Community Christmas Competition 2019

PITOT TUBE

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A bit of background

The Pitot tube is used to measure the relative velocity of an object relatively to its medium. It is found on planes, boats and labs for hopeful fluid engineering students who seek knowledge and recently is has been found in a CFD Christmas Competition for people who decide to carefully spend their free time with OpenFOAM… :-)

By measuring the difference between the dynamic and the static pressure, one can find the velocity by Bernoulli (cf. Wikipedia)

For incompressible flows : $V = \sqrt{\frac{2(p_T - p_S)}{\rho}}$

For compressible flows : $\frac{p_T}{p_S} = \left(1 + \frac{\gamma-1}{2} M^2\right)^{\frac{\gamma}{\gamma-1}}$

$V = 0{,}1\ m/s$

So does it even work?

- *Steady State, single phase (simpleFoam)*
- *2D, CAD as simple as possible*
- *Laminar*

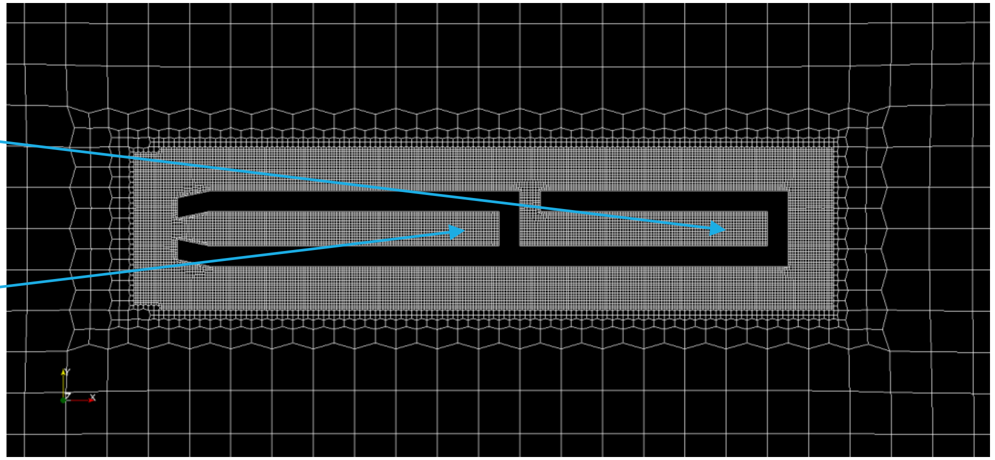
$$V_{CFD} = 0.107\ m.s^{-1} \rightarrow \sim 7\%\ error$$

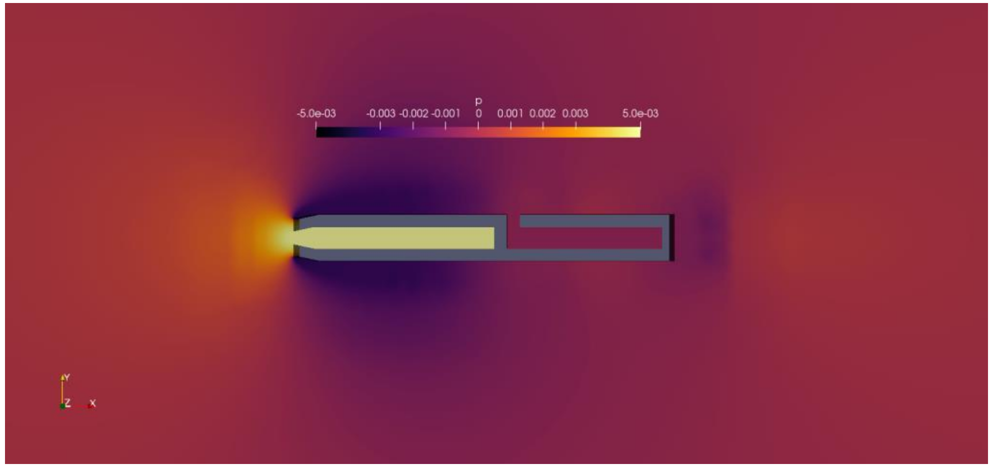
Not great, not terrible!

