COMSOL CONFERENCE EUROPE 2012

SIMPLIFIED NUMERICAL MODEL OF AN AXIAL IMPELLER

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Purpose: simulate the flow field down-stream of an axial impeller, using a simplified numerical method (without modeling the actual blades of the axial hydraulic machinery and consequently without the use of a rotating mesh).

Applications: forced coolers, cooling towers, drying kilns, all sorts of axial mixers for liquid solutions, air flow in computers, axial wind turbines farms or axial marine current turbines farms (with an inverse sign for the force coefficients)

Method: replacing the blades with proper force coefficients added to the body force terms in the Navier-Stokes equations

$$\rho\left(\frac{\partial V}{\partial t}+V\,\nabla V\right)=-\nabla p+\mu\,\nabla^2 V+F$$

$$[F]=N/m^3$$

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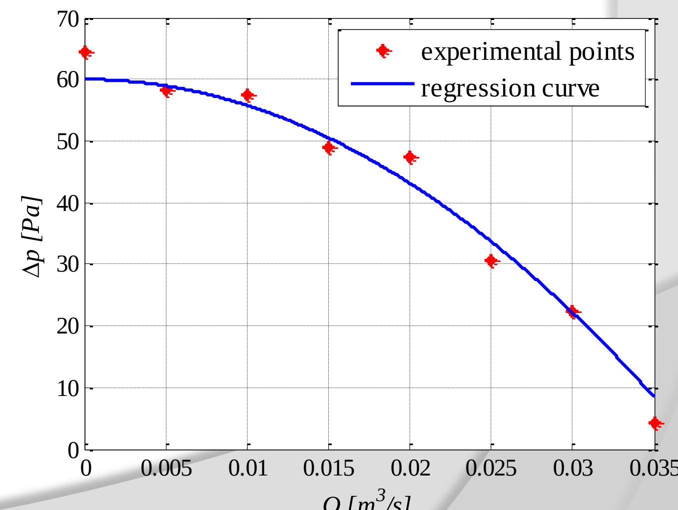
Study case: experimental unit equipped with an axial fan (FM41 unit designed by Armfield)

Needed data for the fan:

- pressure - flow rate curve →
- rotational speed → *n =45 rot/s*



$$\Delta p = A - BQ^2$$

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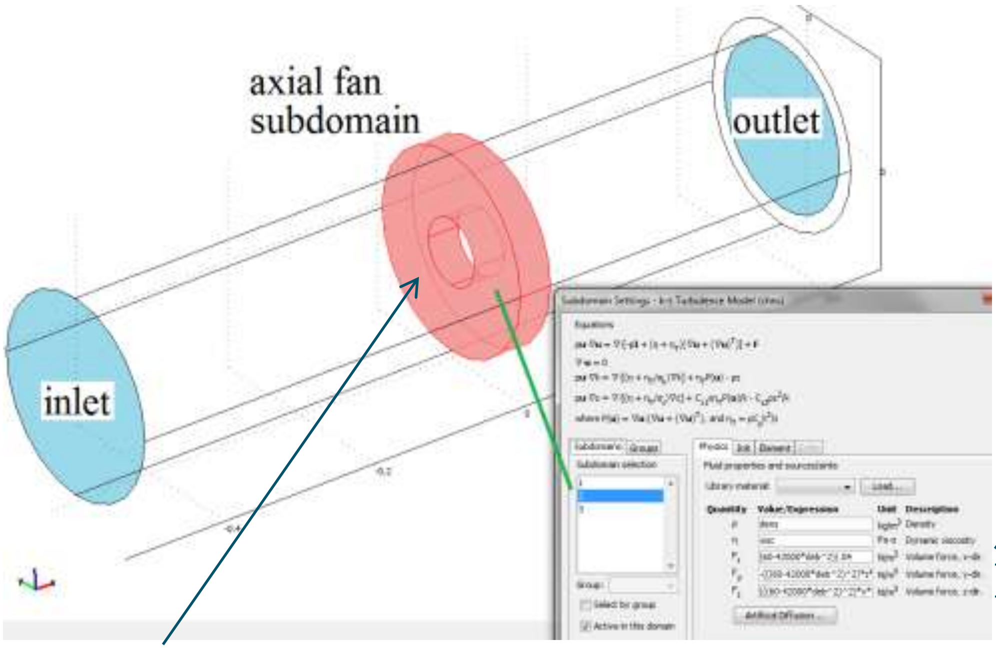
Computational flow domain

