OpenModelica workshops 2021
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Modelling and simulation of Positive displacement machines with OpenModelica

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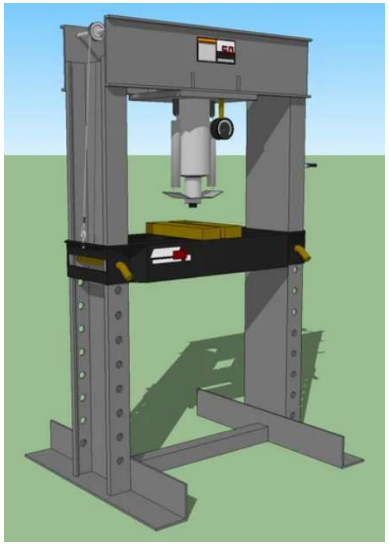
Modelling PD Vane Pumps with OpenModelica

Fluid Power for Industrial and Mobile Applications needs to:

- guarantee performances
- be safe and reliable
- be “low cost”
- be efficient
- be hybrid



To guarantee these features:

- combined use of virtual tools during the design of systems and components

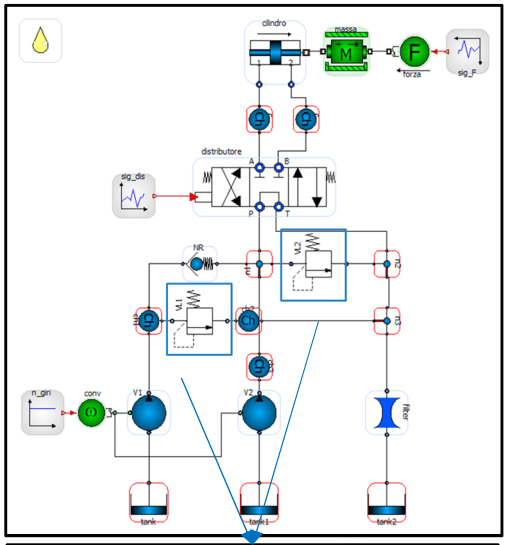
Modelling PD Vane Pumps with OpenModelica

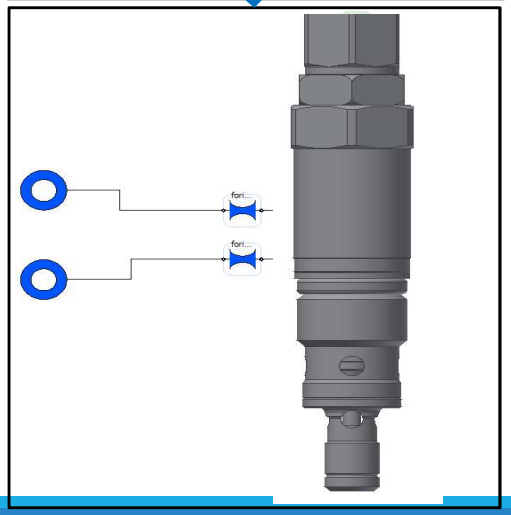
The focus here is on **dynamic behaviour of hydraulic systems and components**

→physical modelling of components
→simplified models of components and modelling of entire systems
→integration of systems of different nature (hydraulic, pneumatic, mechanic, electric, control…)

…**commercial tools available** to do that, **but** :

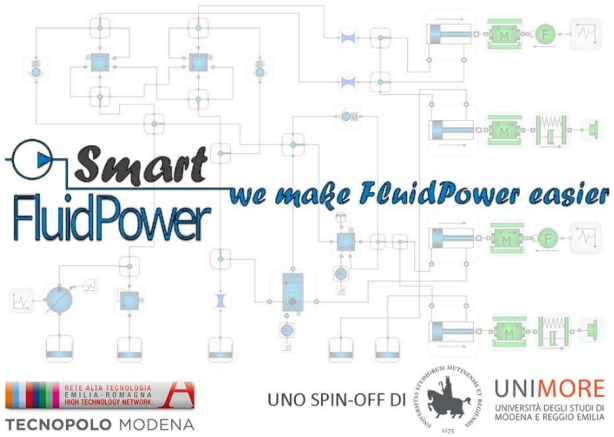
→you can't control, change ,adapt the mathematical models of each element
→ it's more challenging to develop our own design instruments
→it's more challenging to spread the use of virtual simulation in the small-medium fluid power industry (expensive!)





Modelling PD Vane Pumps with OpenModelica

SmartFluidPower library is developed in order to ease the simulation of fluid power components and systems



- **H** — Hydraulic package to model complex circuits with valves blocks, pipes, orifices, sensors, cylinders, motors and pumps
- **M** — Package with translational and rotational mechanical elements, sources and sensors
- **HC** — Package made by blocks that can model hydraulic components in detail, such as pistons, poppets, spools, leakages and seals
- **S** — Package with signal blocks in order to introduce various inputs and make different operations, such as logical ones, conversions and interpolations
- Other packages set the fluid characteristics and insert ports to interface different models
- Logic library with ISO symbols for the components to draw hydraulic schemes and simulate their functionality in stationary conditions

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Modelling PD Vane Pumps with OpenModelica

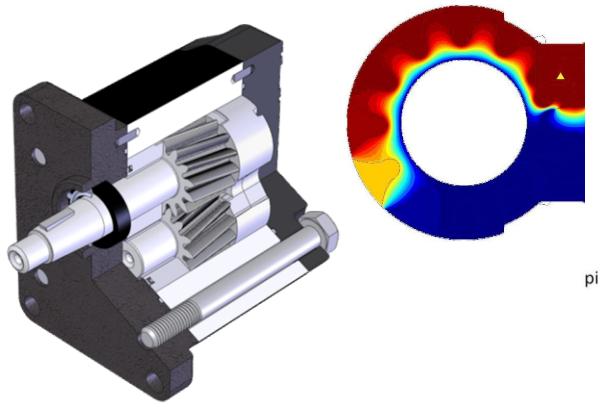
Today we speak about lumped parameter modelling of pumps and motors with our library