Changing the mesh did not help.

$\frac{p_S}{\rho}$

$\frac{p_T}{\rho}$





However at low speeds, it is expected, see:

http://www.surreysensors.com/article/uncertain-pitot-static-probe/

*" This translates to an uncertainty in velocity of about ±0.25% at maximum speed- but more than **±7% at the lowest speeds!** "*

$V = 1\,m/s$ *Christmas Lab Experiment V1*

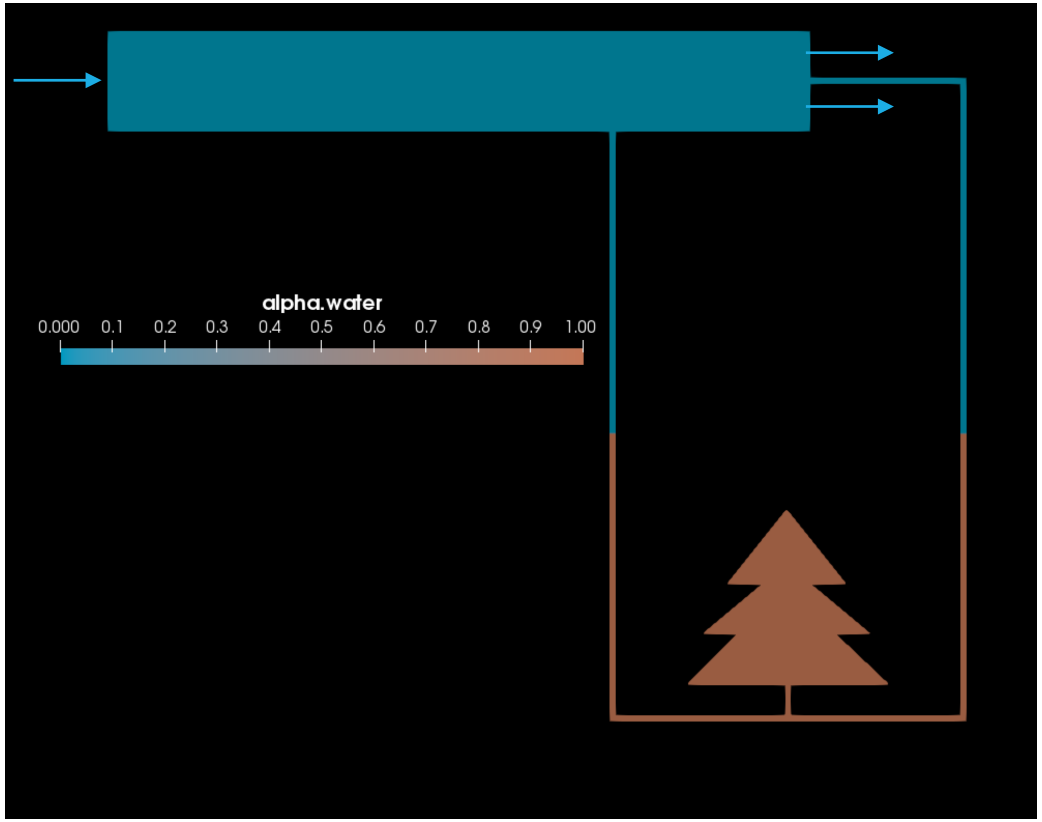
- *Unsteady, multiphase (interFoam)*
- *2D, tiny bit fancier CAD*
- *Turbulent ($k-\omega$ SST with Wall-Functions)*

Imagine a lab experiment: Measure the flow velocity by measuring the height difference in the tube.

$$V_{CFD} = \sqrt{2g\frac{\rho_0 - \rho}{\rho_0}\Delta h}$$

Δh: Obtained by tracking $\alpha = 0.5$ in the pipes

$\rho = \rho_{oil} = 850\ kg.m^{-3}$ *(in pipe)*
$\rho_0 = \rho_{water} = 1000\ kg.m^{-3}$ *(in Christmas tree)*



