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NOVEMBER 22-23 ▪ SÃO PAULO ▪ BRAZIL

Optimization of Pressure Relief Grooves for Multi-Quadrant Hydraulic Machines in Different System Architectures

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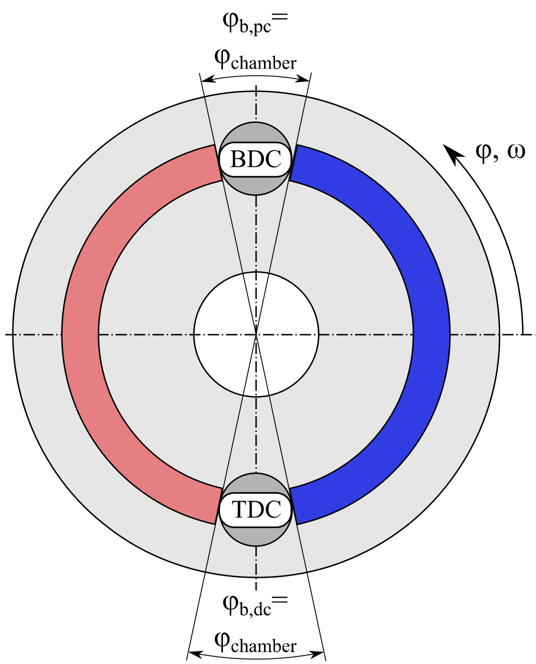
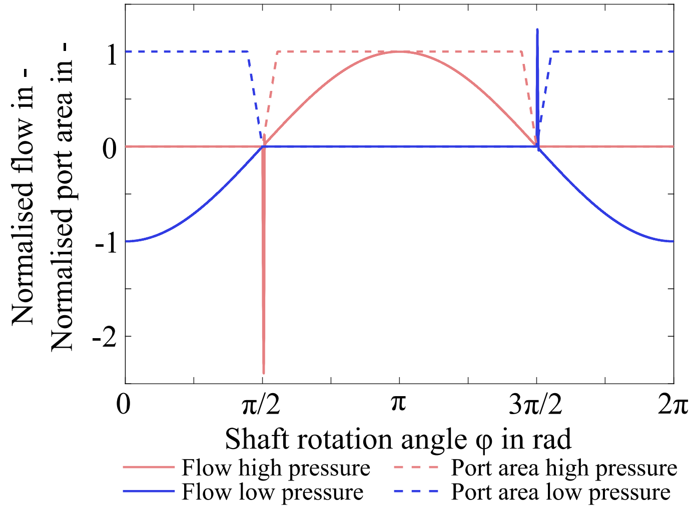
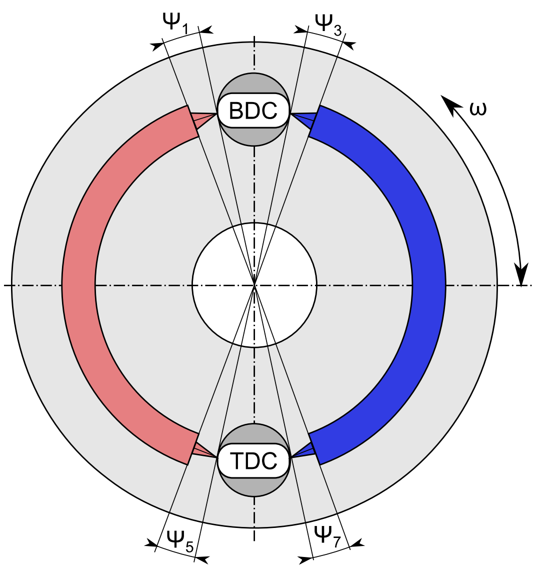
Pressure relief grooves

