University of Naples "Federico II"
Department of Industrial Engineering
Fluid Power Research Group

NUMERICAL AND EXPERIMENTAL ANALYSES OF VANE AND PISTON PUMPS

SCUOLA POLITECNICA E DELLE SCIENZE DI BASE

DIPARTIMENTO DI INGEGNERIA INDUSTRIALE

FPRG – FLUID POWER RESEARCH GROUP

West Lafayette

June 4th, 2019

Index

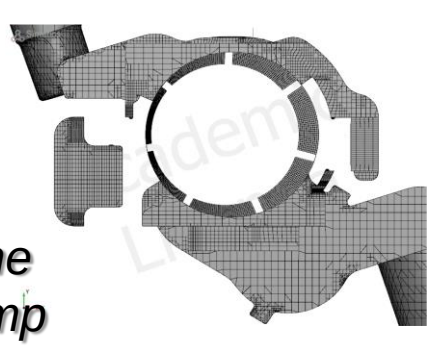
- ***FPRG*** *– University of Naples "Federico II"*

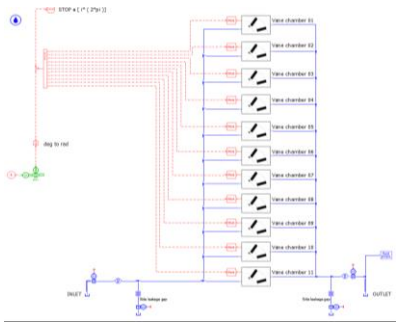
- Vane pumps:
  - Vane Dynamic
  - Chamber filling

- Piston pumps
  - Valve plate design model
  - Lumped parameter CV approach

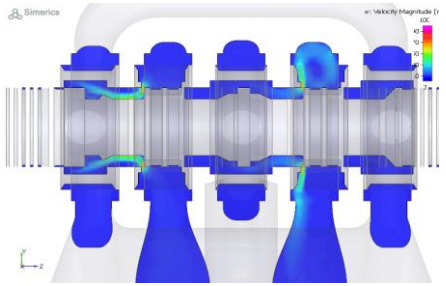
Numerical modeling simulations: 1D and 3D CFD approaches