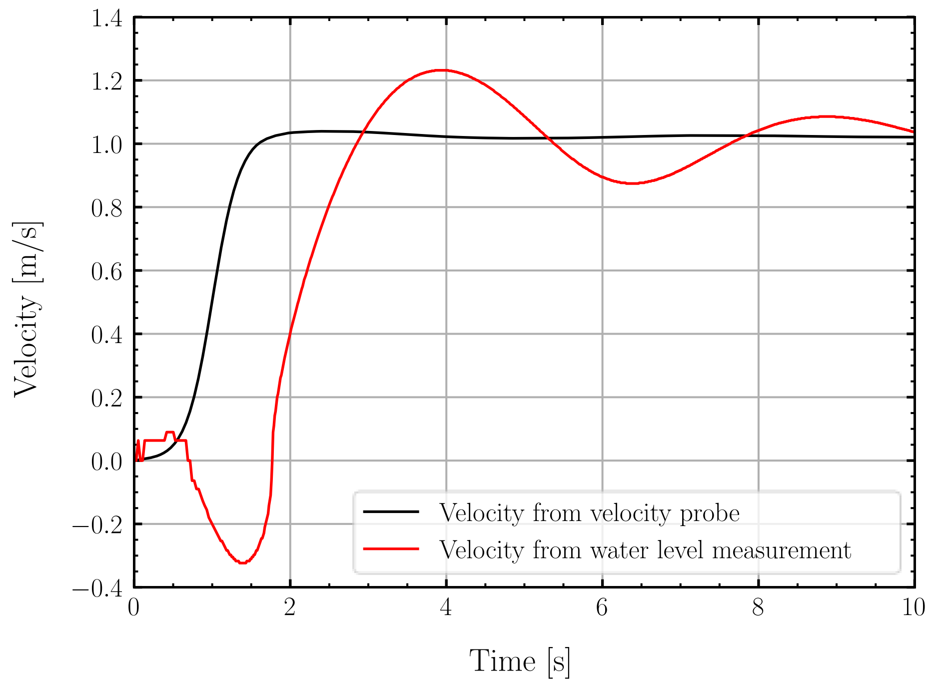
$V = 1\, m/s$ *Christmas Lab Experiment V1*

V_{ref} is measured in the pipe

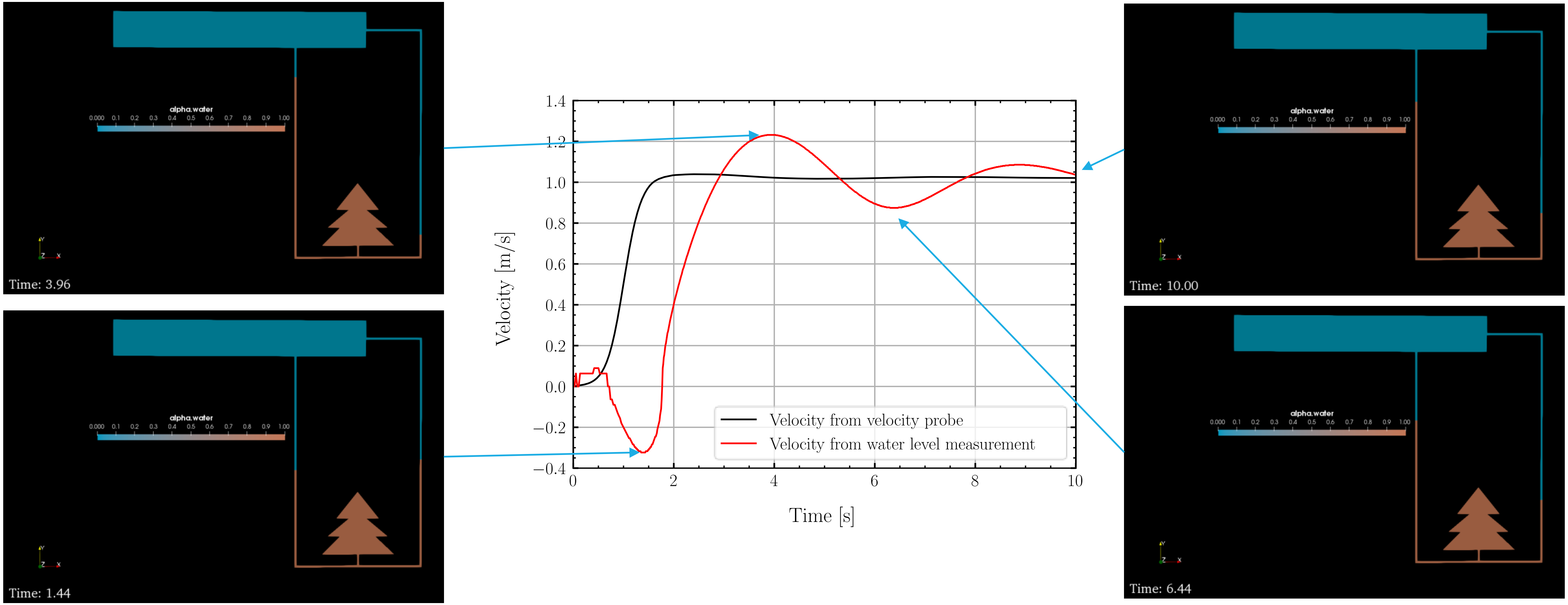
Uff, the very fast velocity increase makes the water in the pipe oscillates! I assume it would converge to V_{ref} more or less.

