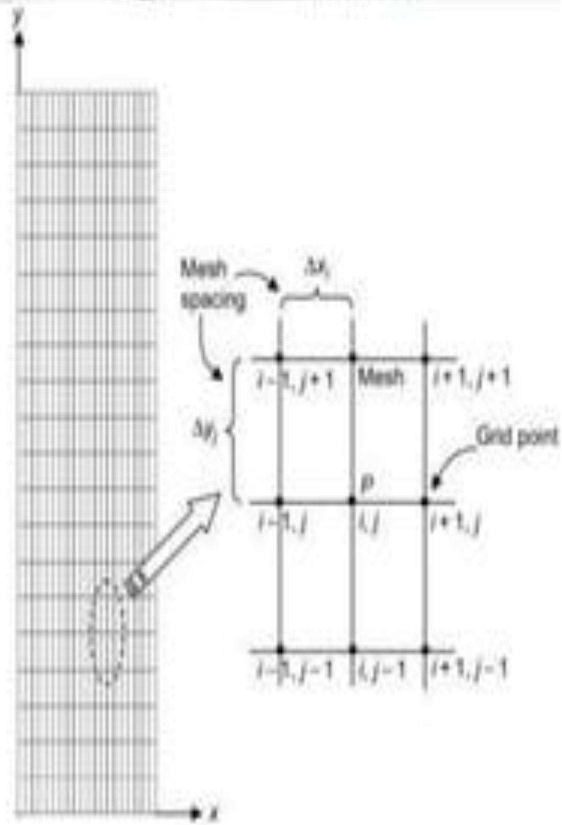
What is grid generation?



The space, where the flow is to be computed – the physical space, is divided into a large number of geometrical elements called cells or control volumes.

This process is termed grid generation (some authors use the term mesh).

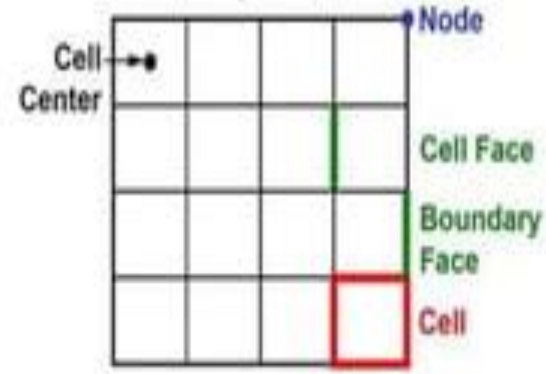
It can also be viewed as placing first, grid points (also called nodes or vertices) in the physical space and then connecting them by straight lines - grid lines.



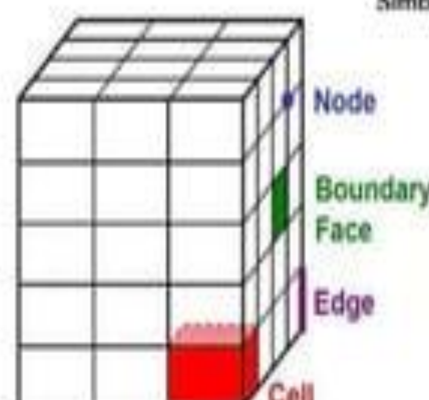
Terminology:

A mesh/grid divides a geometry into many elements. These are used by the CFD solver to construct control volumes.

- Cell = control volume into which domain is broken up.
- Node = grid point.
- Cell centre = centre of a cell.
- Edge = boundary of a face.
- Face = boundary of a cell.
- Zone = grouping of nodes, faces, cells
- Domain = group of node, face and cell zones.