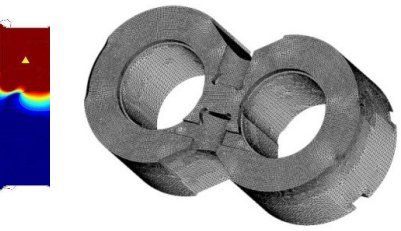
→ Pressure transients (peaks, cavitation risk…)

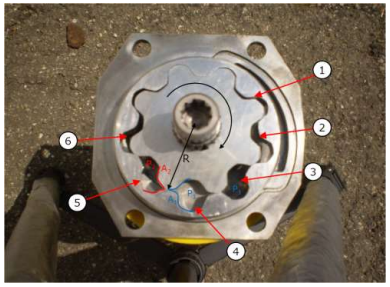
→ Instantaneous flow rate and torque → flow ripple, torque ripple pressure ripple

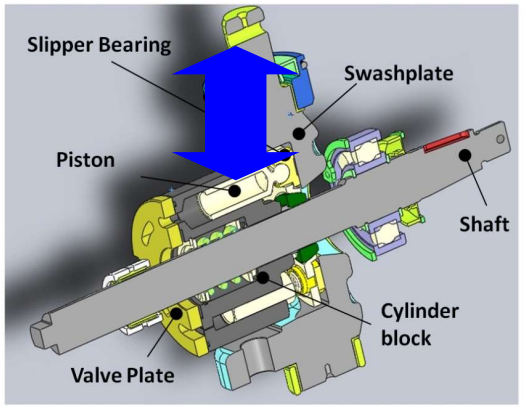
→ Instantaneous forces on the internal elements (displacement control)

