LES simulation of the flow around porous bluff bodies

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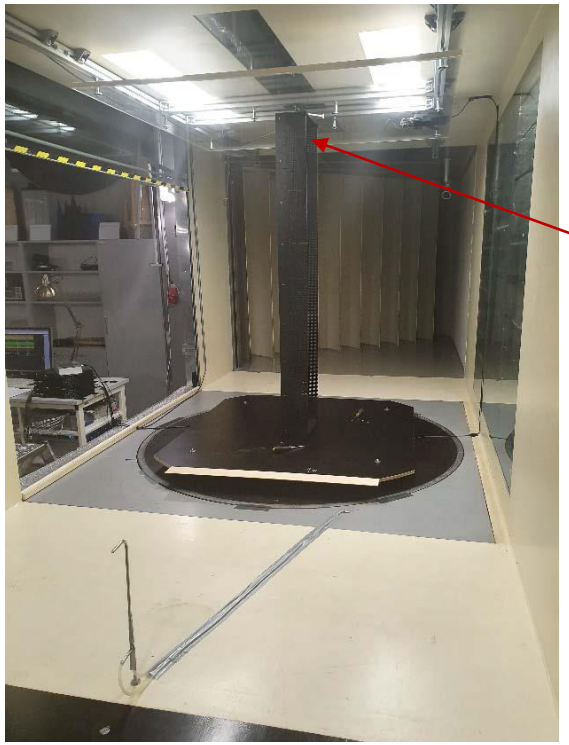
porous barriers on bridge decks

- protection vehicles from cross-wind
- prevention of sand accumulation
- ancillary structures, but strong effect on the the bridge aerodynamics



wind tunnel measurements

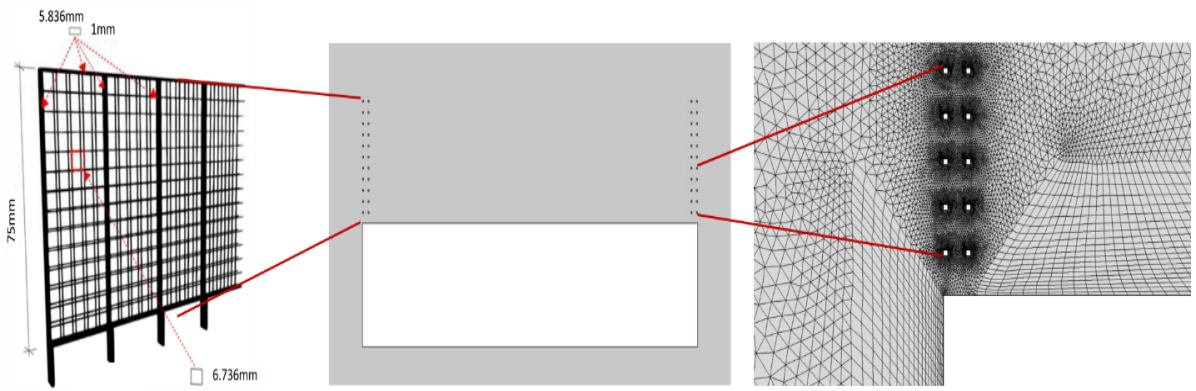
U-profile specimen

air velocity u_0=14m/s
Re=1.4e^5 turbulent flow

impact angle $\alpha=\langle -15,15\rangle°$

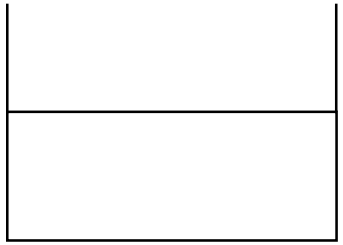
Comparison of 2D SST RANS simulations with measurements

2 modelling attemps



detailed geometry

Resistance coefficient K=K(ε)