Simole 2D Mesh



Points to consider when generating a grid

There must not be any holes/gaps between the grid cells

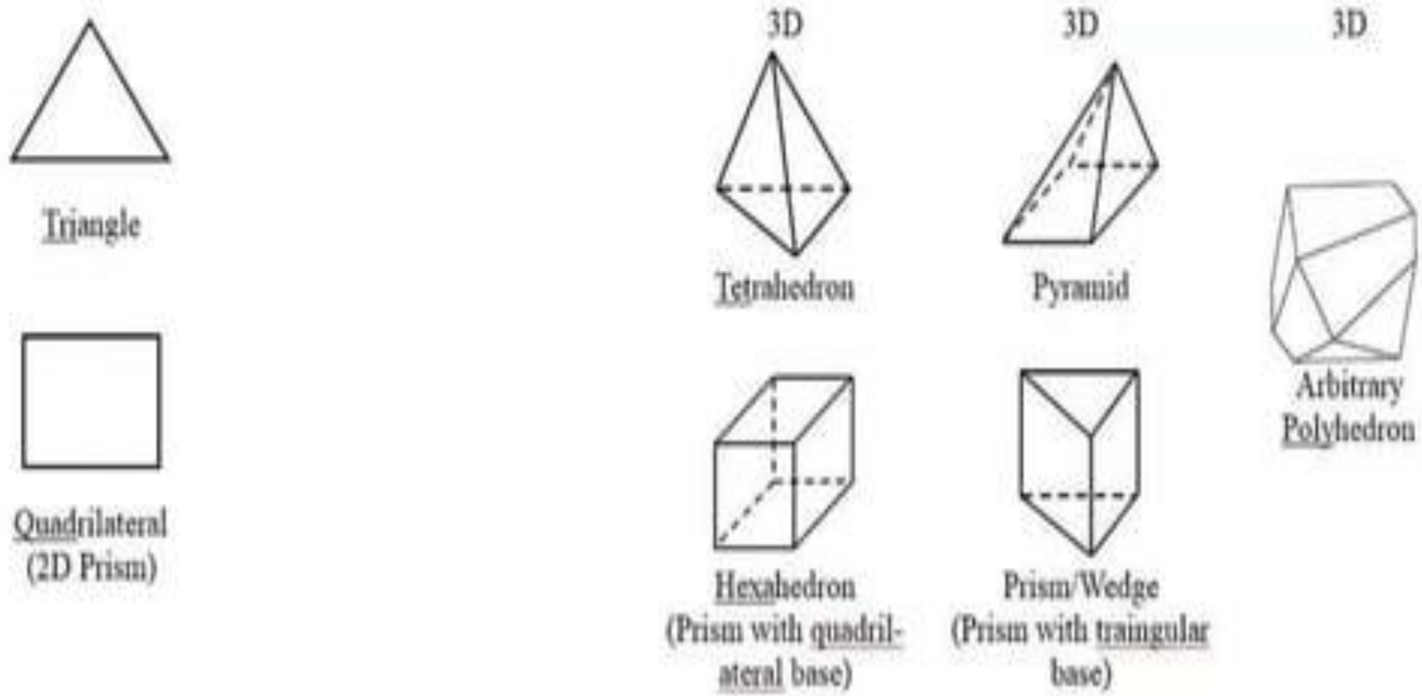
The grid cells do not overlap

The grid should be smooth

There should be no abrupt changes in the size of the grid cells

Grid cells/elements

The grid normally consists of triangular or quadrilateral cells in two dimensions, and tetrahedral, hexahedral, prism, or pyramid cells in three dimensions.

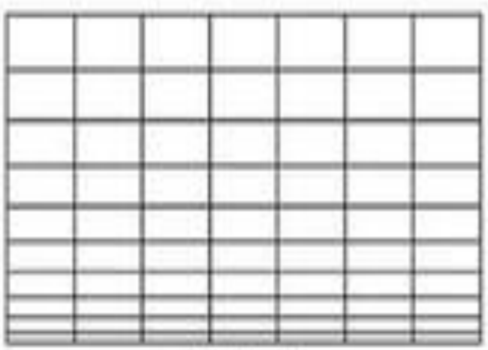


Cartesian and Curvilinear grids

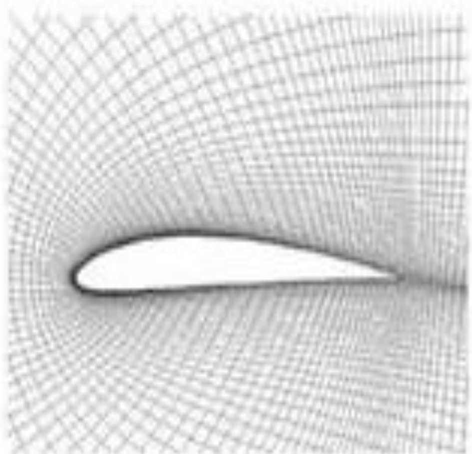
Grids can be Cartesian or Curvilinear (usually body-fitted grids).