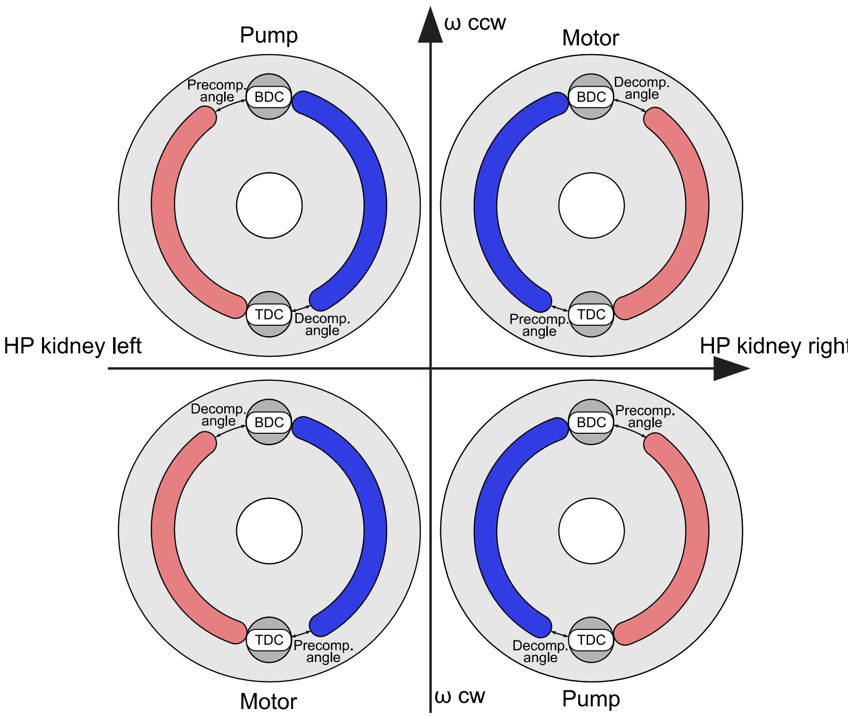
- Pressure relief grooves are typical to reduce noise and losses over a wide operating range







- Operation in different quadrants and different drive cycles leads to different optimal designs!