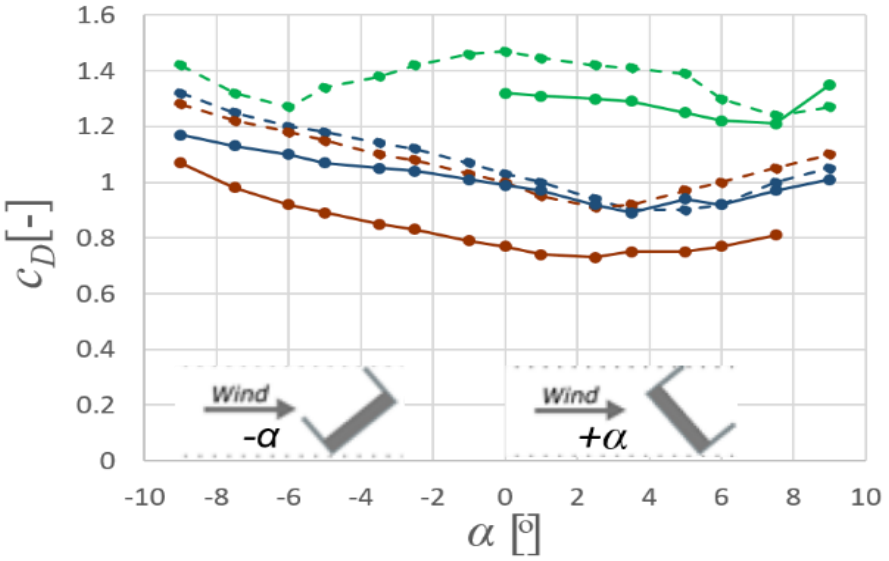


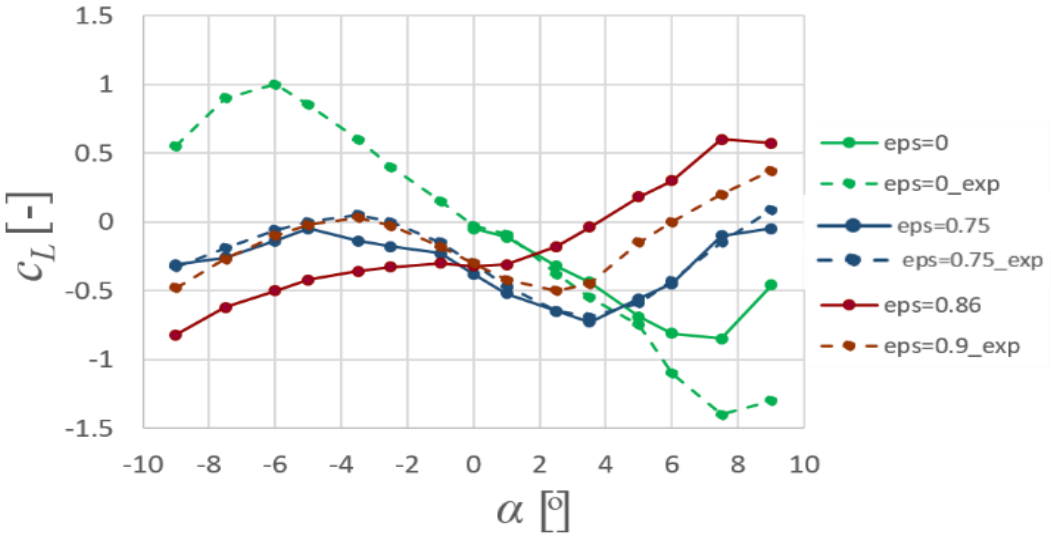
ε -porosity

Comsol implementation

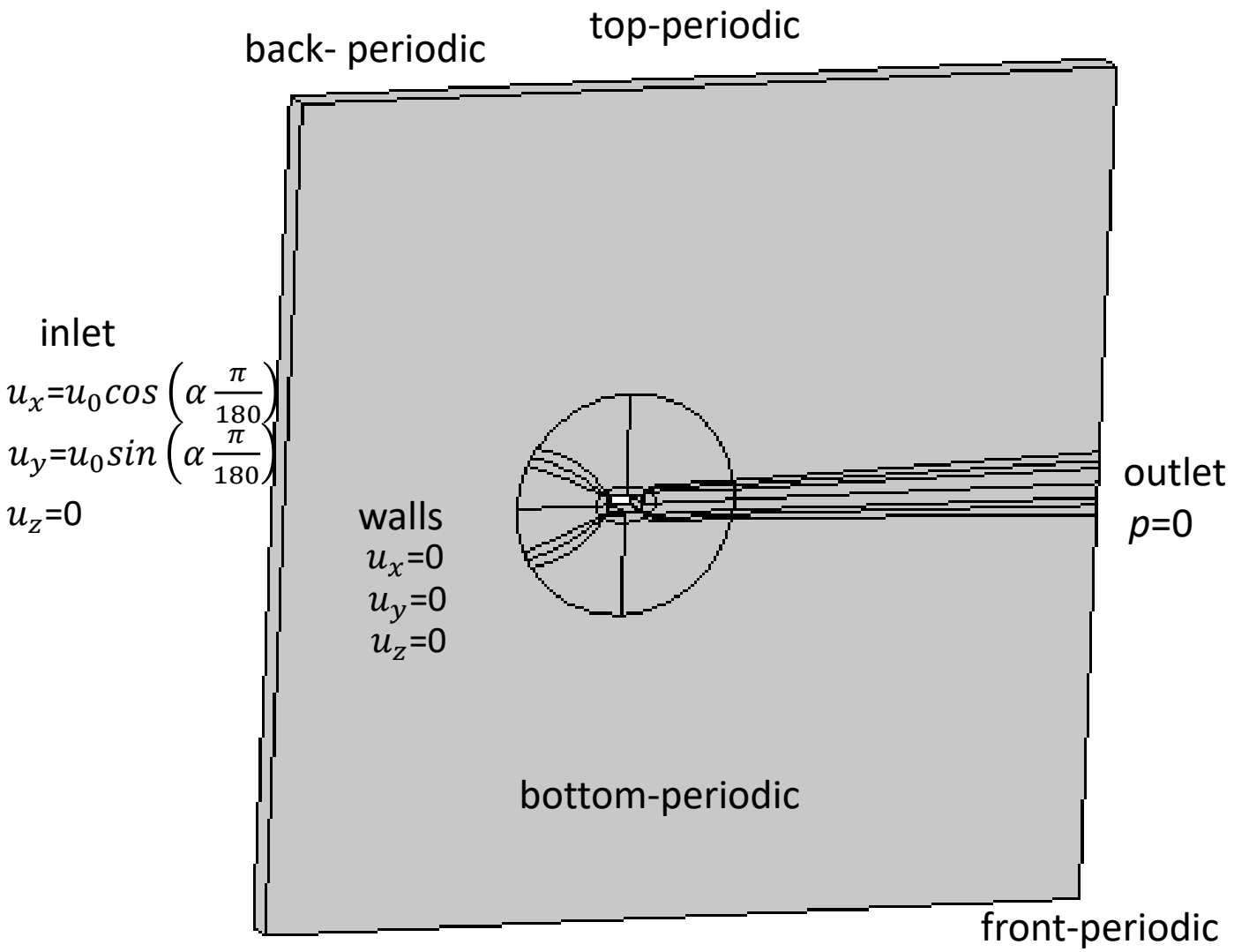
Control flow devices-screen

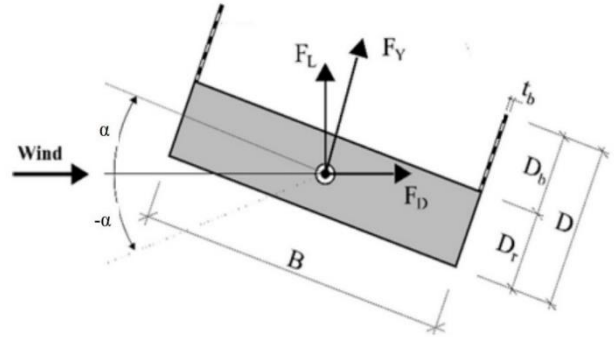
pressure jump





3D LES simulation –computational settings





D=0.15m
B=0.3m
inner depth D_b=0.075m

Spanwise length *L* set to *L/B*=1

Minimum requirement L/B≥ 1
(Tamura et al. 1998)

Modeling of porous zones- volume force

Volume force

$$F_x = -A|u_x|u_x\rho$$
$$F_y = -A|u_y|u_y\rho$$
$$F_z = -A|u_z|u_z\rho$$

resistance coefficient

$$A = \frac{K}{2L}$$

porous layer thickness

$$K(\varepsilon) = \frac{(\alpha_1\varepsilon+2)(\varepsilon-1)}{\varepsilon^2(\alpha_2-1)}$$

$\alpha_1 = 0.5$ $\alpha_1 = 0.1$

Xu,M., Patruno,L., Lo, Yuan-Lung, de Miranda, S. (2020) On the use of the pressure jump approach for the simulation of separated external flows around porous structures: A forward facing step. J. Wind Eng. Ind. Aerodyn. 207