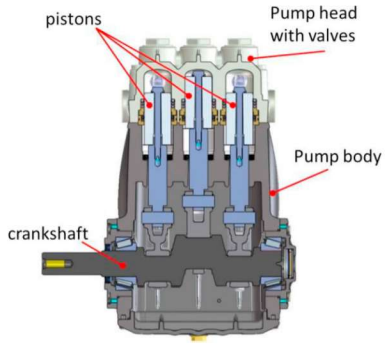
→ Interface with the circuit

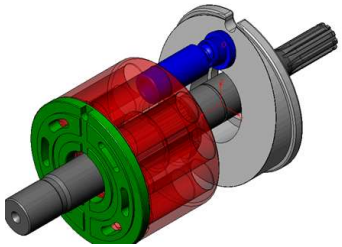






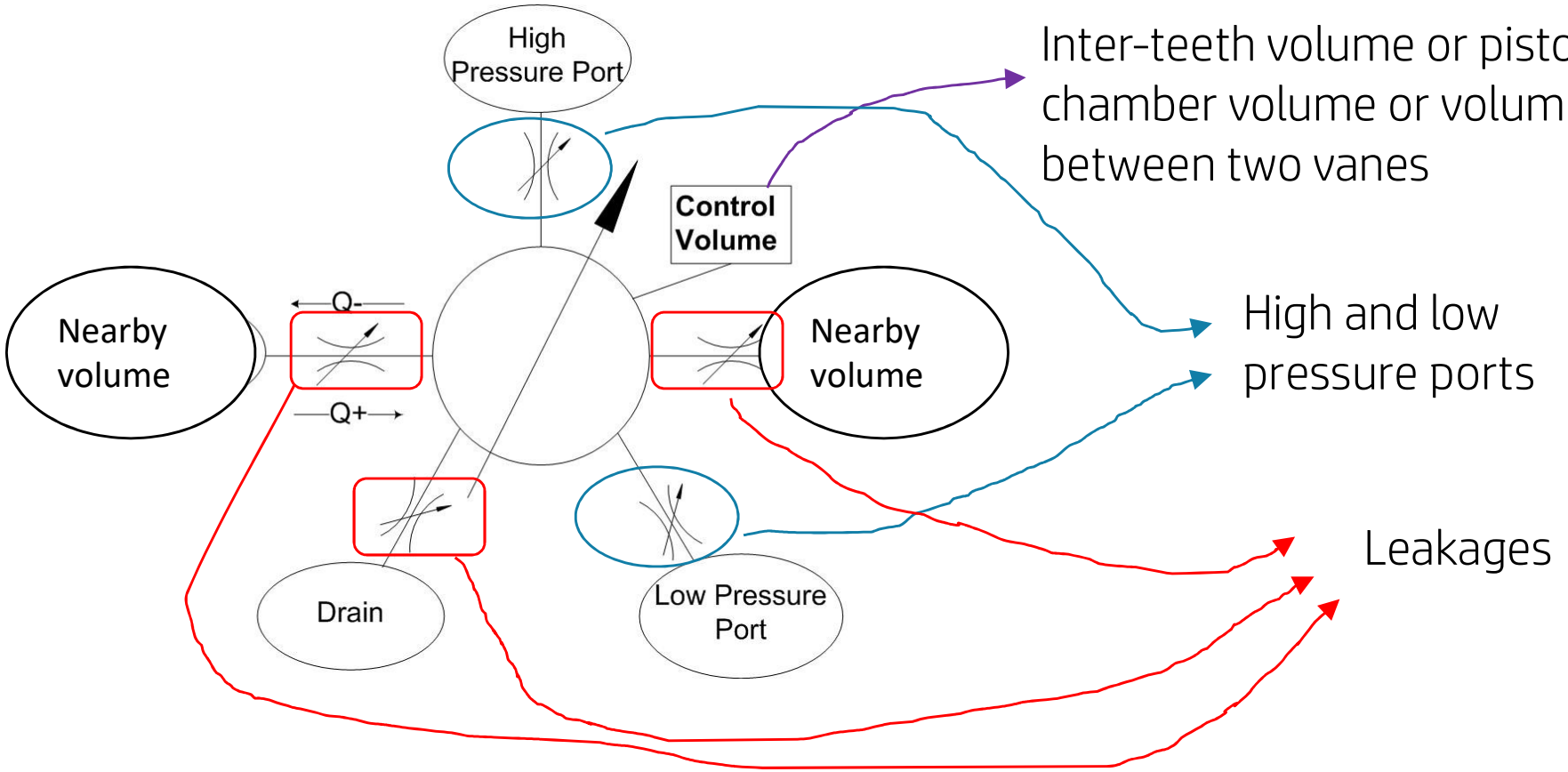






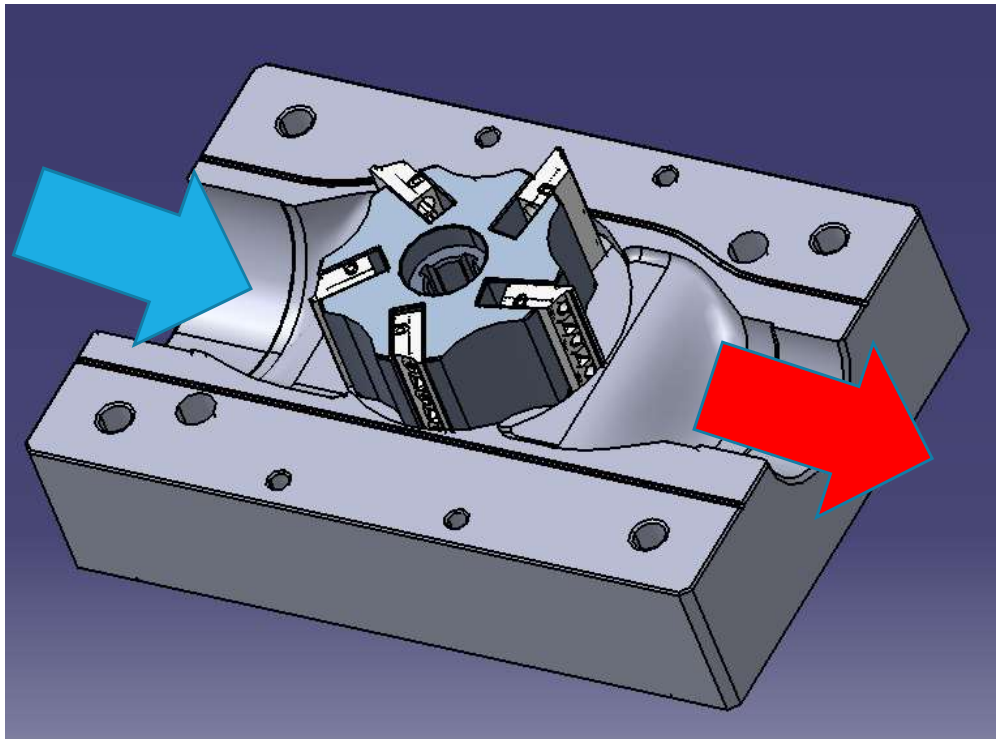
Modelling PD Vane Pumps with OpenModelica

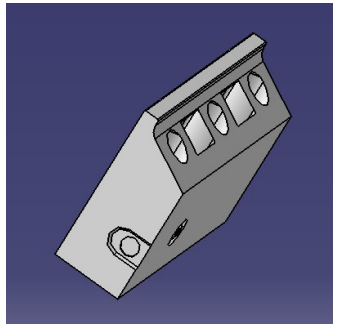
Based on the definition of a Variable Control Volumes within the pump/motor where the pressure transient happens

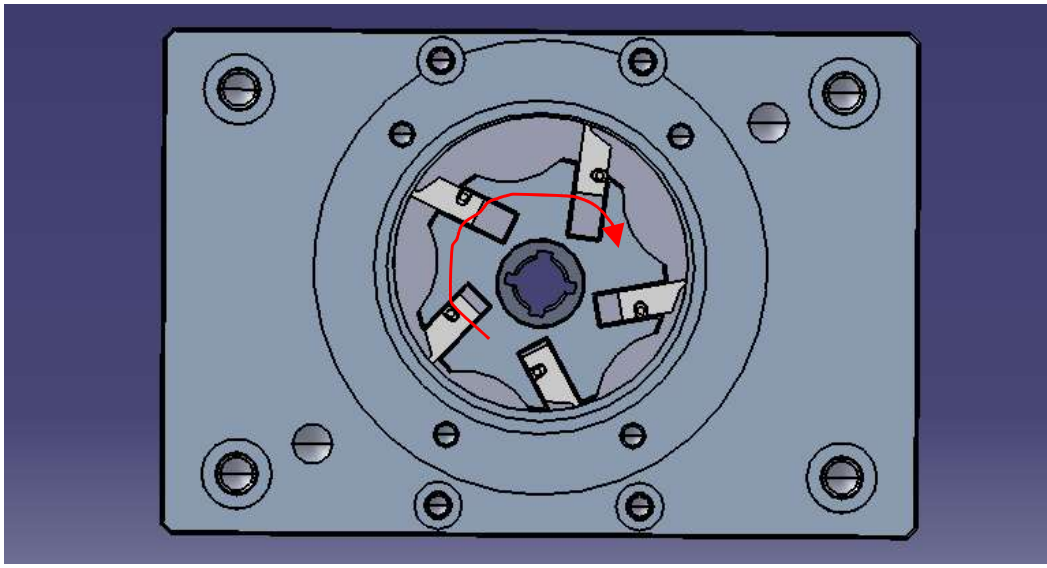


Modelling PD Vane Pumps with OpenModelica

Vane Pump for fuel filling applications (low pressure)