$$k - \varepsilon$$

Turbulence model



Straight forward

$$F_x = \frac{\Delta p}{b} = \frac{60 - 42000Q^2}{0.04}$$

Complex

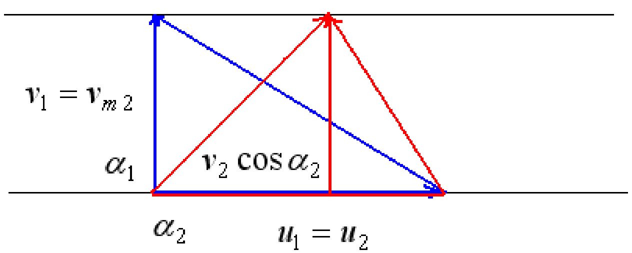
$$Q = \int_{A_i} V \, dA$$

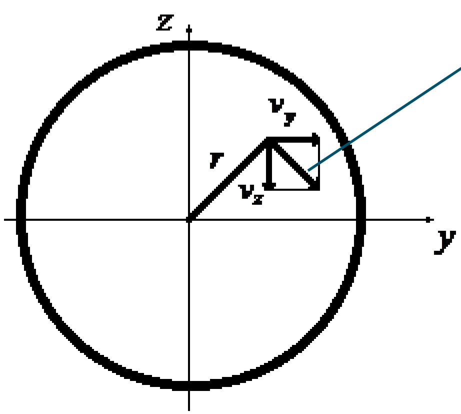
Integration variable

Force coefficients

Main energy equation for pumps (Euler)

$$H_{T\infty} = \frac{1}{g}\left(u_2 v_2 \cos\alpha_2 - u_1 v_1 \cos\alpha_1\right)$$





$$v_2 \cos\alpha_2 = \frac{\rho g H_{T\infty}}{\rho \eta_h u_2} = \frac{\Delta p}{\rho 2\pi n\, r}$$

$$\begin{cases} F_y = \dfrac{\rho \dfrac{v_y^2}{2}}{b} \\ F_z = \dfrac{\rho \dfrac{v_z^2}{2}}{b} \end{cases}$$

$$\begin{cases} F_x = \dfrac{\Delta p}{b} = \dfrac{60 - 42000 Q^2}{0.04} \\ F_y = \dfrac{-\Delta p^2 z\,|z|}{7675\left(y^2 + z^2\right)^2} \\ F_z = \dfrac{\Delta p^2 y\,|y|}{7675\left(y^2 + z^2\right)^2} \end{cases}$$

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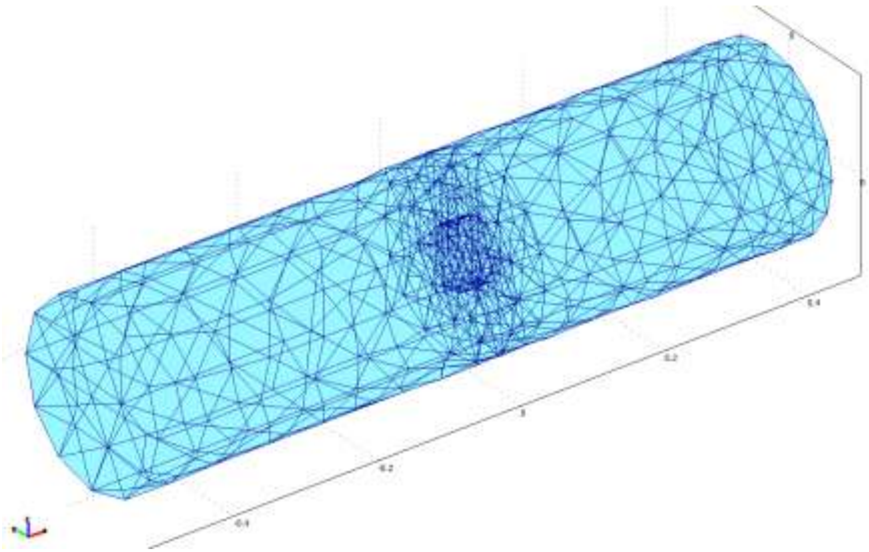
Boundary conditions and mesh