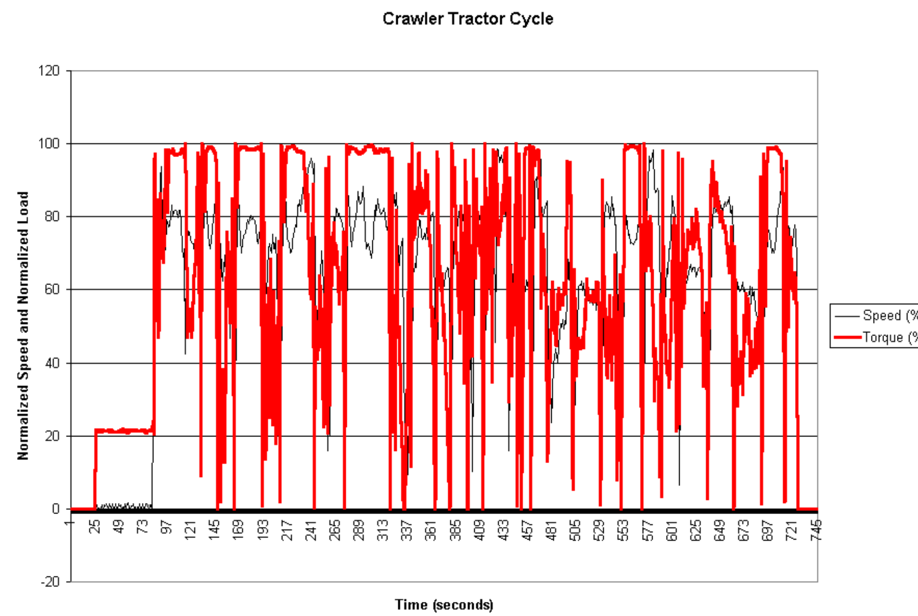
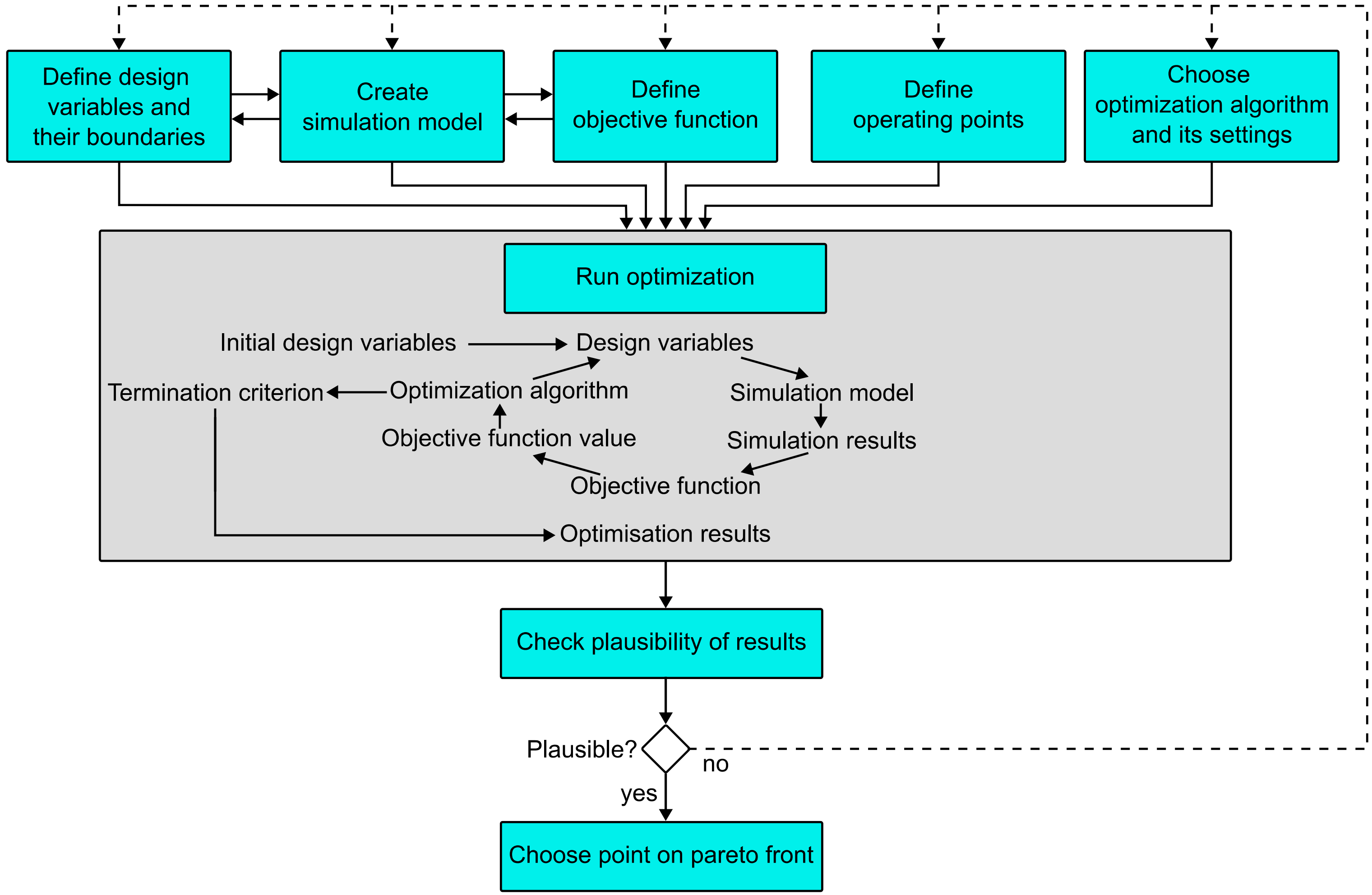


Image source: https://www.epa.gov/sites/default/files/2017-03/crawler.gif (image just for illustration!)