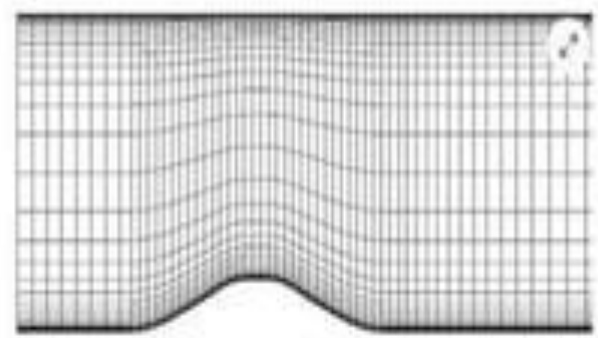
In cartesian, the grid lines are always parallel to the coordinate axes.

In curvilinear, the grid lines are curved to fit boundaries.



Cartesian





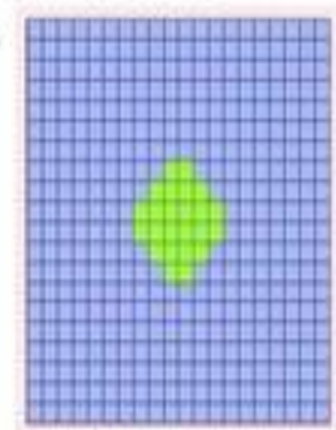
Curvilinear

Fluid flow equation and coordinate system

Most of the fluid flow equations are easily solved by discretizing procedures using the Cartesian coordinate system. In this system the implementation of finite volume method is simpler and easier to understand.

But most of the engineering problems deal with complex geometries that do not work well in the Cartesian coordinate system.

When the boundary region of the flow does not coincide with the coordinate lines of the structured grid then we can solve the problem by geometry approximation.



Representation of 2-D model of flow around cylinder using

Cartesian vs Curvilinear grids

The main advantage of curvilinear/body-fitted grids is that the flow can be resolved very accurately at the boundaries, which is essential in the case of shear layers along solid bodies.

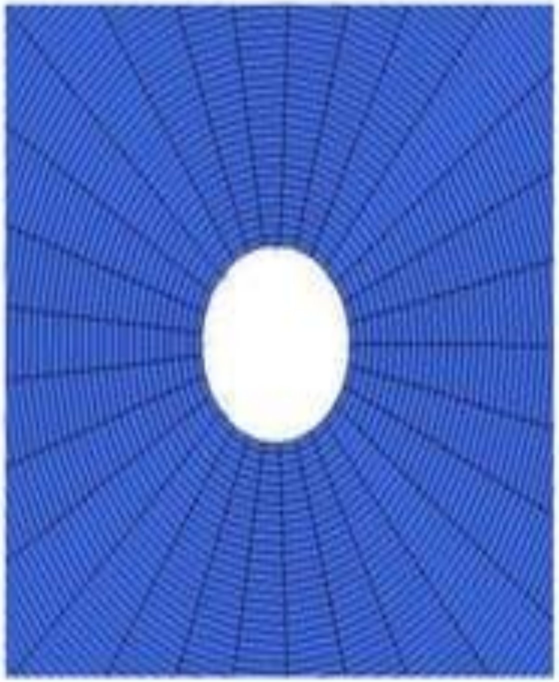
On the other hand, the Cartesian grids where the edges of the grid cells are oriented in parallel to the Cartesian coordinates, can be generated very easily. Their advantage is that the evaluation of the fluxes is much more simple then for body-fitted grids.

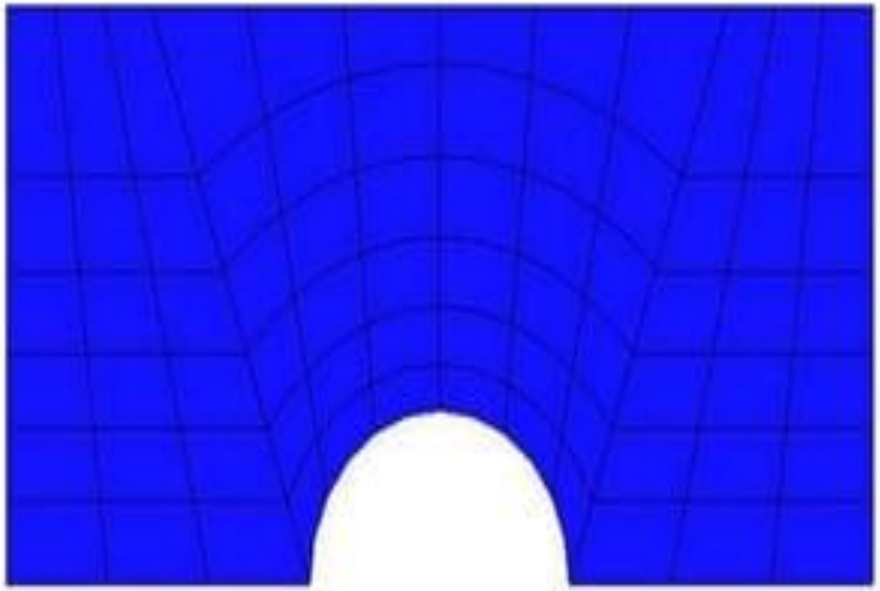
It becomes clear that accurate treatment of the boundaries is hard to achieve. Because of this serious disadvantage, the body-fitted approach is preferred, particularly in the industrial environment, where the geometrical complexity of a configuration is usually very high.