Vane Pump



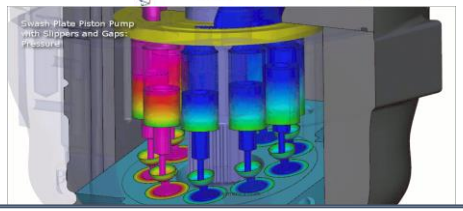


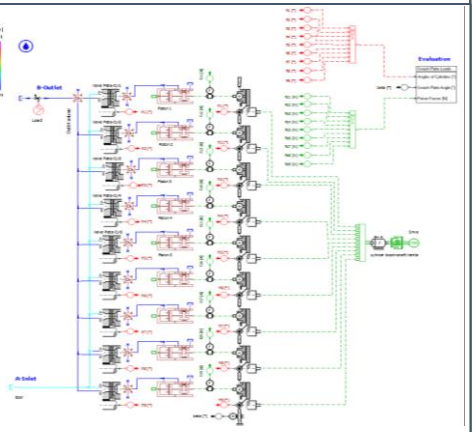
Spool Valve

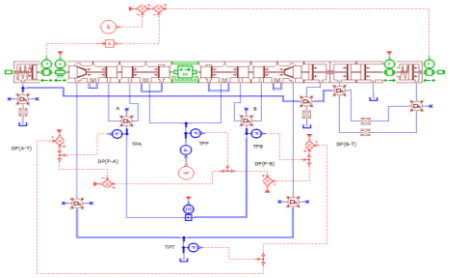


CONTINENTAL HYDRAULICS

Piston Pump

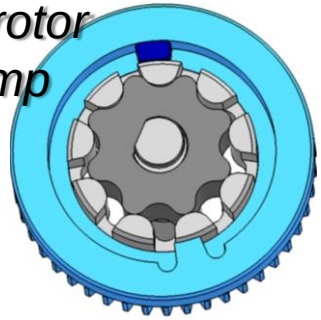


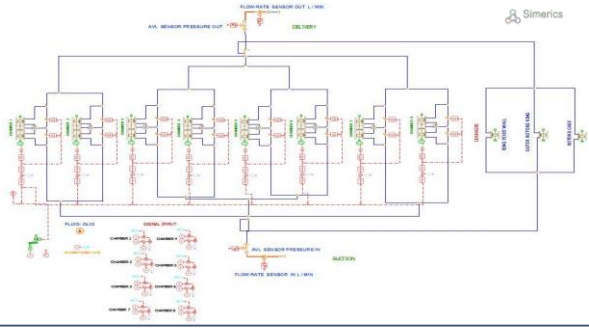


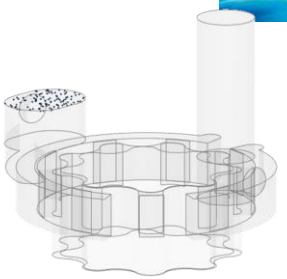


DUPLOMATIC MOTION SOLUTIONS

Gerotor Pump



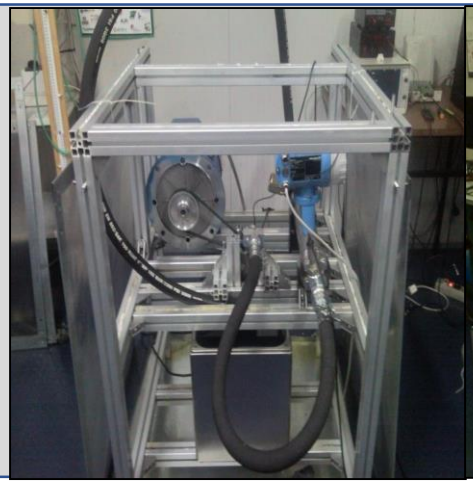


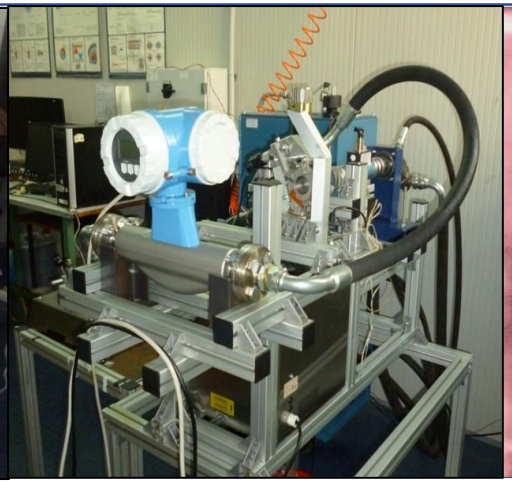


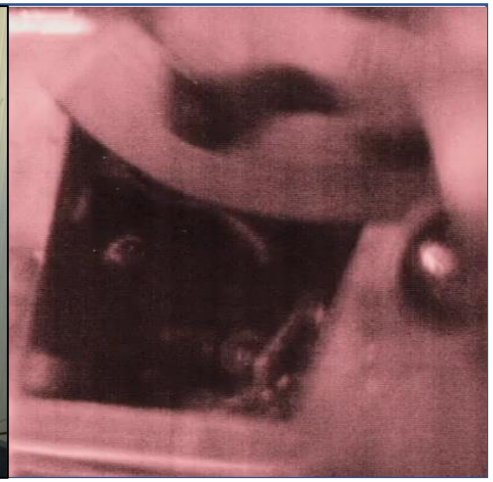
HORIZON 2020

Pumps: experimental setup

Lubrication Pumps





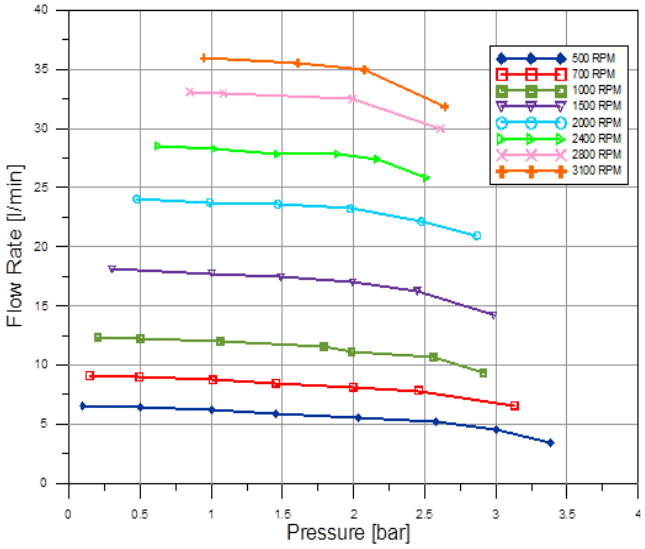


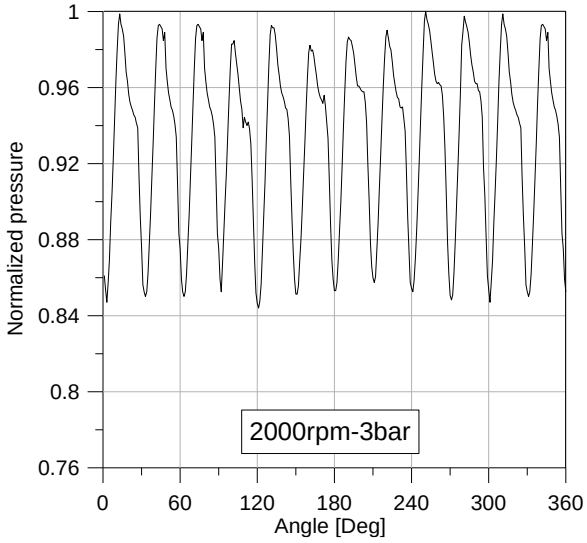
Pressure ripple

Flow-rate

Torque

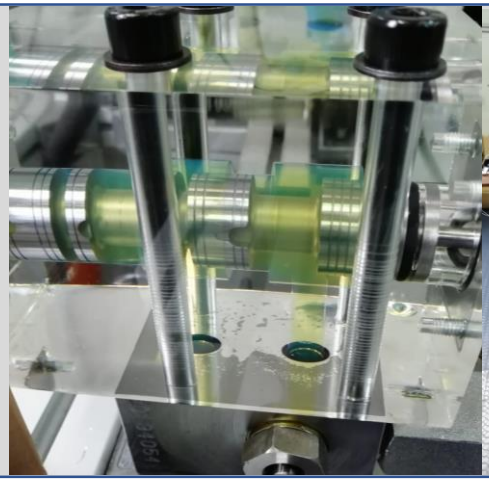
Cavitation phenomenon