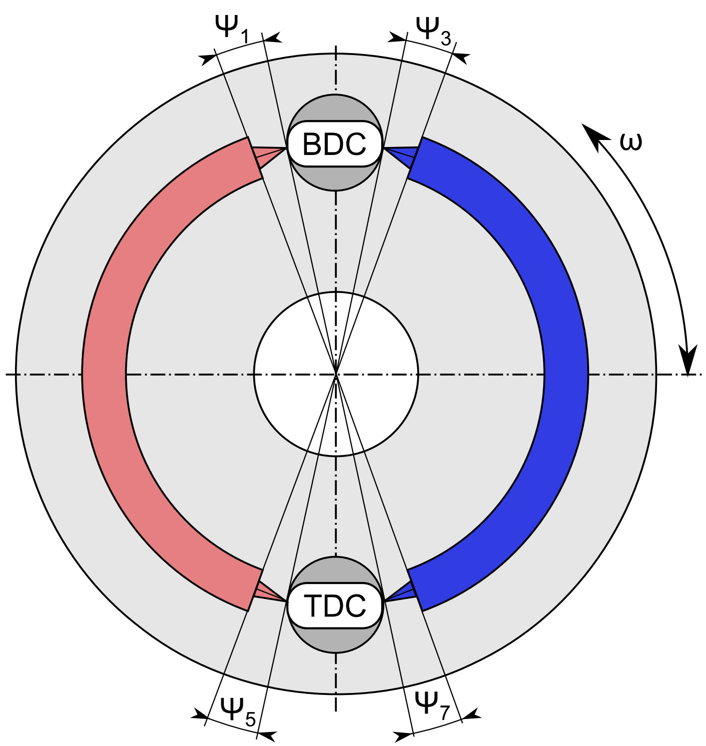
Process flow for design optimization



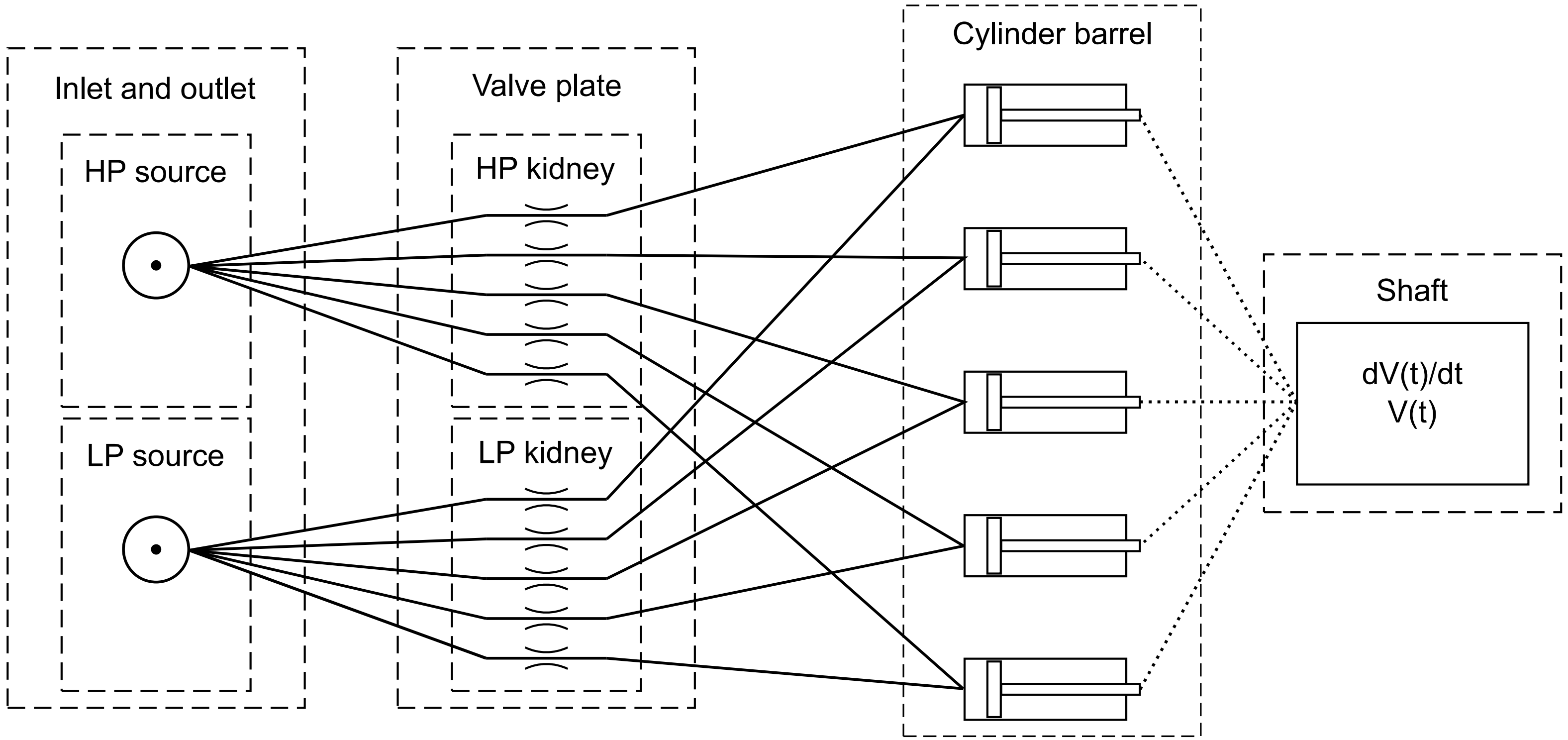
Design variables

- Each groove defined by its length, end the area gradient!
- Better convergence of results than using length and final area as inputs

$$A = k_x \cdot x^n$$



Simulation model

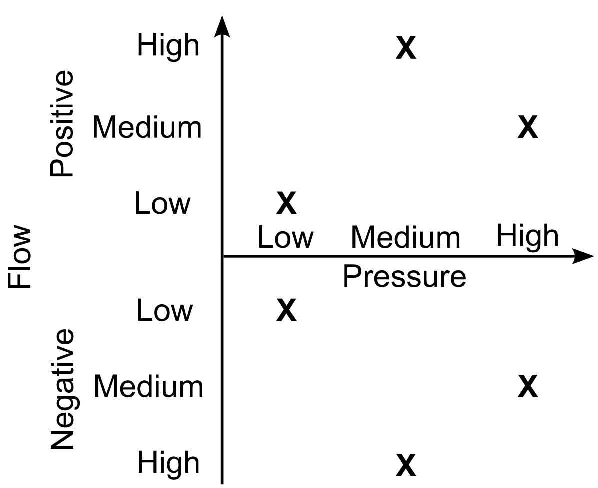