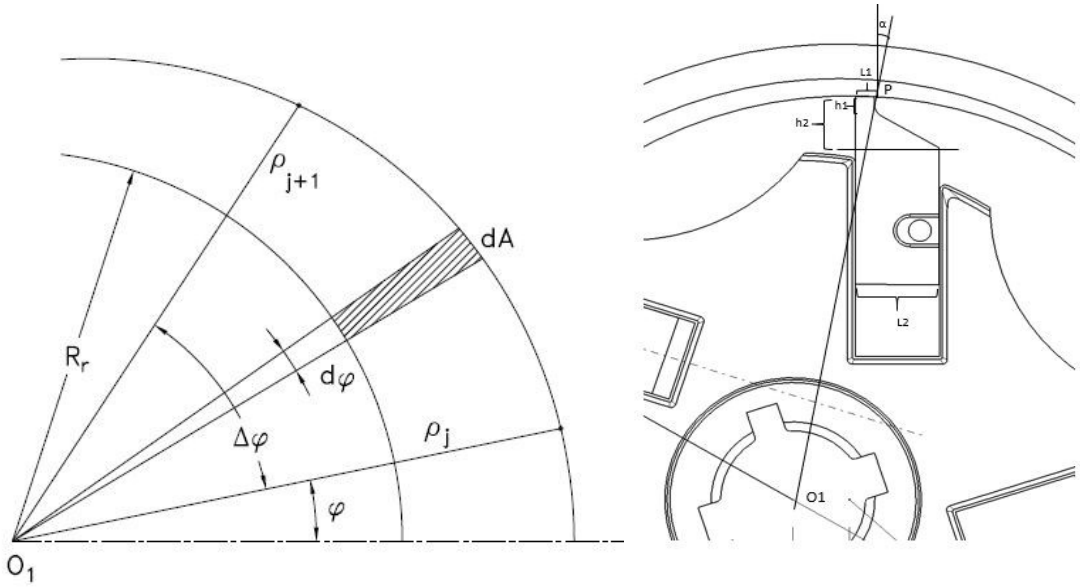


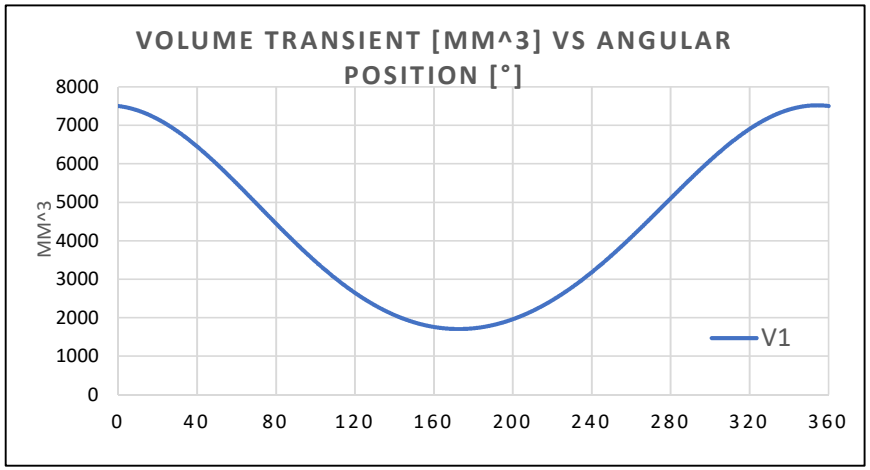
Modelling PD Vane Pumps with OpenModelica

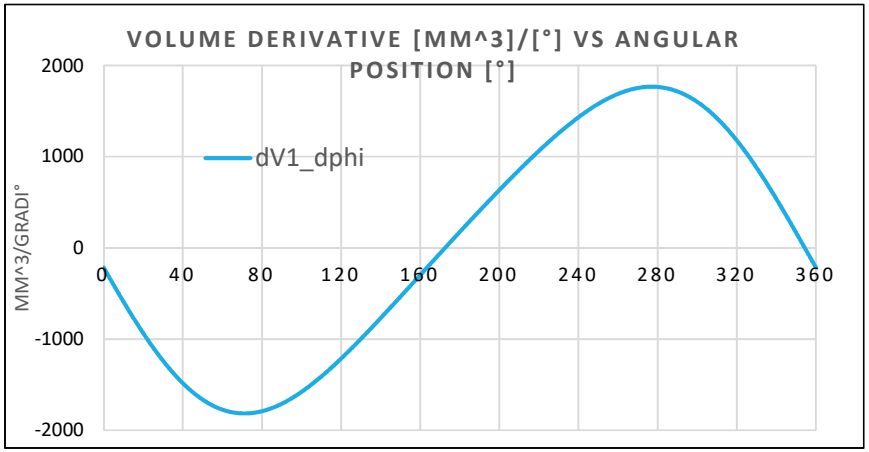
Vane Pump for fuel filling applications (low pressure)

Evaluation of the geometry (volume variation, flow areas) inside OpenModelica

$$\frac{dV_j}{d\varphi} = \frac{1}{2} H \left[\rho_{j+1}^2 - \rho_j^2 - 2\, R_r \frac{dh_j}{d\varphi} \gamma_j - 2\, R_r \left(\frac{L2}{Rr} - \gamma_j \right) \frac{dh_j}{d\varphi} \right]$$