Valves: experimental setup

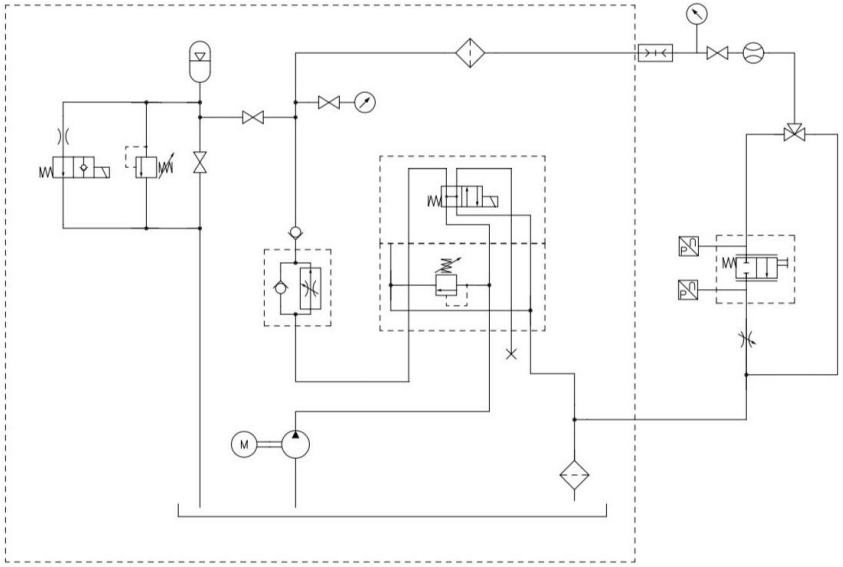
Hydraulic valves



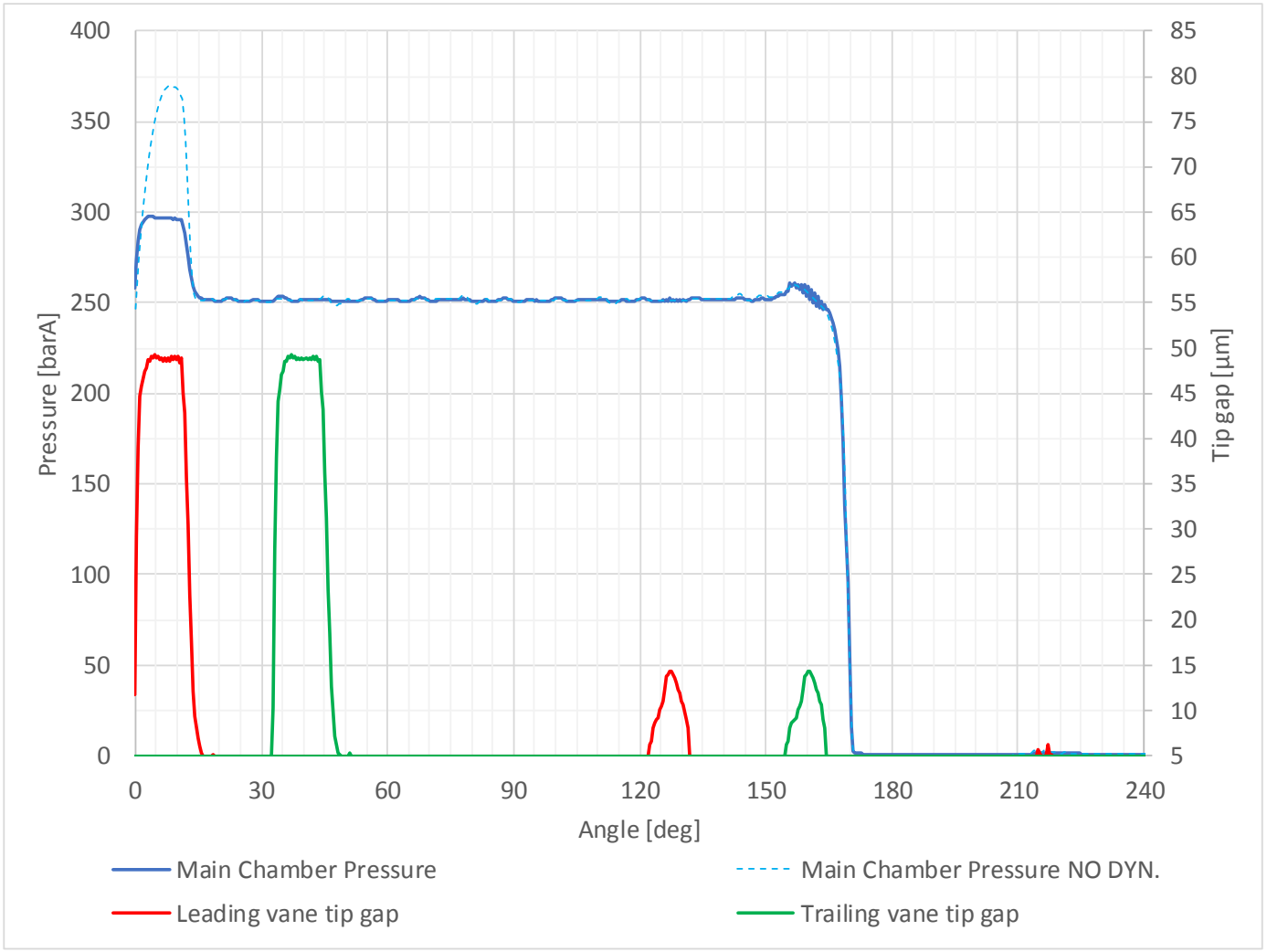
Pressure

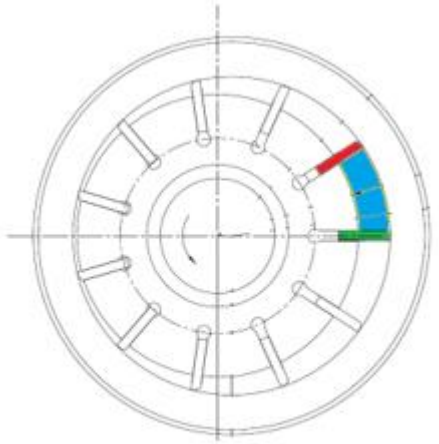
Flow-rate

Cavitation phenomenon



Vane dynamic





Trailing Vane

Leading Vane

Main Chamber ***MC***

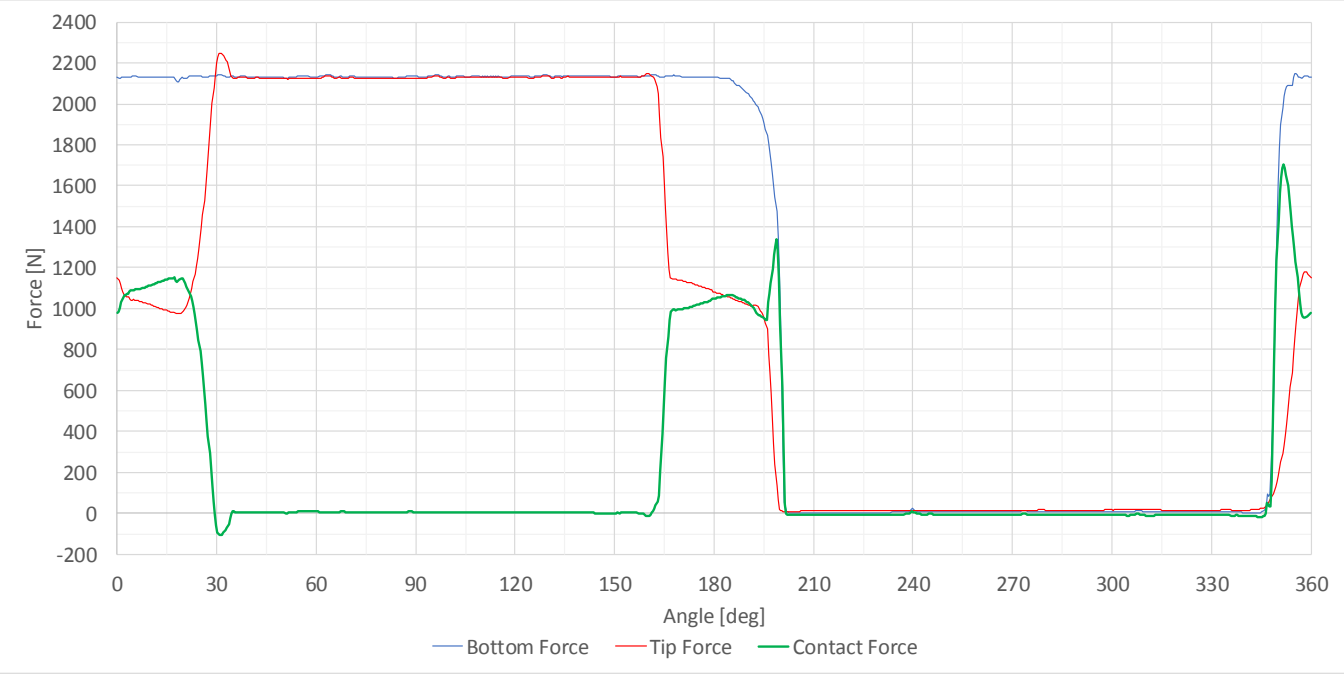
Vane dynamic

The contact force for each vane can be evaluated using the following equation:

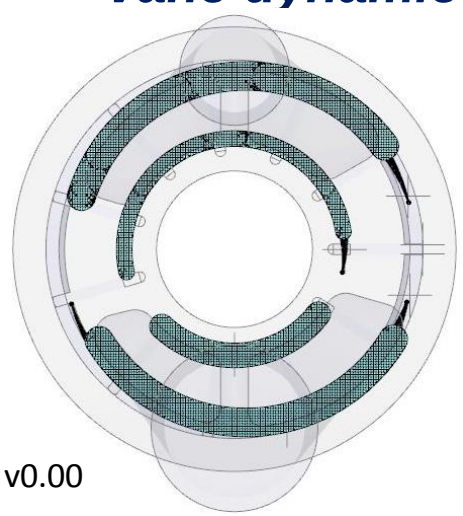
$$F_t = F_p + F_c + F_f$$

Where:

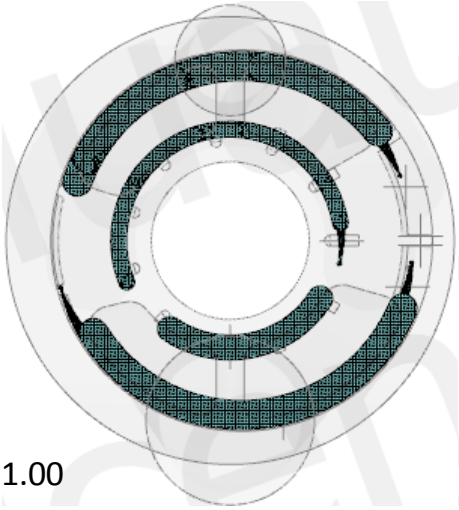
- $F_p = p_{r,uv} \cdot A_{uv} - p_{r,tv} \cdot A_{tv}$
- $F_c = m_v \cdot \omega^2 \left(\rho - \frac{l_v}{2}\right)$ The vector ray ρ is: $\rho = \sqrt{e^2 + R_S^2 + eR_s \cos(\varphi + \delta)}$