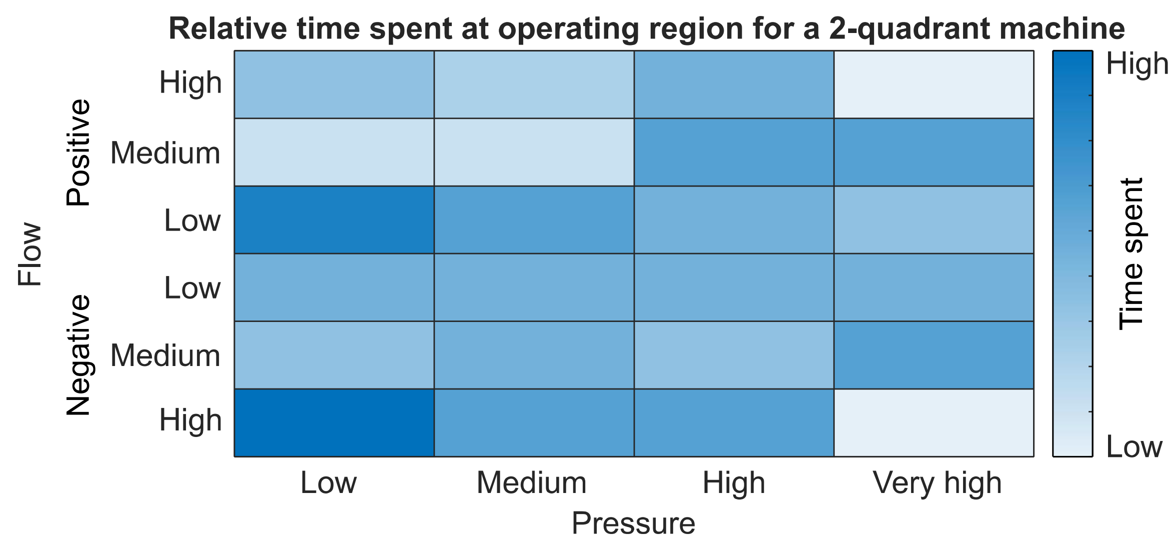
Objective function

- Consideration of
  - flow pulsations
  - losses
- Weighting of each operating point required to achieve ”average” flow pulsations and losses
- Soft constraints handled by a penalization factor on the objectives
  - too high pressure peaks
  - too low pressure (cavitation)
- Trade-off between objectives takes place a posteriori!