u_x, u_y, u_z -velocity field
ρ –air density

Drag coefficient $c_D = c_{Dw} + c_{Dp}$

$c_L = c_{Lw} + c_{Lp}$

τ- wall shear stress
S- reference area
u_{in}-inlet velocity

1 porous zone

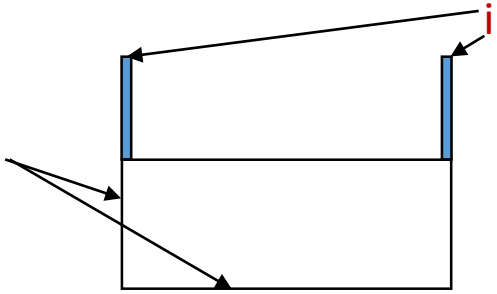
in porous area

$$c_{Dp} = 2(F_x \cos\alpha + F_y \sin\alpha)/\rho u_{in}^2 S$$

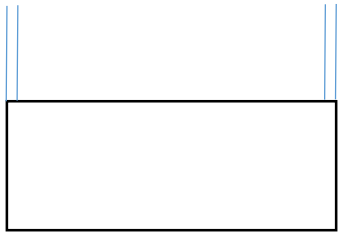
$$c_{Lp} = 2(F_y \cos\alpha - F_x \sin\alpha)/\rho u_{in}^2 S$$

on walls

$$c_{Dw} = 2\tau_x/S\rho u_{in}^2$$
$$c_{Lw} = 2\tau_y/S\rho u_{in}^2$$

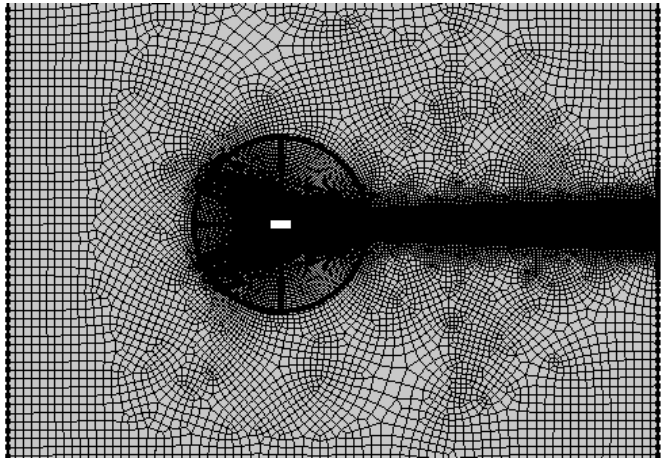


2 porous zones

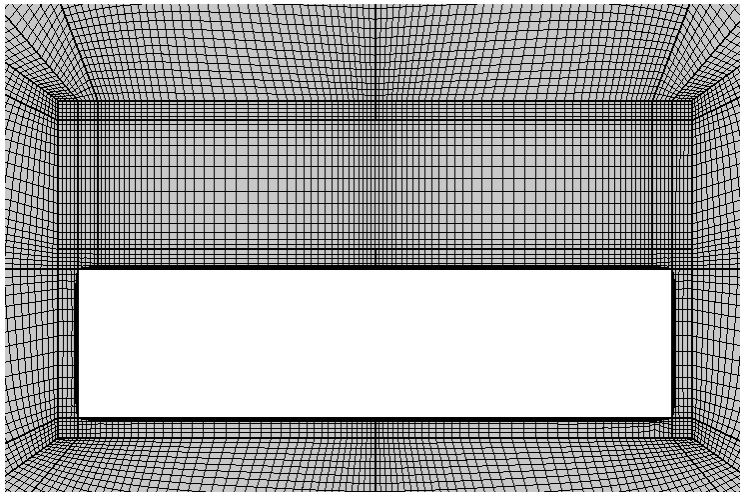


3D LES simulation -computational mesh

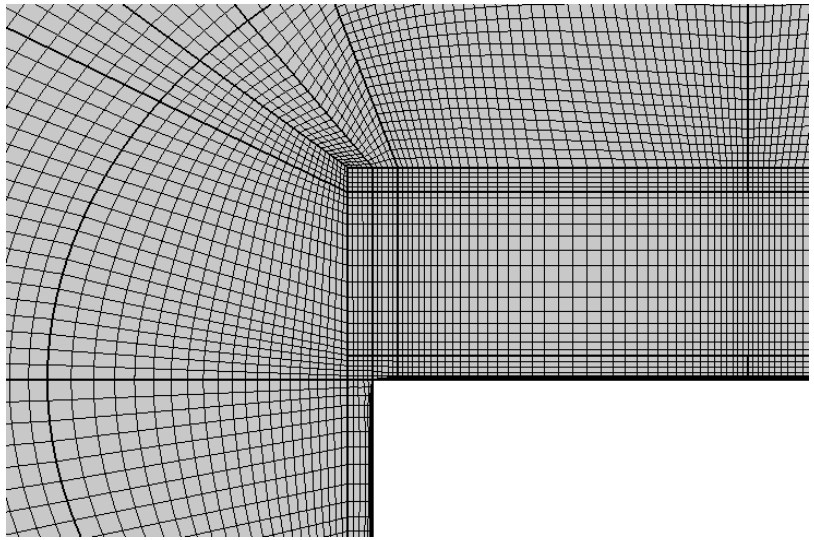
Hexahedral mesh, hybrid mesh in x-y plane, structured along z dimension- number of equidistant layers n_z=24



meshing of computational domain



mesh around rectangle



detail of mesh in boundary layer

3D LES simulation- results I.