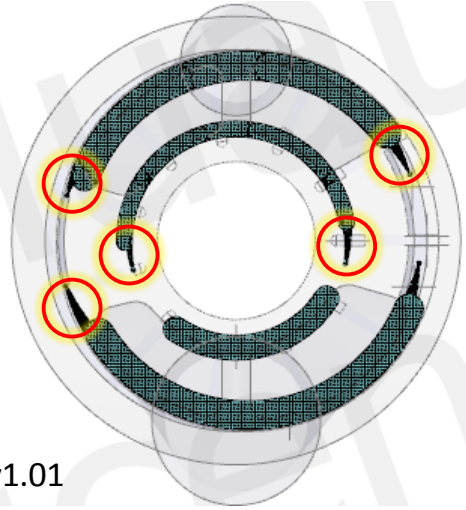
Vane dynamic



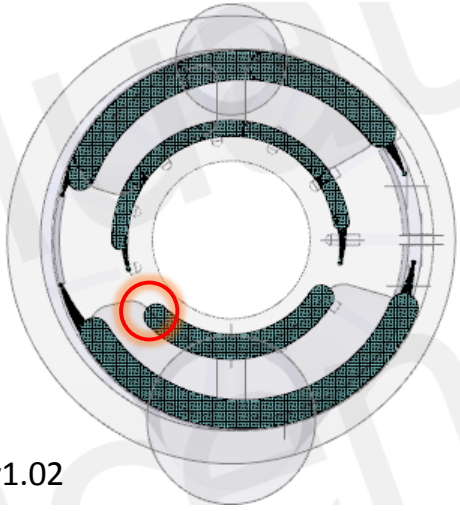
v0.00



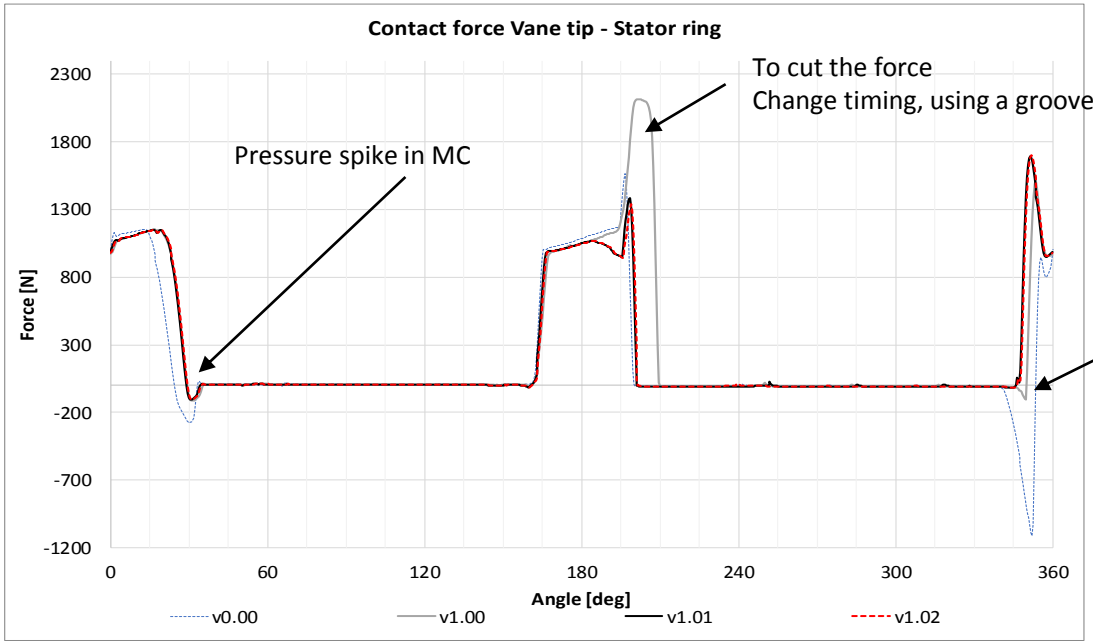
1.00



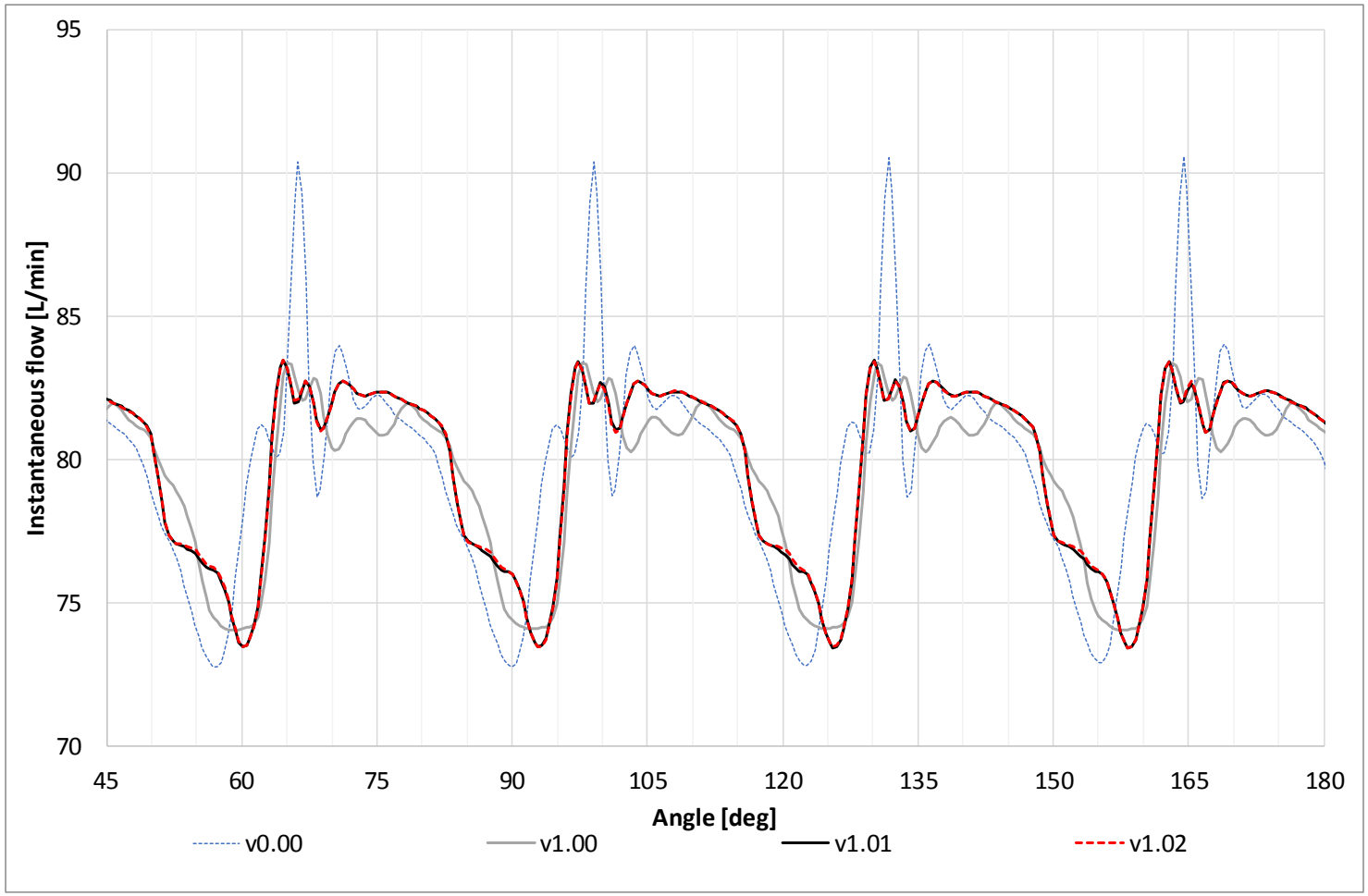
v1.01



v1.02

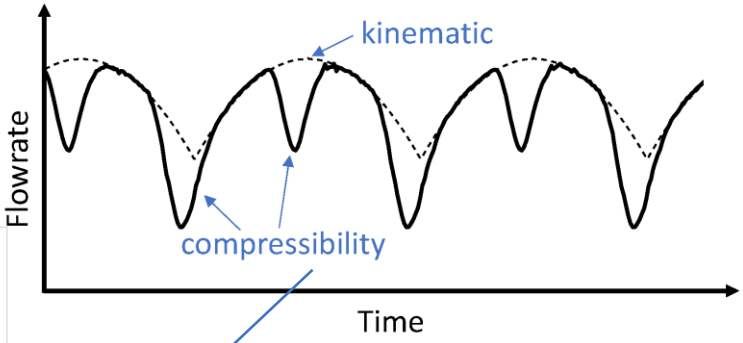


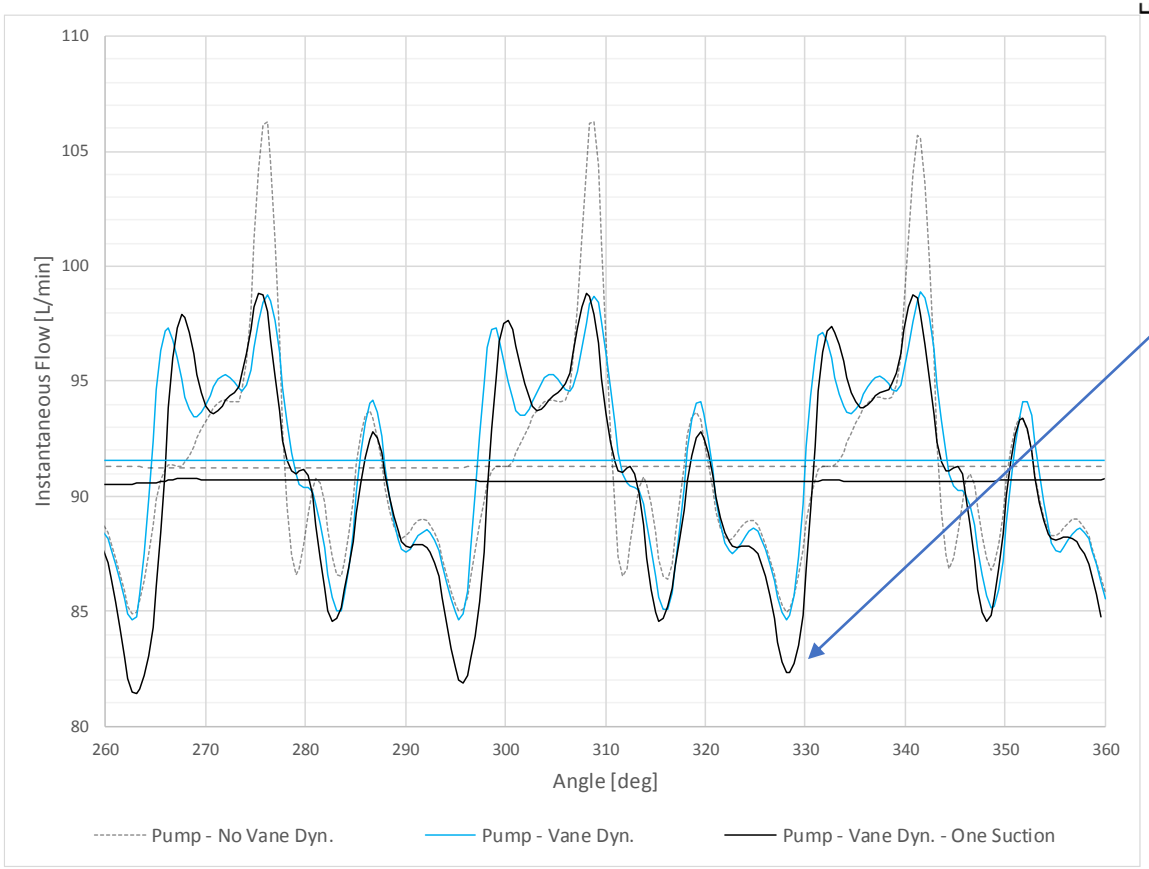
Vane dynamic



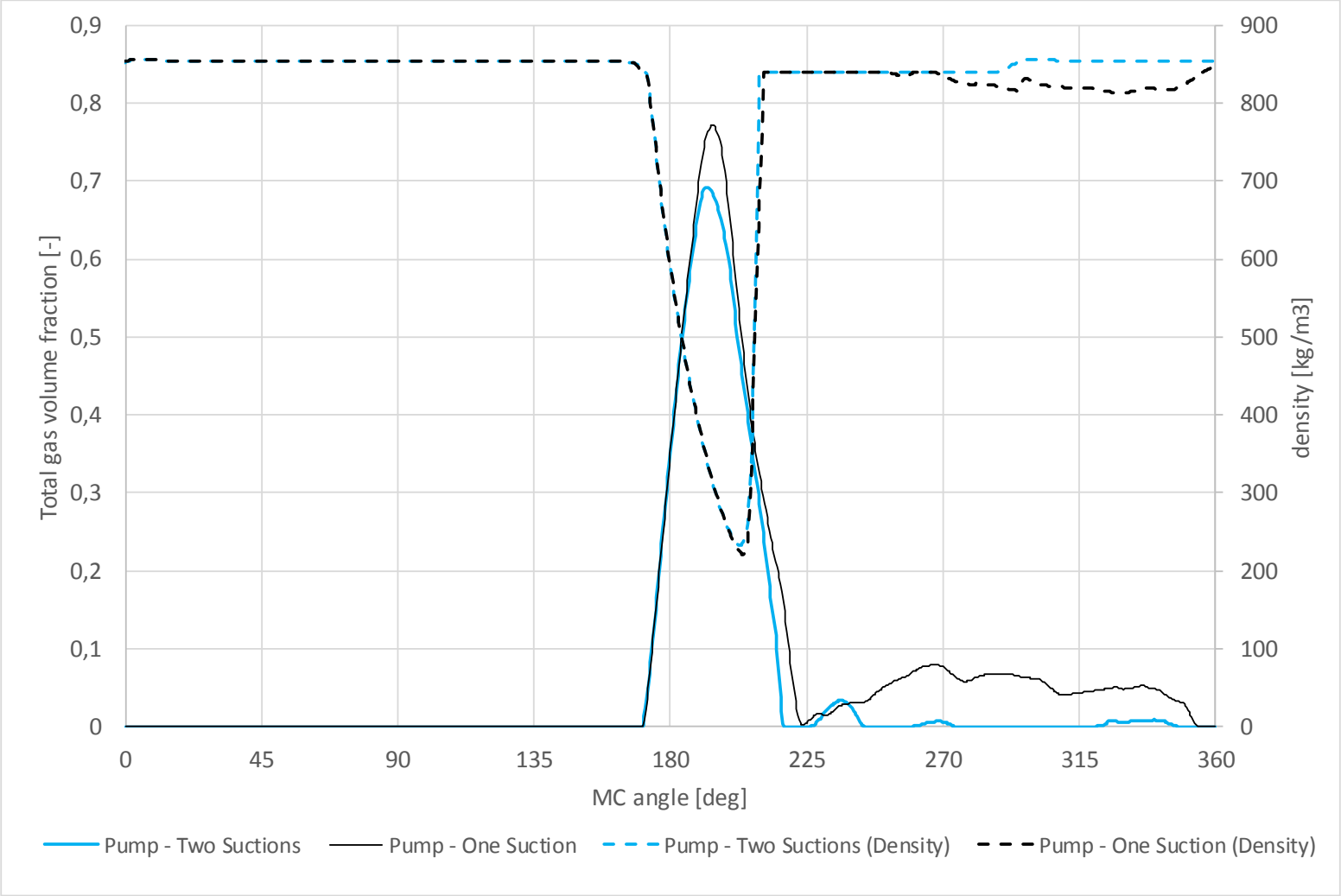
Vane Pumps

Chamber filling





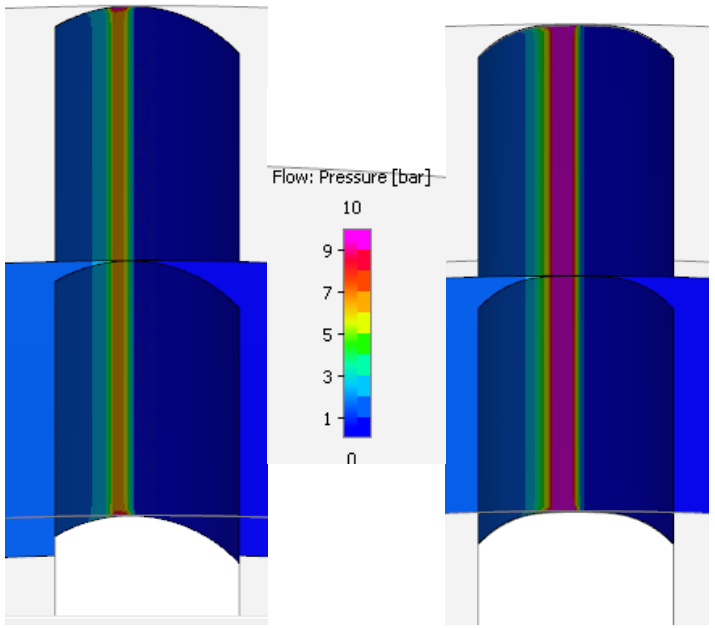
Chamber filling



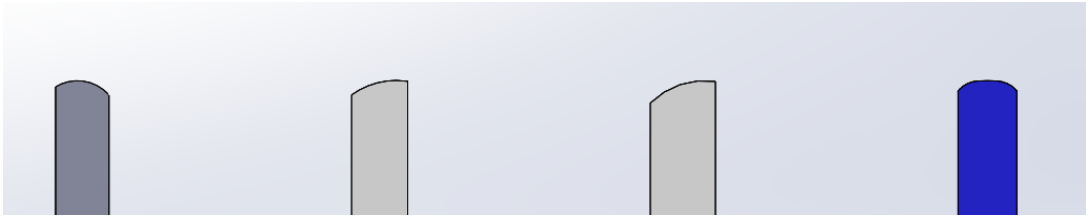
Vane Pumps: Future Works

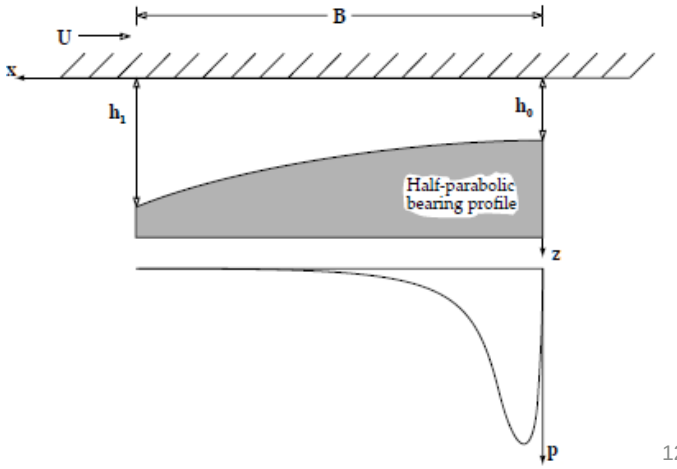
Vane tip profile