Choice of operating points

- Drive cycle is reduced to characteristic operating points in order to reduce compuational effort
- Consider most relevant operating points, and points that could lead to pump damage (i.e., most cavitation critical points)
- Weighting according to time spent in operating point





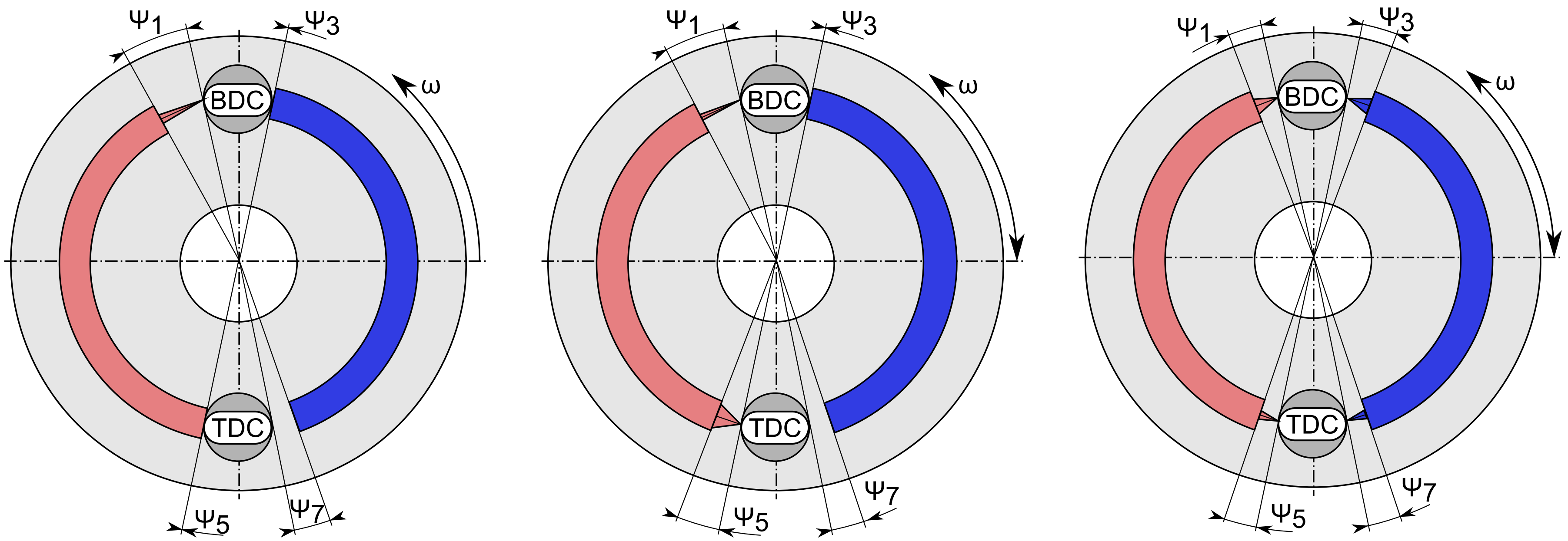
Optimization algorithm

- For multi-objective optimization, a Non-Sorted Genetic Algorithm (NSGA-II) is typical
- Allows a-posteriori trade-offs

Results for principal design (1/2)