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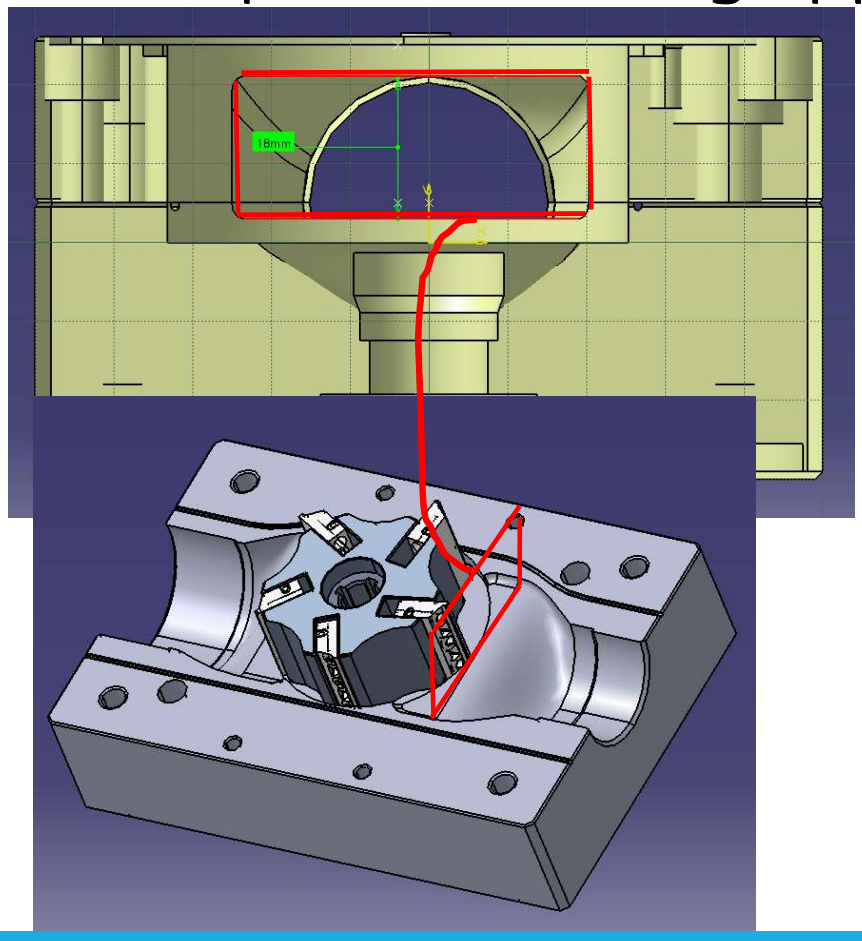
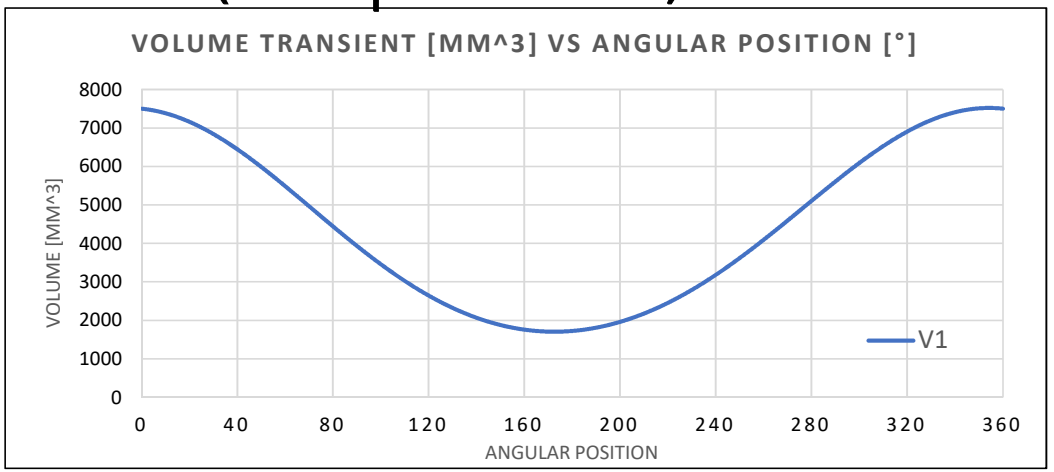
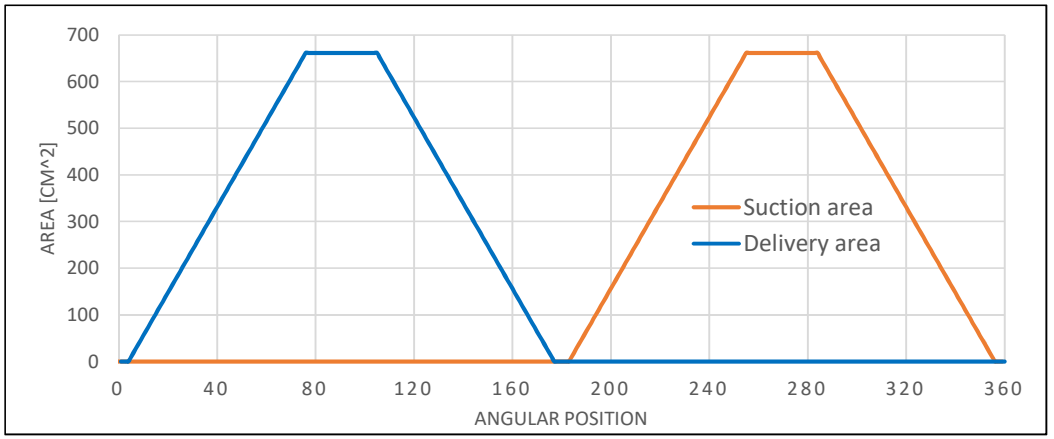
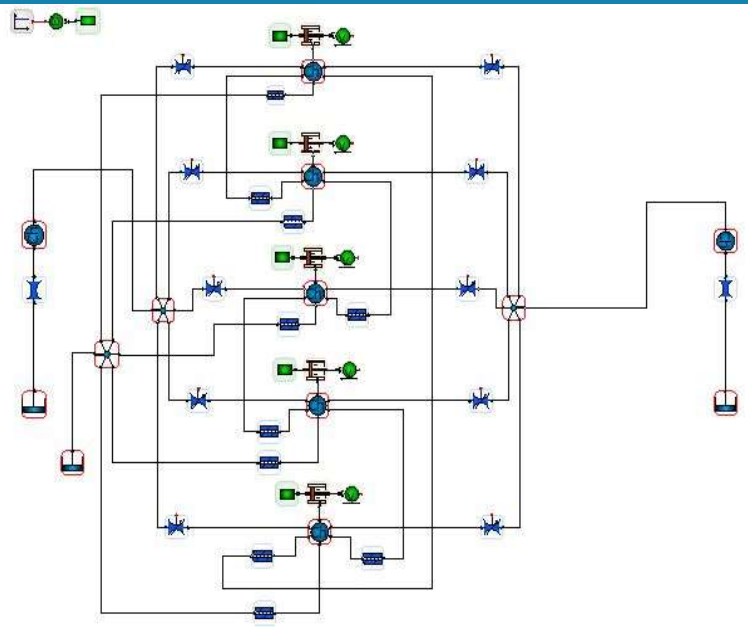
Vane Pump for fuel filling applications (low pressure)





