Programming Module

Session-4

Turbulent Inflow Boundary Condition

For atmospheric boundary layer flows the logarithmic law is the most accurate mathematical function for describing the variation of the mean wind velocity with height above the ground.

The logarithmic law for atmospheric boundary layer $$U(z) = U_{10}\left(\frac{z}{10}\right)^{\alpha}$$

α terrain roughness

U_{10} the mean wind velocity at height 10m above ground

Z height above ground

z_0 measure of the roughness of the ground surface

$$\alpha = \left(\frac{1}{ln\left(z_{ref}/z_0\right)}\right)$$

z_{ref} the height above the ground where the power law is matching the logarithmic law

Turbulence intensity: $I_u = \dfrac{1}{log_e(z/z_0)}$ turbulent kinetic energy: $k = \dfrac{3}{2}(UI_u)^2$

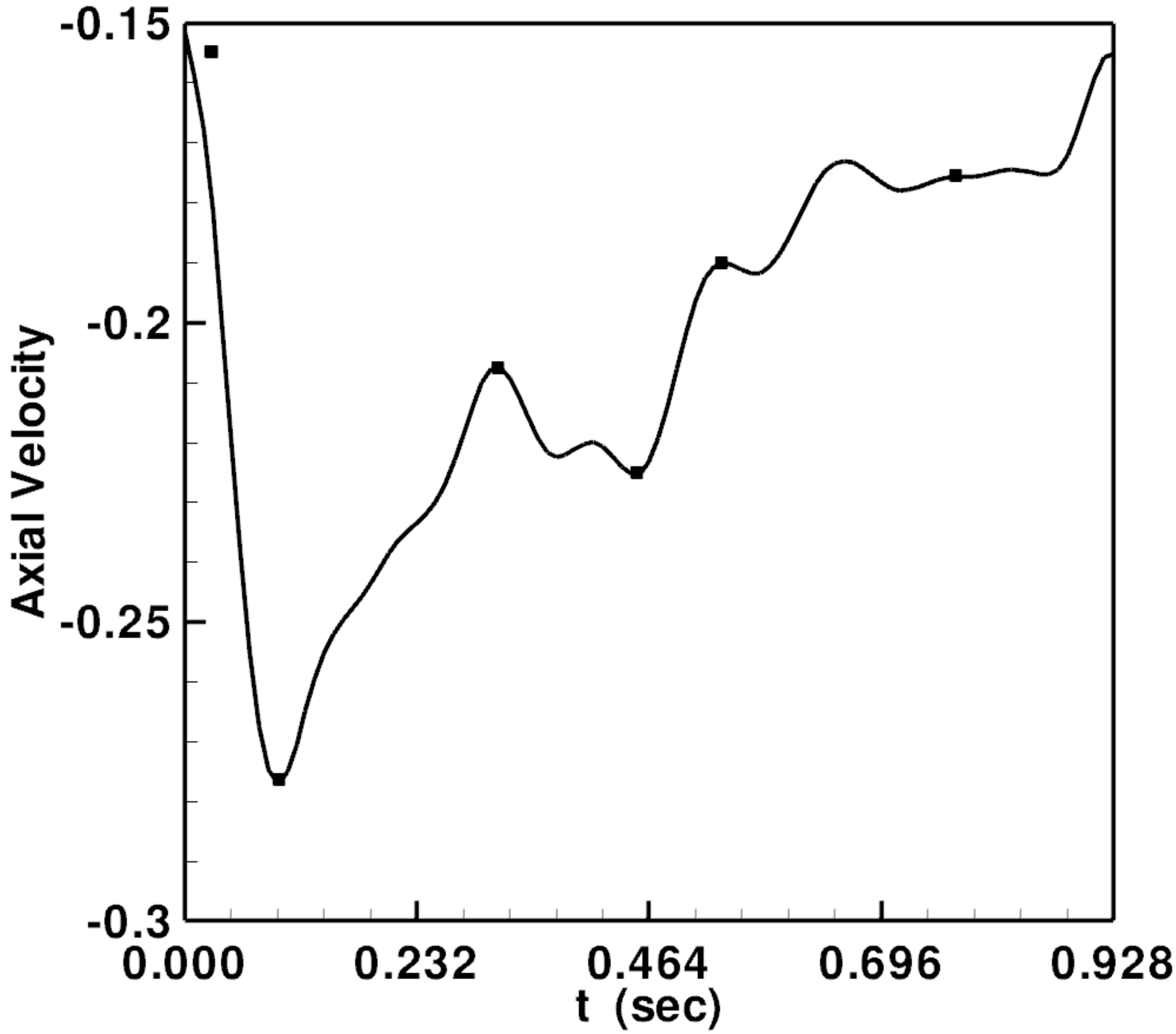
Turbulent Inflow Boundary Condition

epsilon

$$\varepsilon = \frac{C_\mu^{0.75} k^{1.5}}{l}$$

$$omega(\omega) = \frac{\varepsilon}{C_\mu k} \qquad C_\mu = 0.09$$

Inlet Pulsatile Boundary Condition



Inlet Pulsatile Boundary Condition

```
    U = (
&       -((MEAN) + (-0.0080467)*COS(1 *2.*PI*TIME/PERIOD) +
&              (0.086438)*SIN(1 *2.*PI*TIME/PERIOD) +
&             (-0.0057042)*COS(2 *2.*PI*TIME/PERIOD) +
&              (0.036684)*SIN(2 *2.*PI*TIME/PERIOD) +
&             (-0.037873)*COS(3 *2.*PI*TIME/PERIOD) +
&             (0.023462)*SIN(3 *2.*PI*TIME/PERIOD) +
&            (-0.019703)*COS(4 *2.*PI*TIME/PERIOD) +
&            (0.0023512)*SIN(4 *2.*PI*TIME/PERIOD) +
&            (-0.019301)*COS(5 *2.*PI*TIME/PERIOD) +
&            (0.006191)*SIN(5 *2.*PI*TIME/PERIOD) +
&            (-0.015524)*COS(6 *2.*PI*TIME/PERIOD) +
&           (-0.0082778)*SIN(6 *2.*PI*TIME/PERIOD) +
&            (-0.013376)*COS(7 *2.*PI*TIME/PERIOD) +
&           (-0.007184)*SIN(7 *2.*PI*TIME/PERIOD) +
&             (8.3728e-005)*COS(8 *2.*PI*TIME/PERIOD) +
&            (-0.0034172)*SIN(8 *2.*PI*TIME/PERIOD) +
&             (-0.0061556)*COS(9 *2.*PI*TIME/PERIOD) +
&            (-0.0056501)*SIN(9 *2.*PI*TIME/PERIOD) +