Hydrodynamic Load Capacity



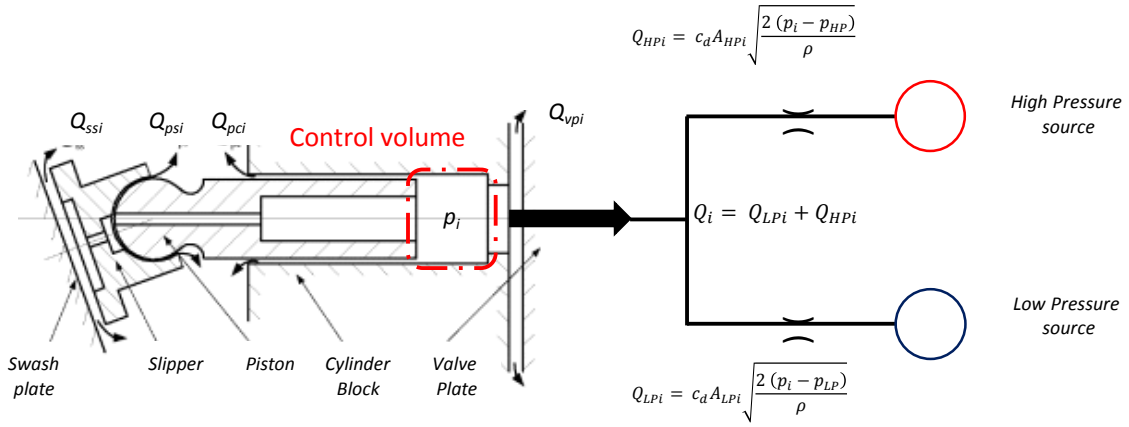
Different vane types:





Lumped parameter – Control volume approach

- Each control volume CV has homogeneous properties, such as pressure and temperature;
- CV is a capacitive element, it calculates the pressure as function of the net ingoing flow rate;
- CVs are connected by resistive components (variable orifices), calculating flow rate as function of the pressure drop.



$$\frac{dp_i}{dt} = \frac{\beta}{V_i}\left(Q_i - Q_{ssi} - Q_{psi} - Q_{pci} - Q_{vpi} - \frac{dV_i}{dt}\right)$$