Orthogonal and Non-orthogonal grids

In orthogonal grids (for example, Cartesian or polar meshes) all grid lines cross at 90º.

In non-orthogonal grids, the grid lines do not intersect at 90 degree angle.





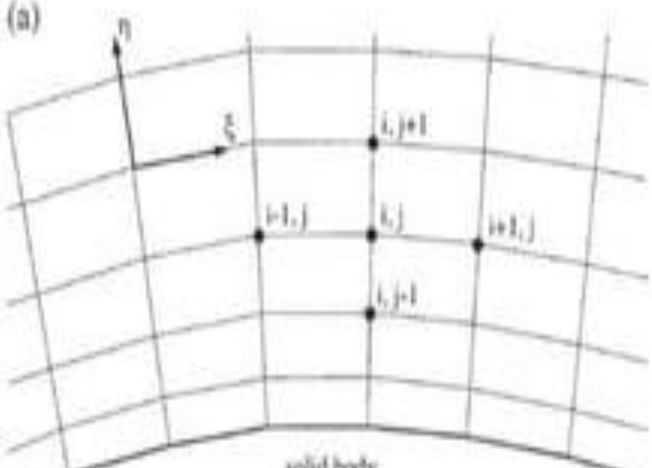
Structured grids

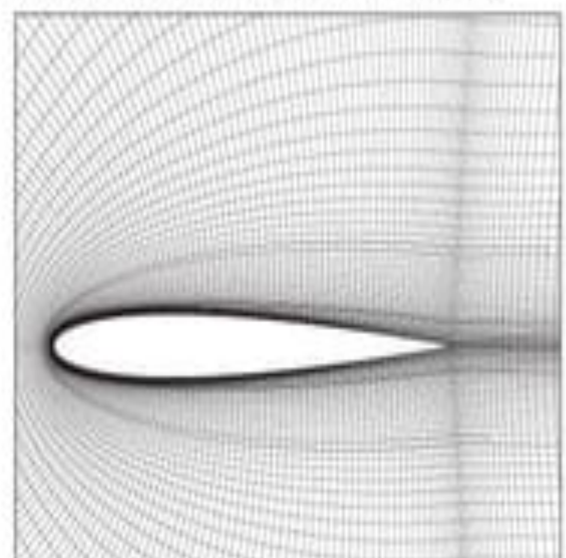
Interior grid points have a fixed number of neighbouring grid points

Each grid point (vertex, node) is uniquely identified by the indices i , j , k and the corresponding Cartesian coordinates $x_{i,j,k}$, $y_{i,j,k}$, and $z_{i,j,k}$

The grid cells are quadrilaterals in 2-D and hexahedra in 3-D. If the grid is body-fitted, we speak of curvilinear grid.

(a)