That is a bad system to live-track unsteady flows :D

Gif : https://media.giphy.com/media/KD1BcXIQVs6xHv26Lb/giphy.gif



$V = 1\,m/s$ *Christmas Lab Experiment V1*

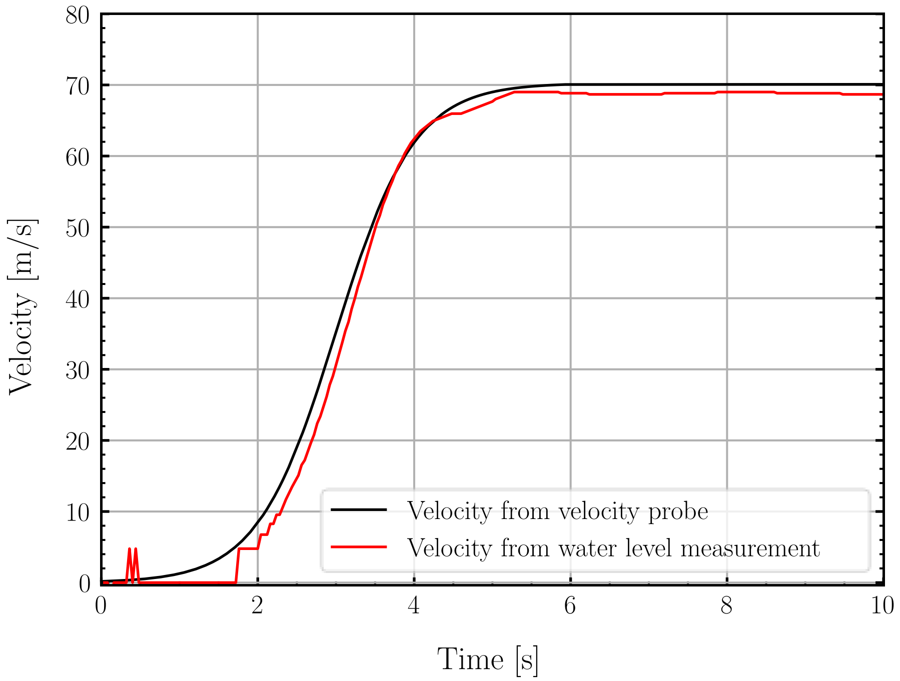


$V = 69\ m/s$ Christmas Lab Experiment V2

The same thing is done, with different fluids, different speed, and a way smoother prescribed velocity at the inlet. Now results look way better ☺

At $t = 10s$*, the error is* 2%*, which is good enough.*

Water was used in the pipe and mercury as the heavy fluid.



$V = 100 - 240\, m/s$ *Dragster*

I tried something very cool with FSI, having some piece deformed by the pressure difference in the chamber, but the case diverged and I did not find out the mistake unfortunately!

Another time!

Thank you for the Competition, see you next year !