- Atmospheric pressure, no viscous stress, on both inlet and outlet sections
- Logarithmic wall function on all other boundaries except the ones connecting the subdomains
- Open boundaries connecting the subdomains

- 4158 tetrahedral elements
- 1200 triangular boundary elements
- 172 edge elements
- 28 vertex elements

} 33406 degrees of freedom

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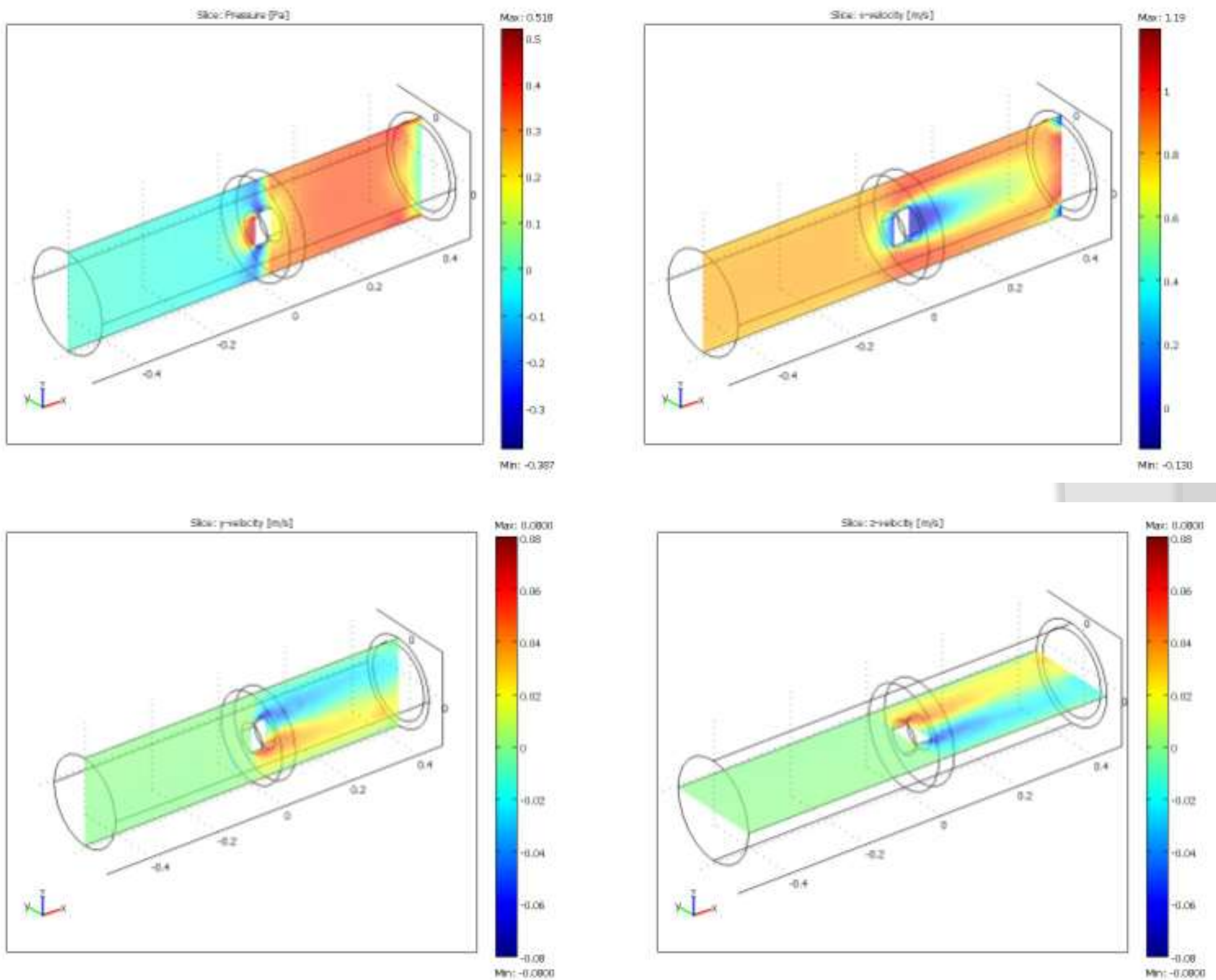
Results