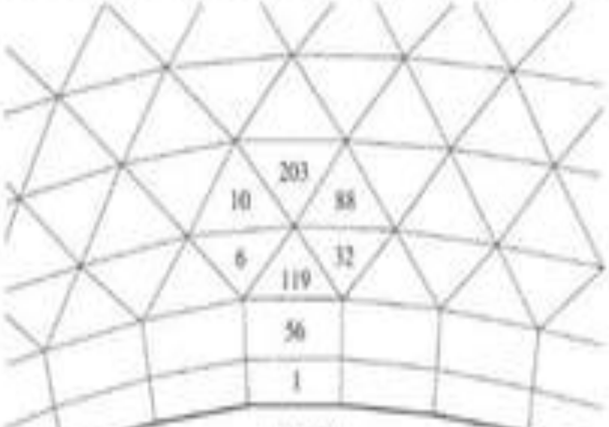


Unstructured grids

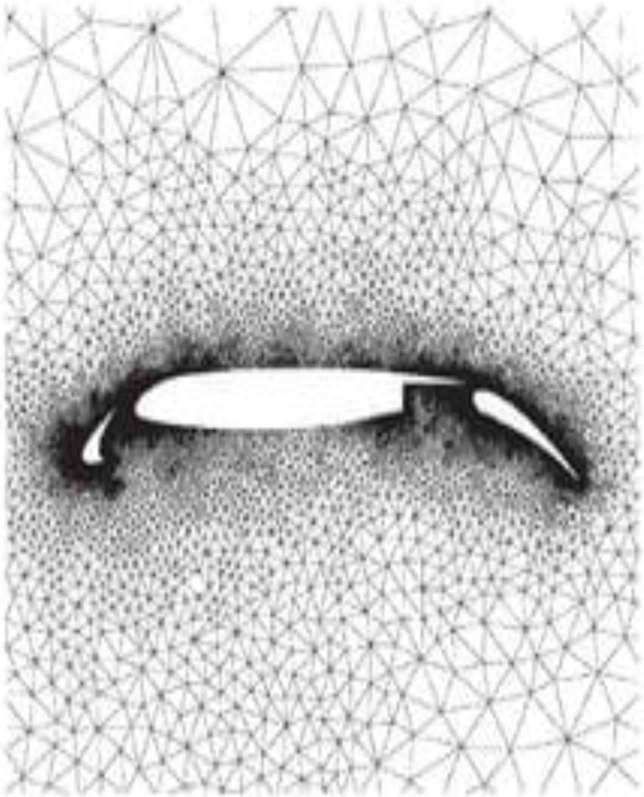
Grid cells as well as grid points have no particular ordering, i.e., neighbouring cells or grid points cannot be directly identified by their indices.

In the past, the grid cells were triangles in 2D and tetrahedra in 3D.

Today, unstructured grids usually consist of a mix of quadrilaterals and triangles in 2D and of hexahedra, tetrahedra, prisms and pyramids in 3D, in order to resolve the boundary layers properly. Therefore, we speak in this case of hybrid or mixed grids.



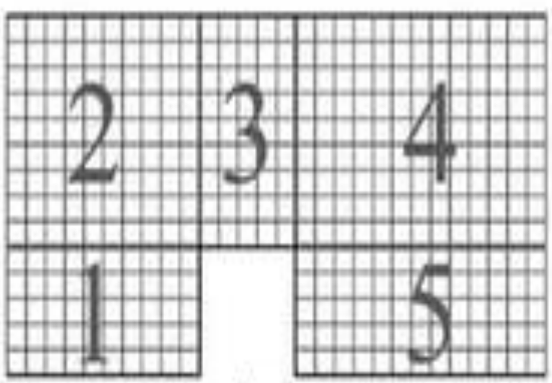
A triangular grid for a three-element aerofoil



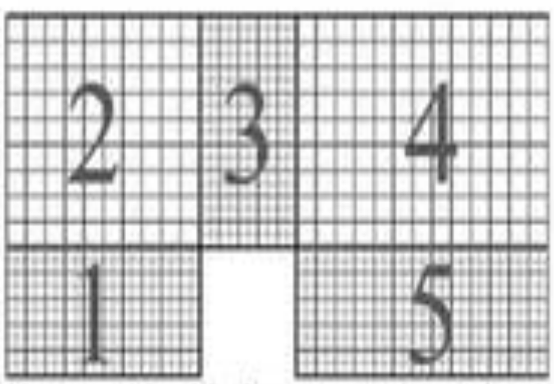
Block-structured Grids

In multi-block structured grids the domain is decomposed into a small number of regions, in each of which the mesh is structured.

A common arrangement is that grid lines match at the interface between two blocks, so that there are cell vertices that are common to two blocks i.e. matching cells. In some cases, the cell counts do not match at the interface i.e. non-matching cells. Non-matching cells (which could be 2 to 1, 3 to 2, ...) should be avoided as much as possible as they tend to increase the computational time.



Matching block structures



Non-matching block structures (2 to 1 here)

Block-structured mesh for a transonic aerofoil