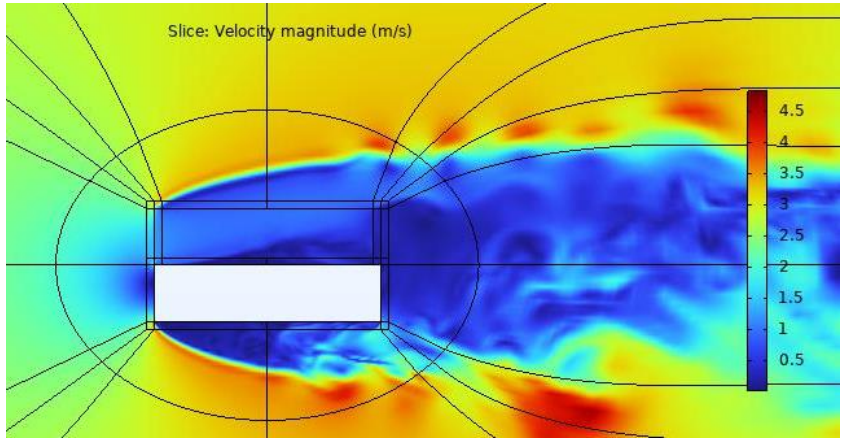
$\varepsilon = 0.5, \alpha = 0°, u_{in}$=2.8m/s