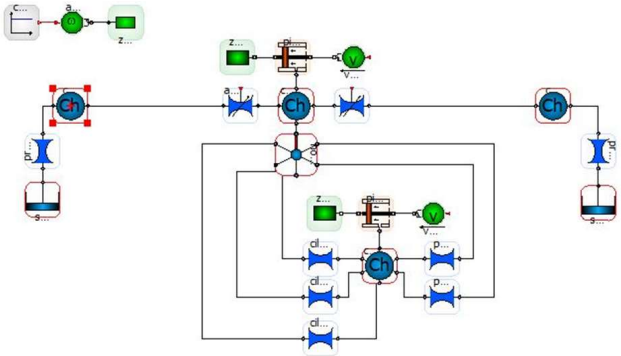


Modelling PD Vane Pumps with OpenModelica



Simplified model with input geometry coming from the routine written in OpenModelica

Advanced model with vane displacement and velocity as input



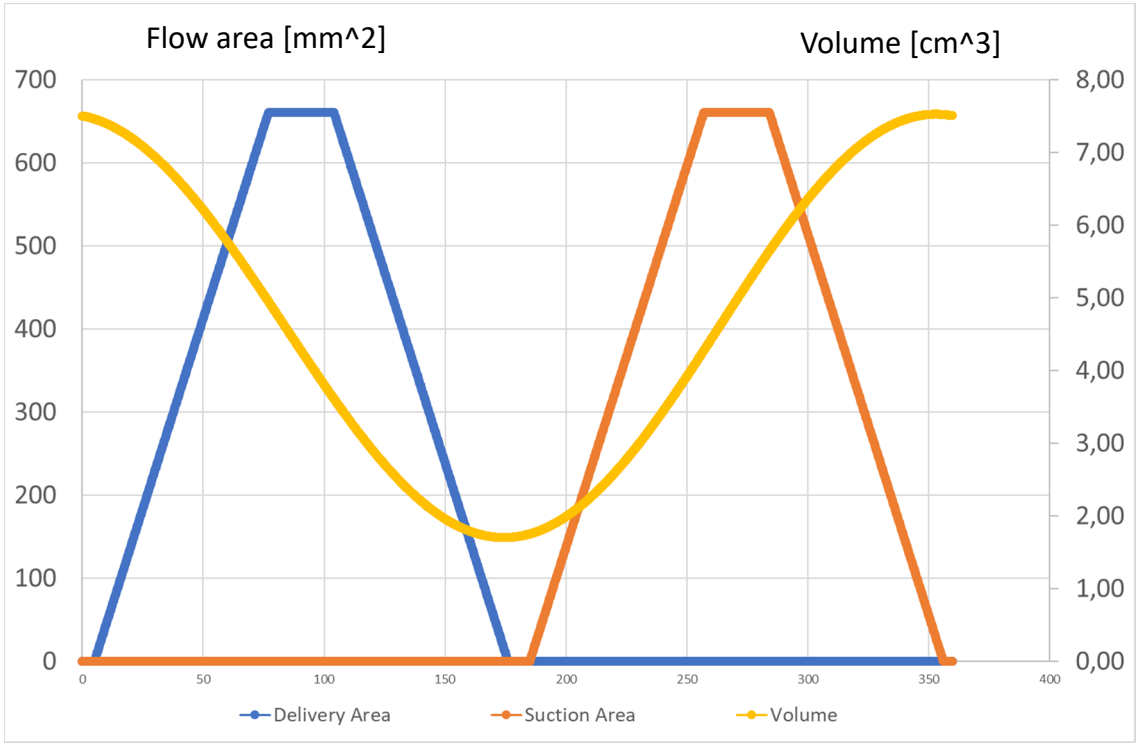
$$\frac{dp}{dt} = \frac{B}{V}\left[\sum_{i=0}^{n} Q_i - \frac{dV}{dt}\right]$$

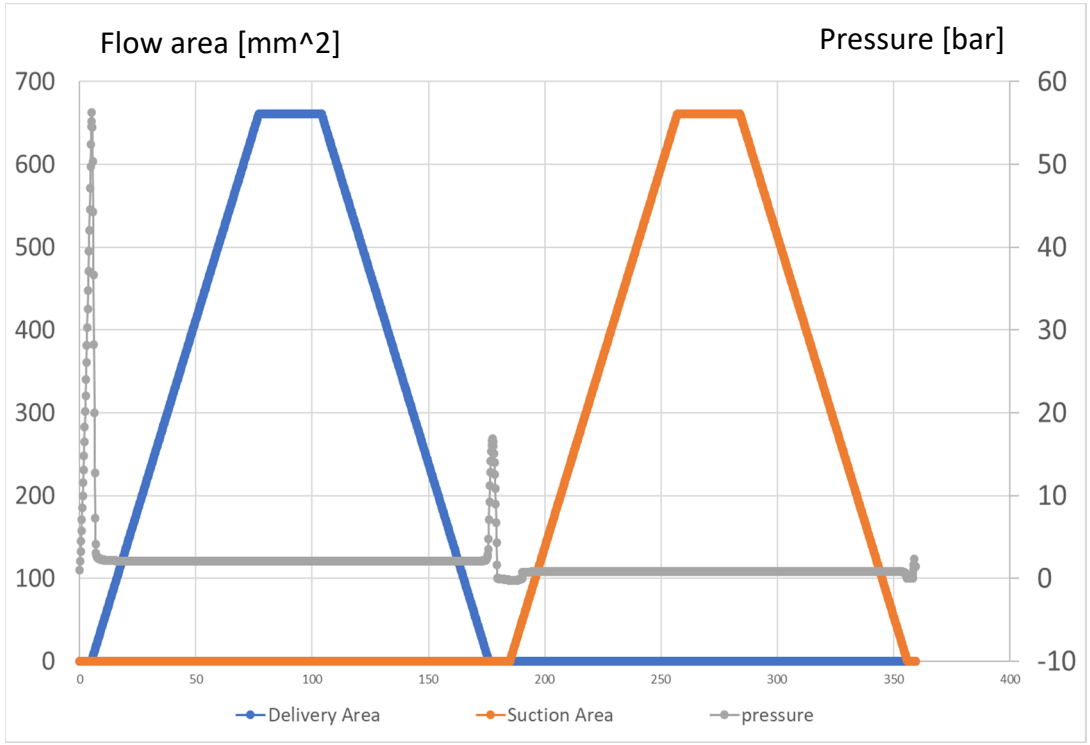
$$\omega = \frac{d\theta}{dt} \Rightarrow \frac{dp}{d\theta} = \frac{B}{V}\left[\sum_{i=0}^{n} \frac{Q_i}{\omega} - \frac{dV(\theta)}{d\theta}\right]$$