&             (0.0014531)*COS(10*2.*PI*TIME/PERIOD) +
&           (-0.0035759)*SIN(10*2.*PI*TIME/PERIOD))  )/  MEAN * 0.205
```

```
MEAN      = 0.511
PERIOD    = 0.928
PI        = 3.141592654
```

Polynomial Patch deformation

The polynomial here will be second order in both x and y

$$z = \mathrm{X2} \cdot x^2 + \mathrm{X1} \cdot x + \mathrm{Y2} \cdot y^2 + \mathrm{Y1} \cdot y + \mathrm{Cconst}$$

To be able to describe a surface in any direction by only x and y a new coordinate system is set up that will be used for the polynomial.

The **xAxis** and **yAxis** denote the transformation from the fixed coordinate system.

The **origin** denotes the origin of the new coordinate system.

defTime controls how long time the deformation should take

periodic is set to 1 if the deformation should move back to original position after deformation and then repeat (active flow control).

These input values will be declared in

libMyPolynomVelocityPointPatchVectorField.H

Polynomial Patch deformation

First the points on the patch relative to the coordinate system of the polynomial are found.

These points are then rotated from the fixed coordinate system, $(x; y; z)$, into the coordinate system of the polynomial,$(X; Y;Z)$.

The rotation is done using the following dentition of Euler angles.

Where line of nodes N is the intersection between the two coordinate systems xy and XY planes.

α is the angle between the x-axis and the line of nodes, β is the angle between the z-axis and the Z-axis and γ is the angle between the line of nodes and the X-axis.

Polynomial Patch deformation

Rotation matrix R

$$\mathbf{R} = \begin{bmatrix} \cos\alpha\cos\gamma - \sin\alpha\cos\beta\sin\gamma & -\cos\alpha\sin\gamma - \sin\alpha\cos\beta\cos\gamma & \sin\beta\sin\alpha \\ \sin\alpha\cos\gamma + \cos\alpha\cos\beta\sin\gamma & -\sin\alpha\sin\gamma + \cos\alpha\cos\beta\cos\gamma & -\sin\beta\cos\alpha \\ \sin\beta\sin\gamma & \sin\beta\cos\gamma & \cos\beta \end{bmatrix}$$

$$\underline{\hat{p}} = \underline{p}\mathbf{R}$$

Thank you