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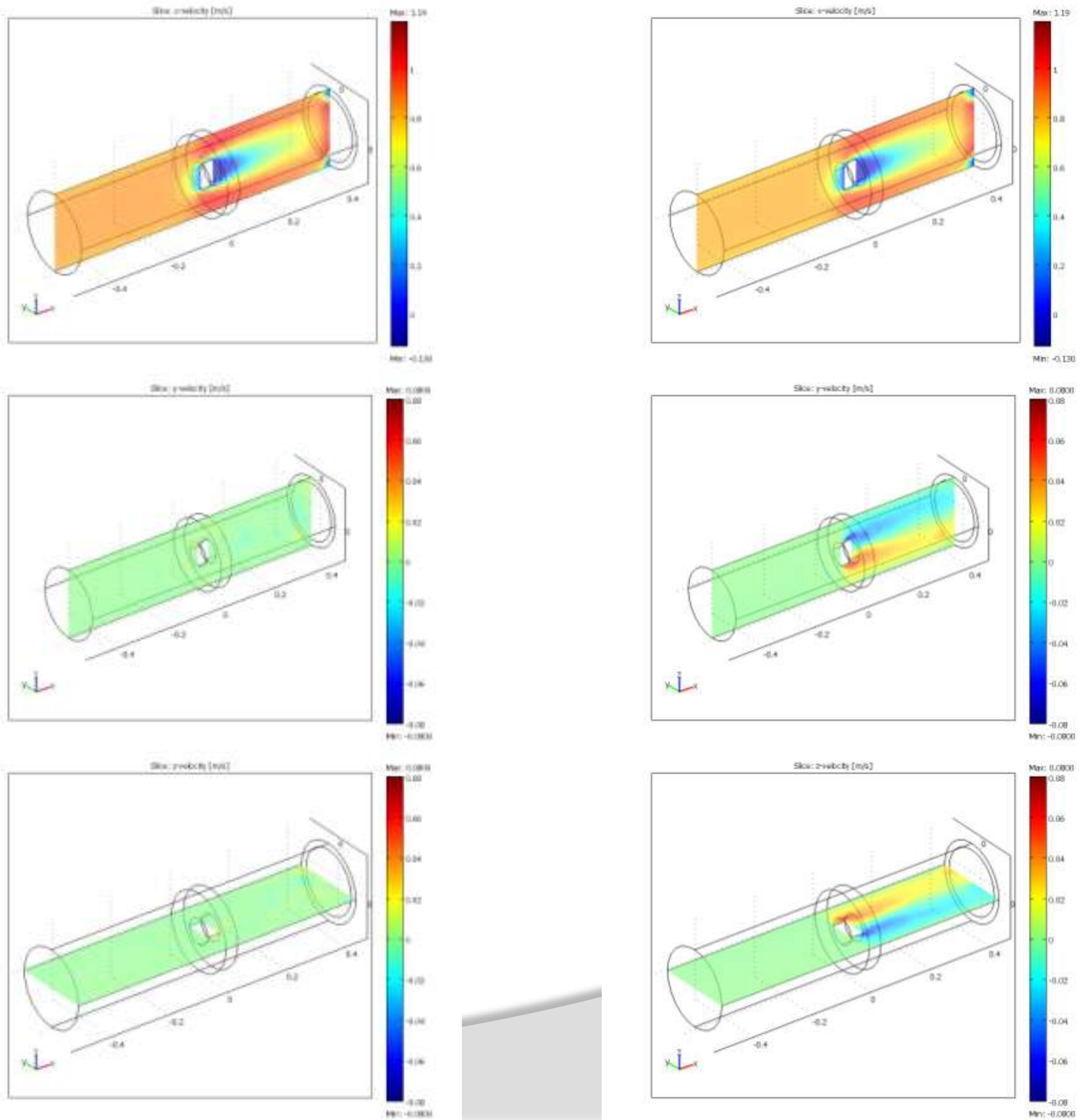
Velocity

x component

y component

z component



Conclusions

- Computed results are found to be in good agreement with the pressure – flow rate curve measured on the FM41 experimental unit.

- The method has proven to save a lot of computational time, e.g. one computation took less than 18 minutes on a workstation with 16GB memory and 2 quad-core Intel Xeon 2.66GHz processors

Thank you.