Turbulent flow rate
Laminar flow rate

Modelling PD Vane Pumps with OpenModelica

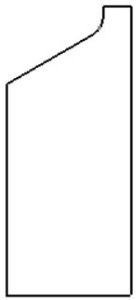
Results @ delivery pressure = 2 bar, rotational speed 3000 rpm

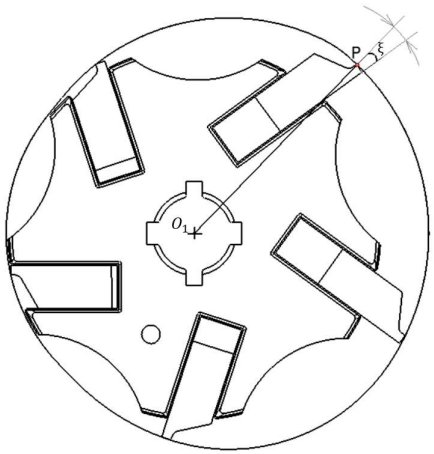


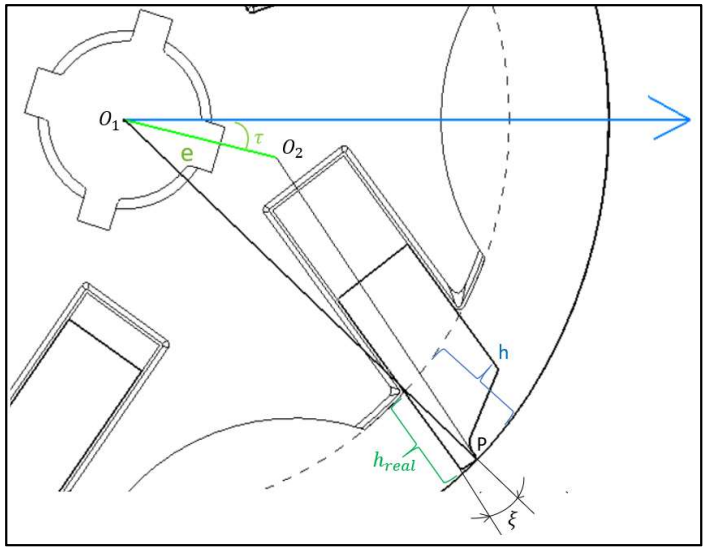


Modelling PD Vane Pumps with OpenModelica

Design Analysis







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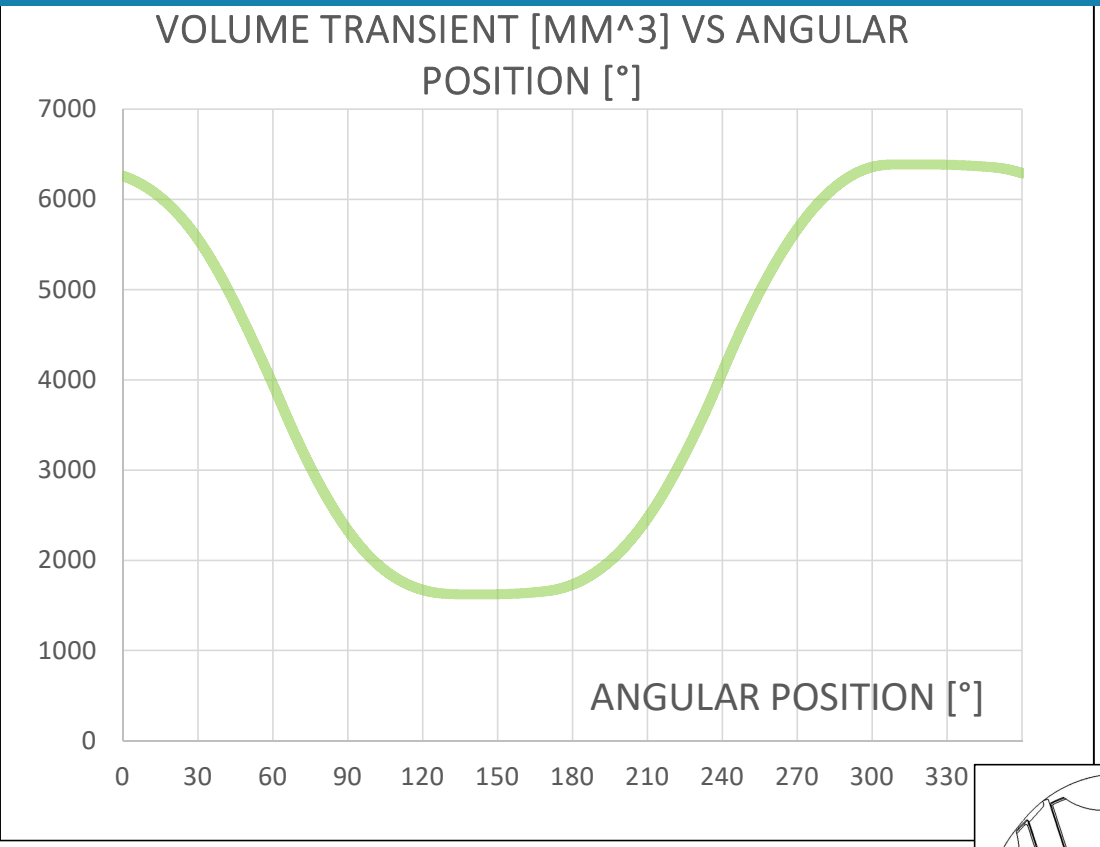