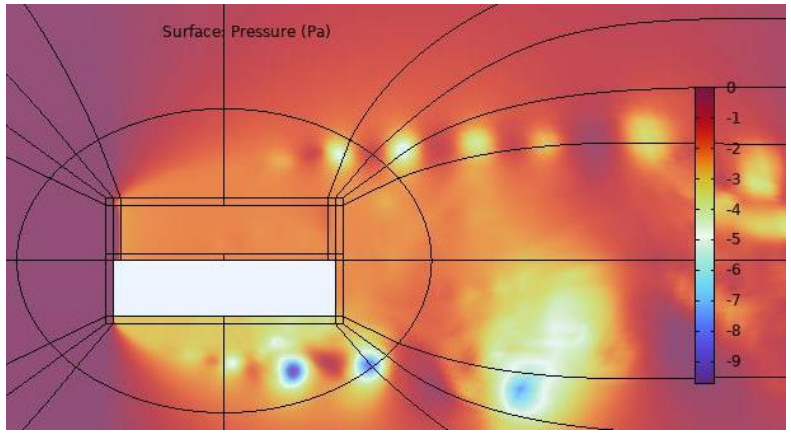
Experimental results

c_D=1.33

c_L=-0.34

1 porous zone

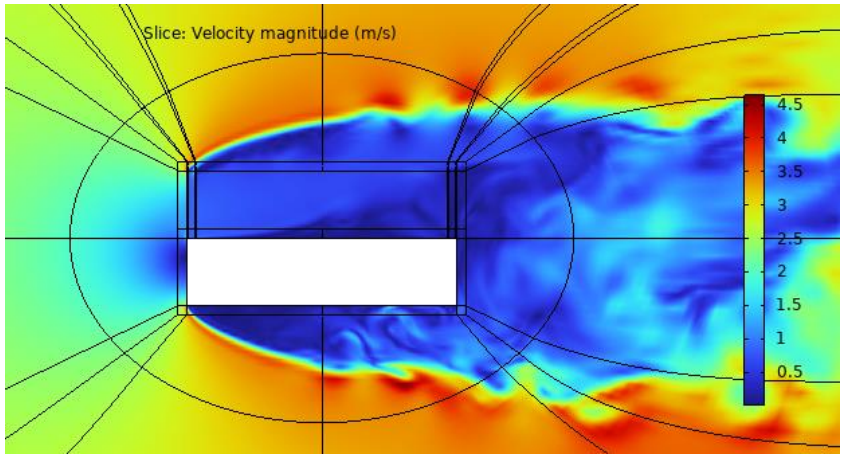


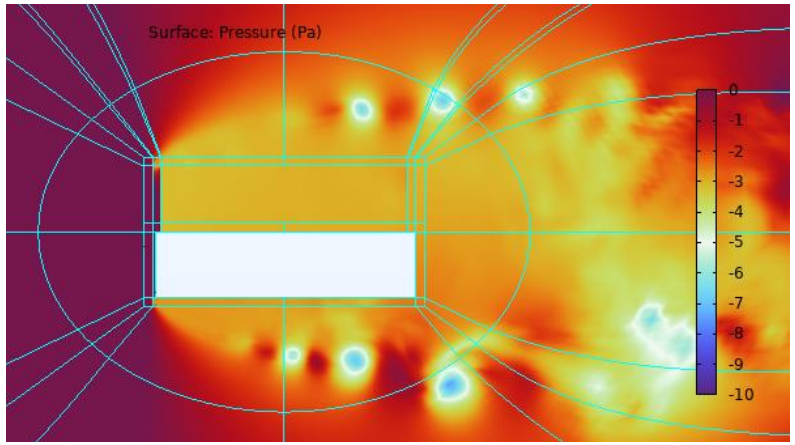


c_D=1.37

c_L=-0.2

2 porous zones

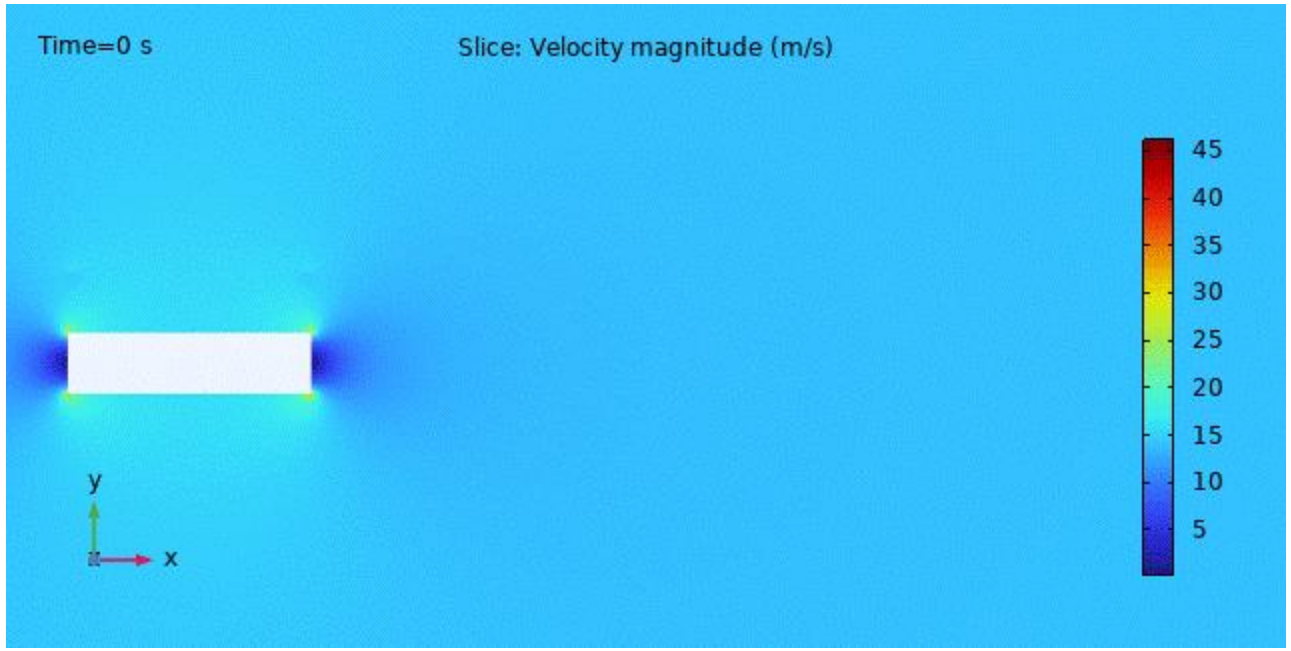




c_D=1.41

c_L=-0.13

3D LES simulation- results II.



Conclusions

- simulations of the air flow around u-profile having porous barrier were performed in Comsol Multiphysics software
- pressure jump attempt based on the opposite volume force was used
- obtained drag and lift coefficients are in qualitative agreement with measured data
- parametric study including various angles of attack and various porosities is planned