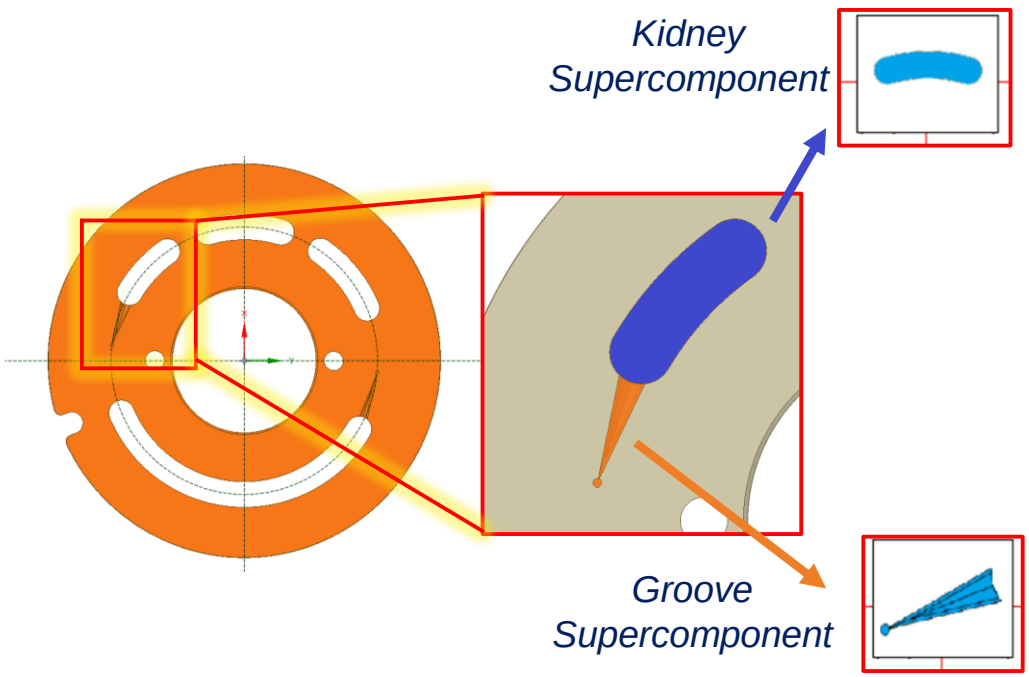
- The approach is consisting of two simulations:
  1. ***Valve plate Design***, where the valve plate sectional areas are evaluated: the outputs of this model (tables) become inputs for the following model;
  2. ***Vectorial piston pump***, modeled according to the CV approach

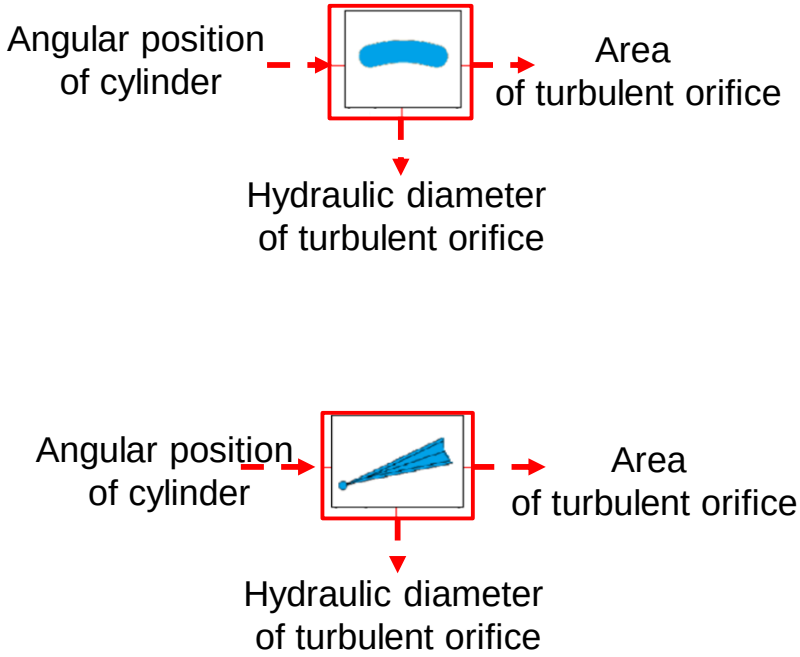
Simcenter Amesim

1 – Valve plate design model

The model has two main supercomponents:

- ***Groove SC***, to evaluate the slots;
- ***Kidney SC***, to evaluate the kidneys opening areas.

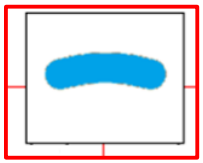




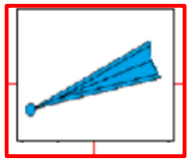
Simcenter Amesim

1 – Valve plate design model

Real Parameters:



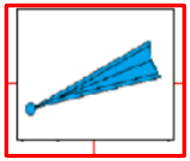
1. Pitch radius
2. Barrel footprint angular extension
3. Barrel slot radius
4. Kidney radius
5. Kidney opening angle
6. Kidney closing angle

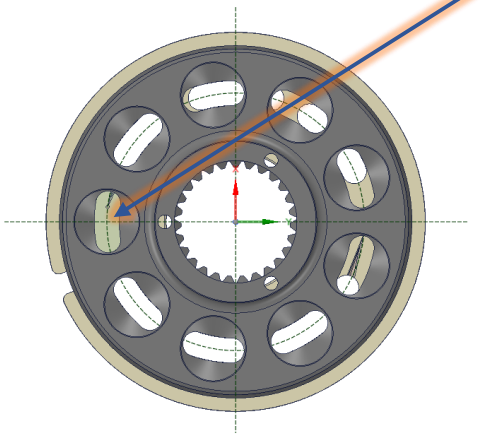


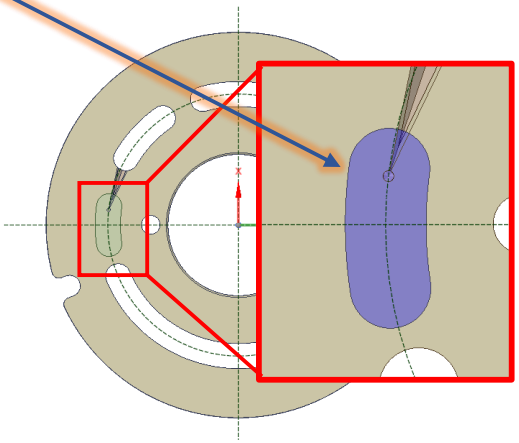
1. Pitch radius
2. Barrel footprint angular extension
3. Barrel slot radius
4. Hole radius
5. Hole opening angle
6. Hole closing angle
7. Slot starting height
8. Slot slope
9. Slot angle design (triangular slot)

Piston Pumps

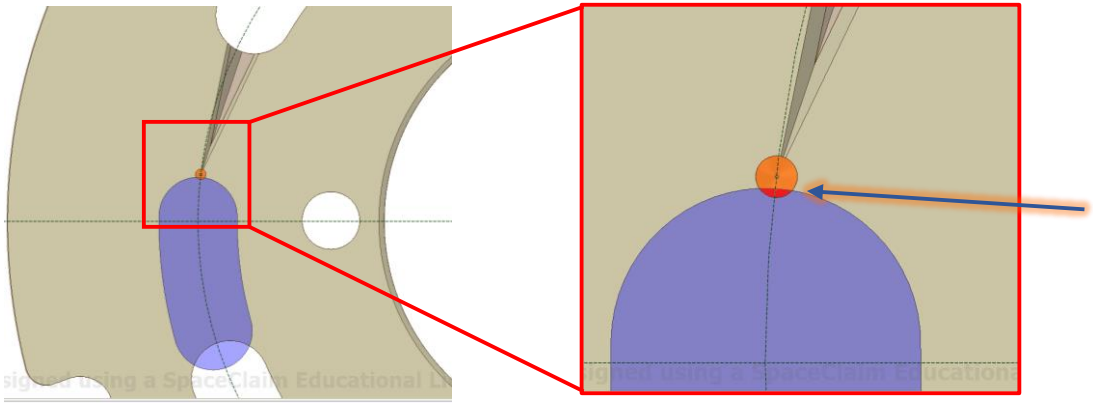
1 – Valve plate design model





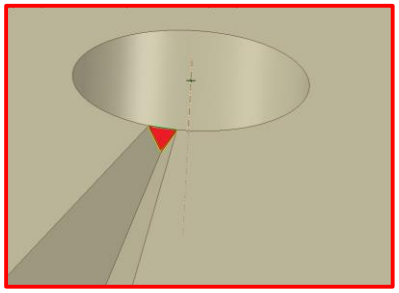


Hole area:

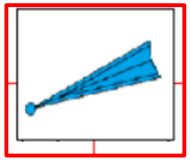


In red the area evaluated by the Groove SC

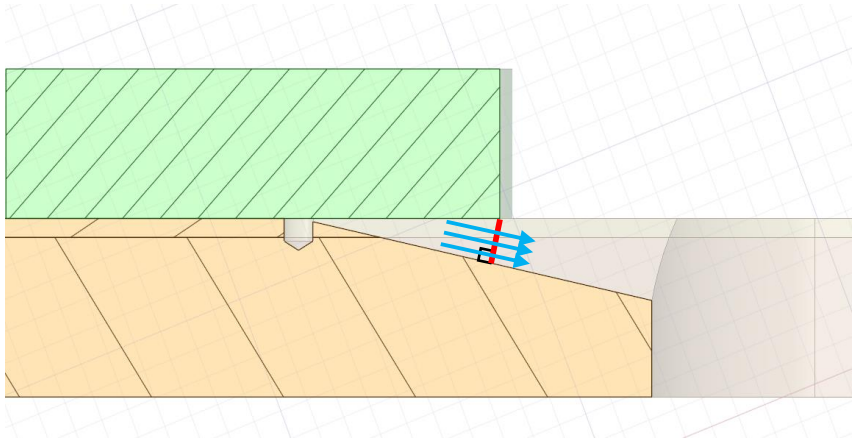
Limited by:

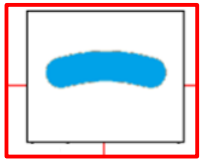


1 – Valve plate design model

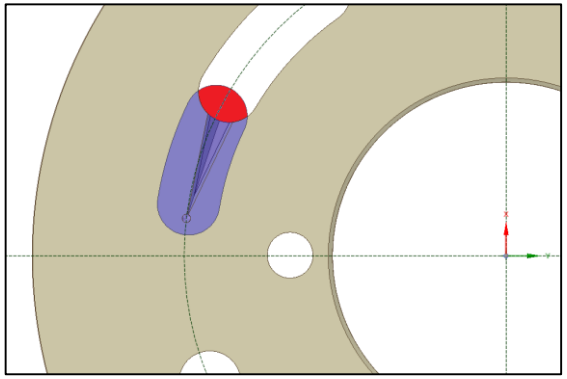


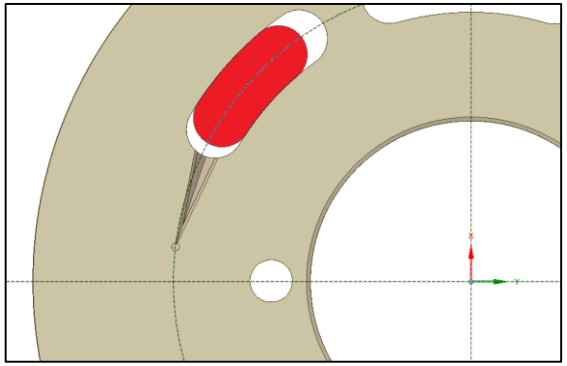
Slot area: the slope angle is considered





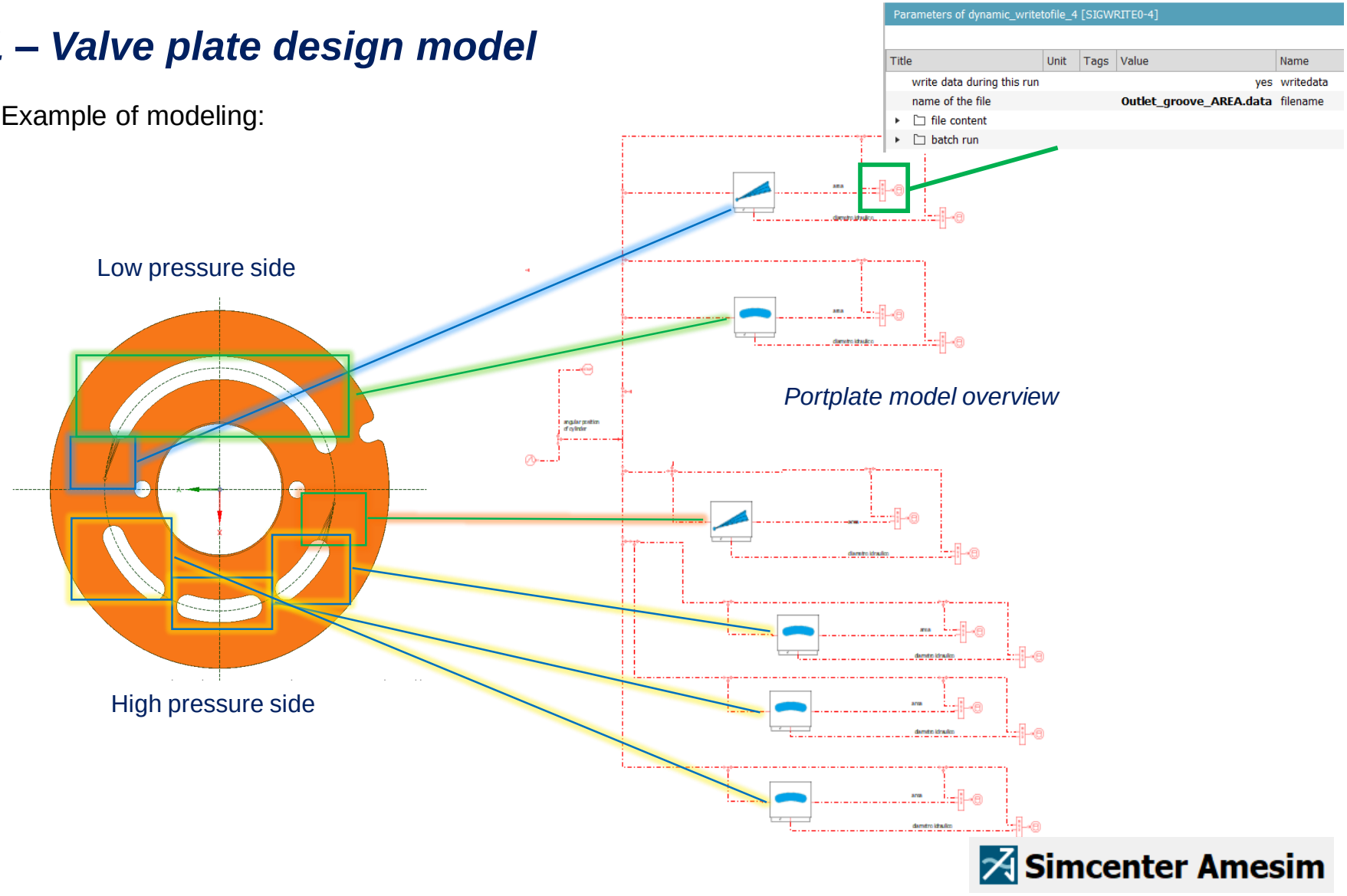
Kidney area and its limit (barrel footprint area):





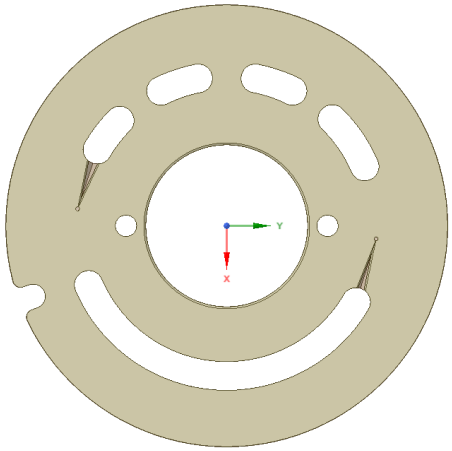
1 – Valve plate design model

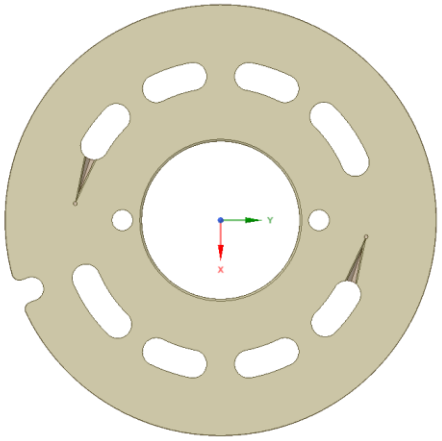
Example of modeling:

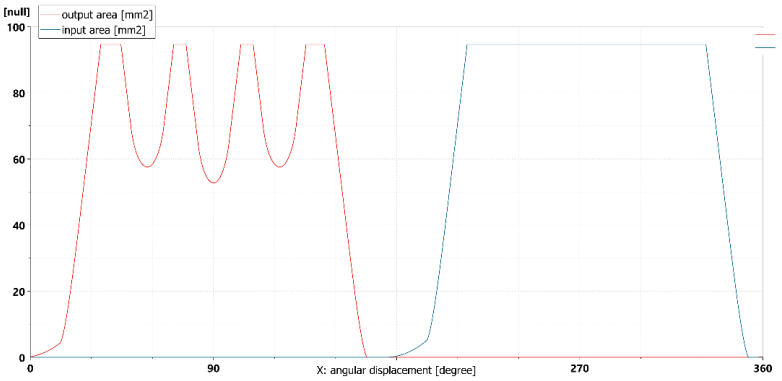


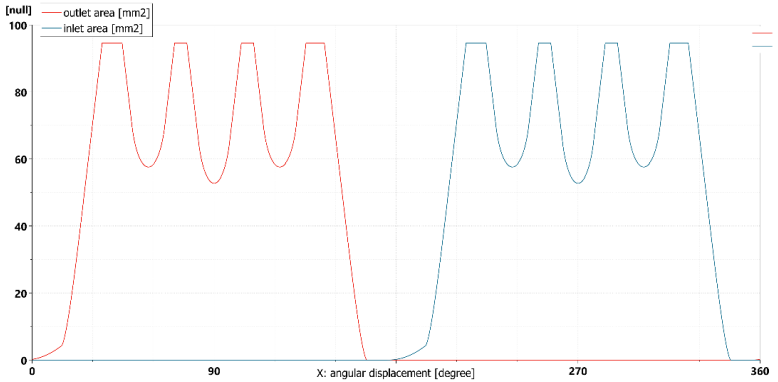
1 – Valve plate design model

Example of modeling:

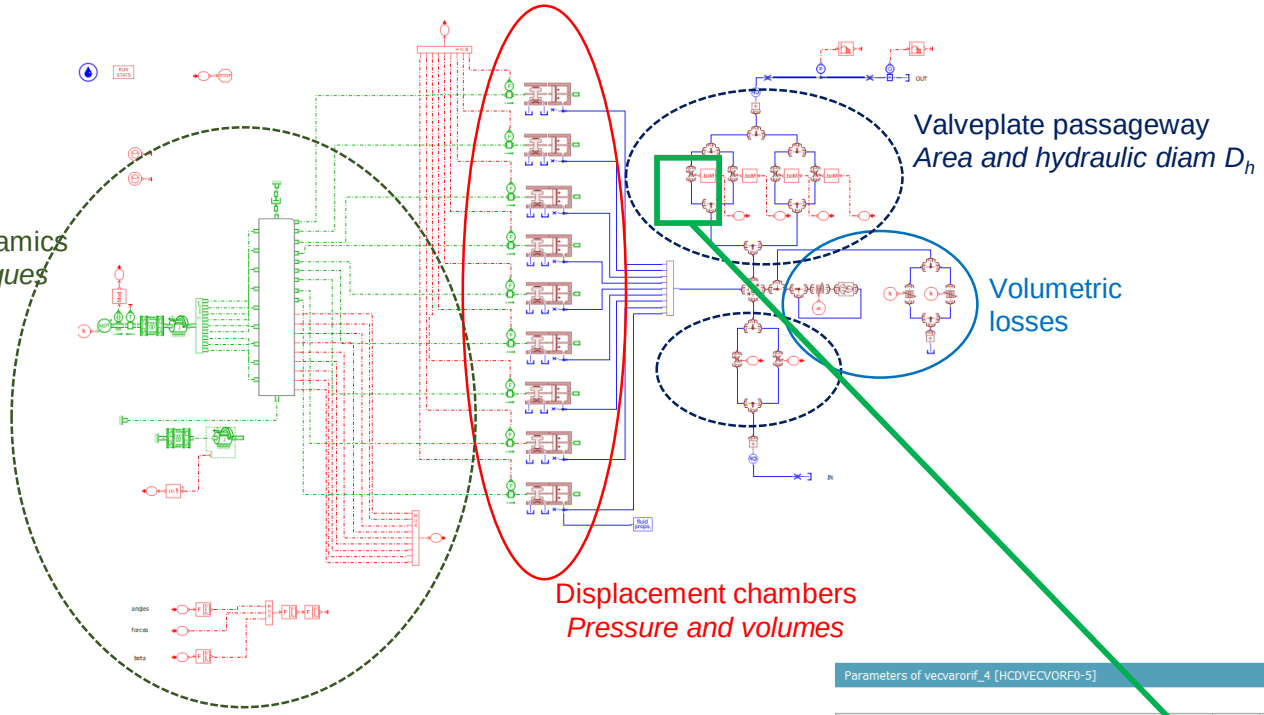








2 – Lumped parameter CV approach



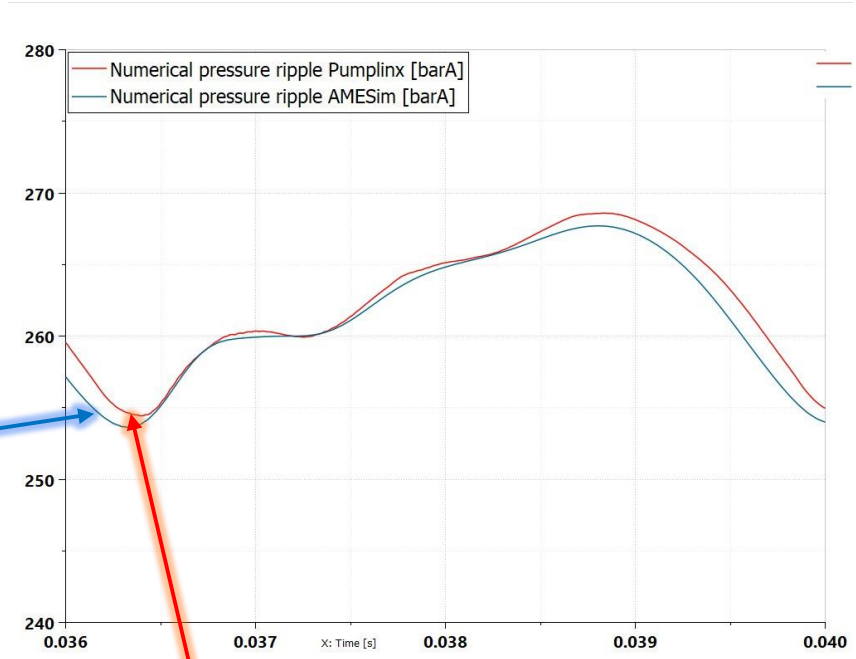
Parameters of vecvarorif_4 [HCDVECVORF0-5]

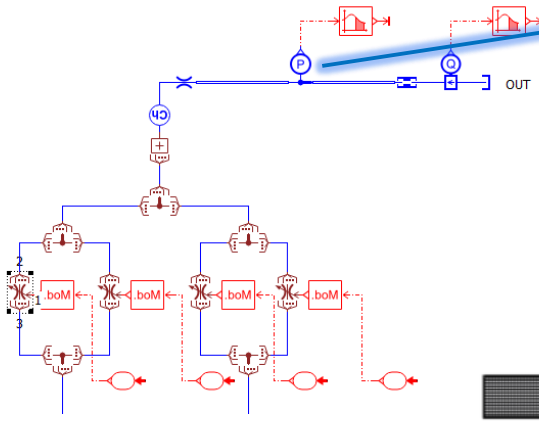
Title	Unit	Tags	Value	Name
index of hydraulic fluid			0	indexf
vector size			**9**	z
number of signal inputs			1	nbinput
geometry of orifices			regular	mode
maximum flow coefficient Cq	null		0.7	cqmax
critical flow number (laminar/turbulent)	null		**100**	lamc
periodicity	degree		360	period
filename or expression for area[mm**2] = f(theta)			**Outlet_groove_AREA.data**	area1
filename or expression for hydraulic diameter[mm] = f(theta)			**Outlet_groove_HYD_DIAM.data**	hd1
table settings				

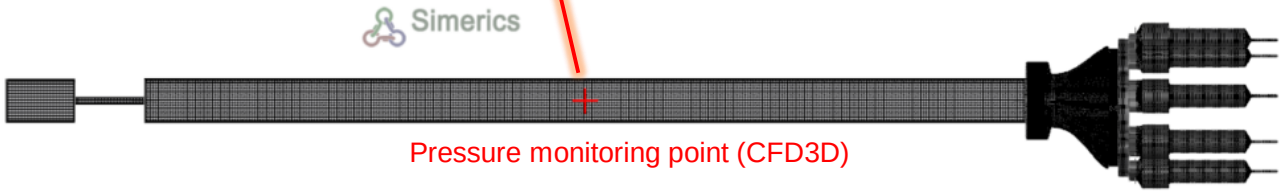
Approach validation

The approach is validated comparing the results with a CFD simulation:

Here is showed a comparison on a pressure ripple:







Thank you for your attention

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SCUOLA POLITECNICA E DELLE SCIENZE DI BASE

DIPARTIMENTO DI INGEGNERIA INDUSTRIALE

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