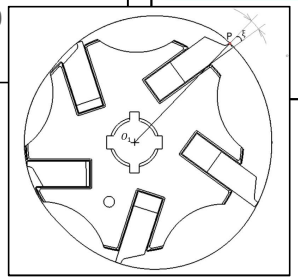
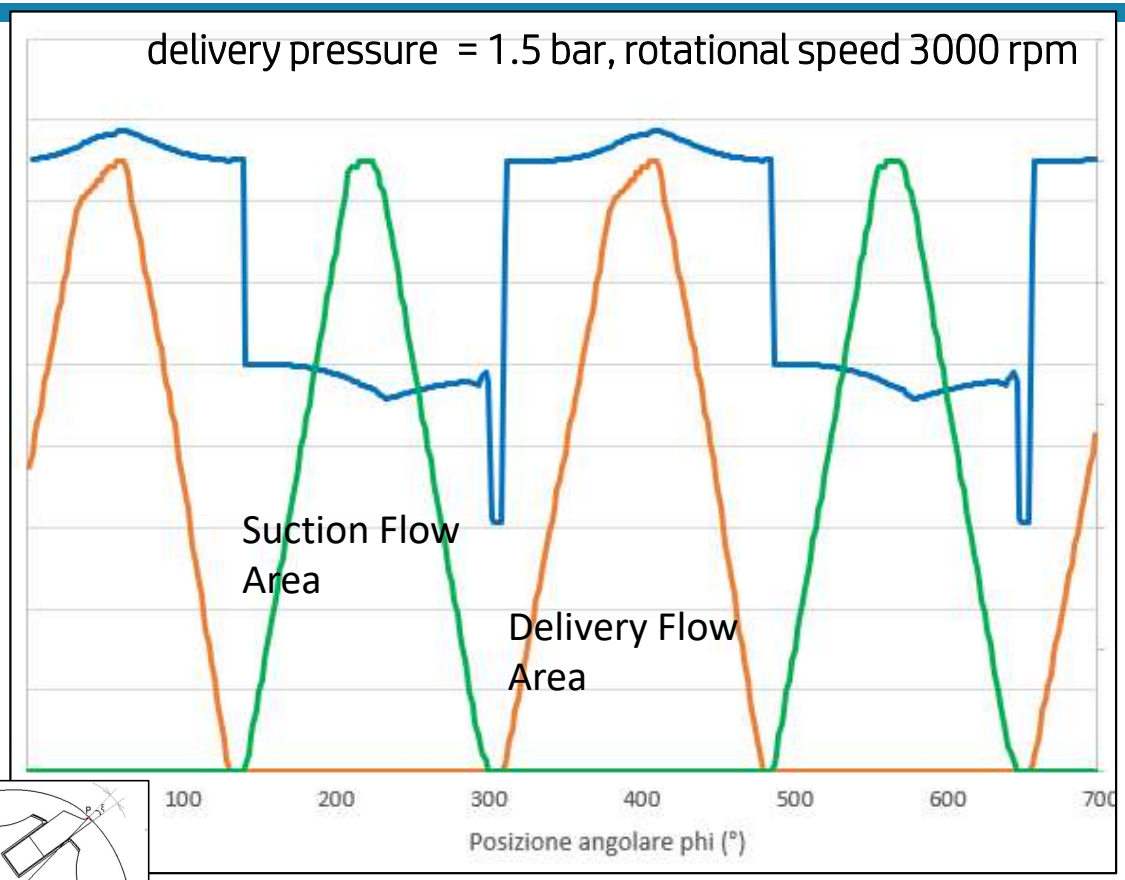
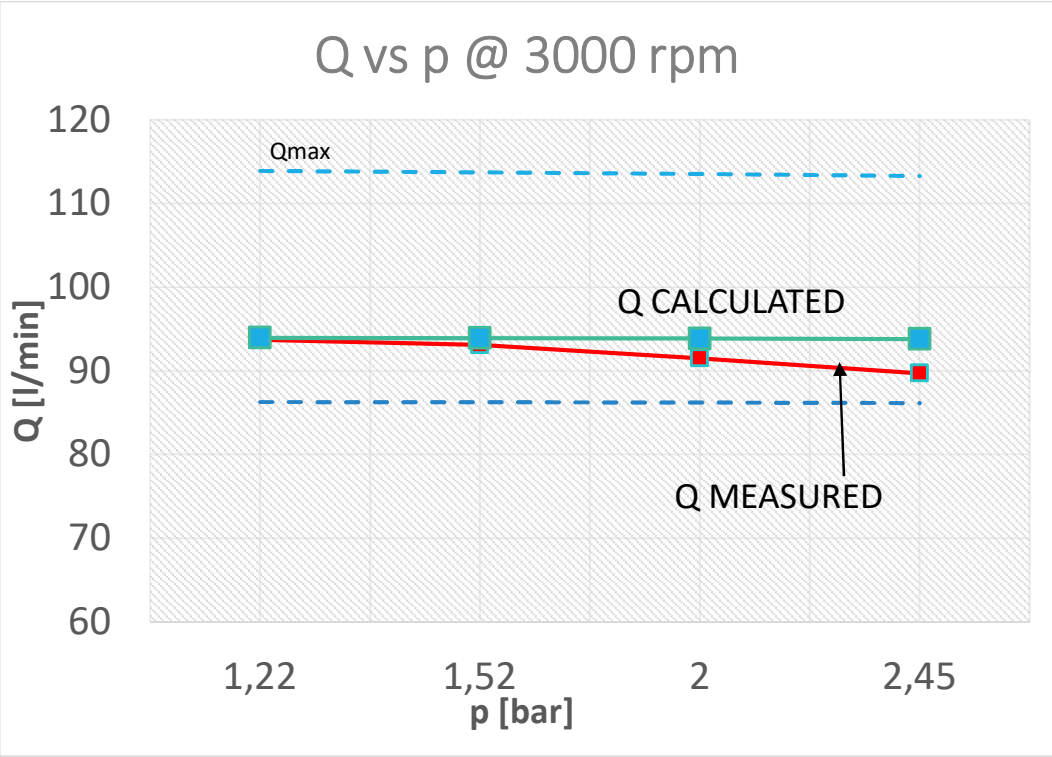






Modelling PD Vane Pumps with Ope



Remarks:

→Better identify leakages!

→Good design tool for geometry variation and pressure and flow rate transients evaluation

→Integration of the geometry and «hydraulic» performances evaluation within the same tool

→post-processing via VB or other tools

Thank you for your kind attention