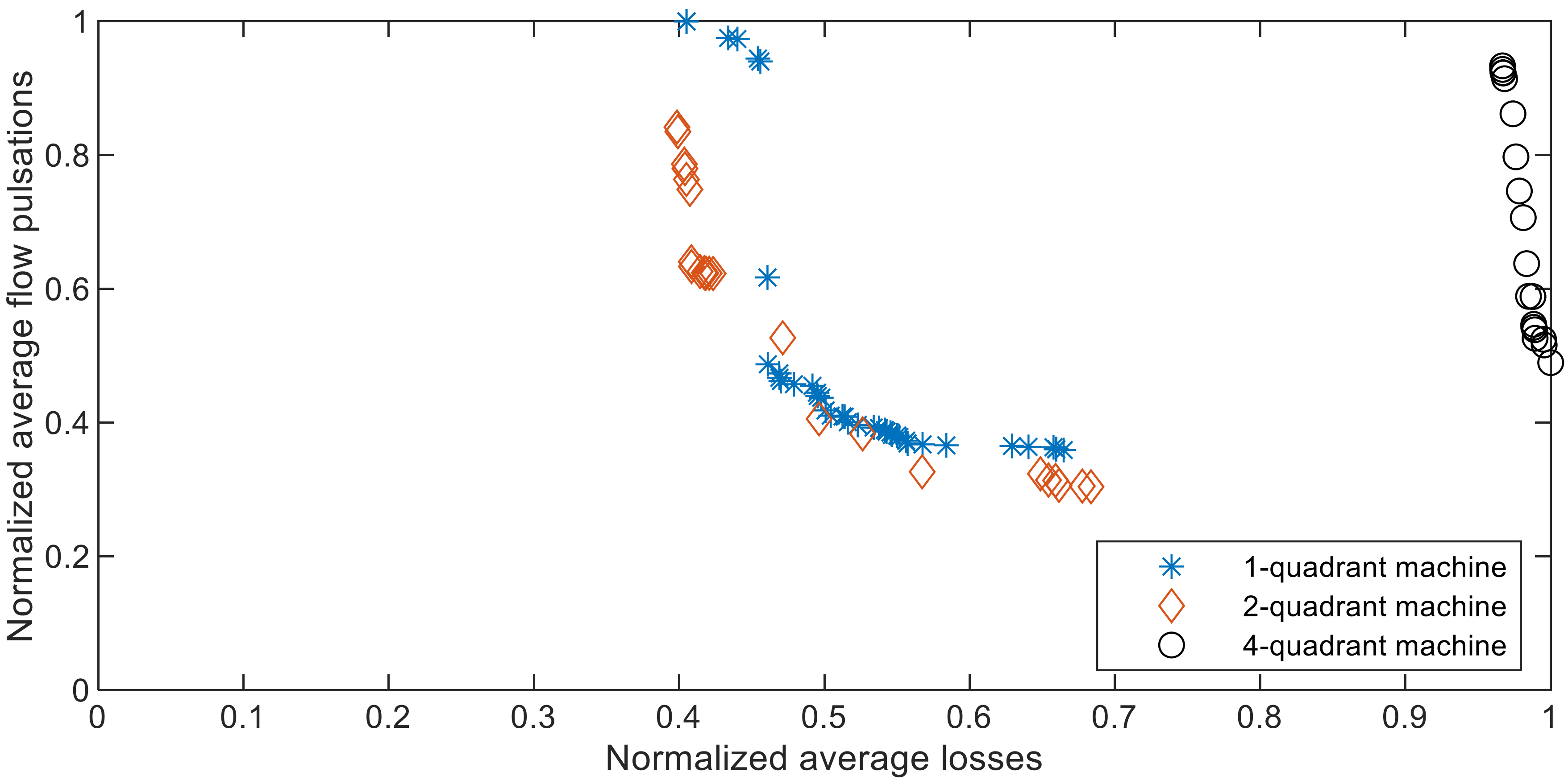
- Visualization of typical design results
- 1- & 2-quadrant design quite similar!
- More and shorter grooves for 4-quadrant operation required to avoid cavitation!

1-quadrant **2-quadrant** **4-quadrant**



Results for principal design (2/2)

- 1- & 2 quadrant operation almost same performance
- **Penalty for enabling 4-quadrant operation!**



Conventional system vs. EHA system

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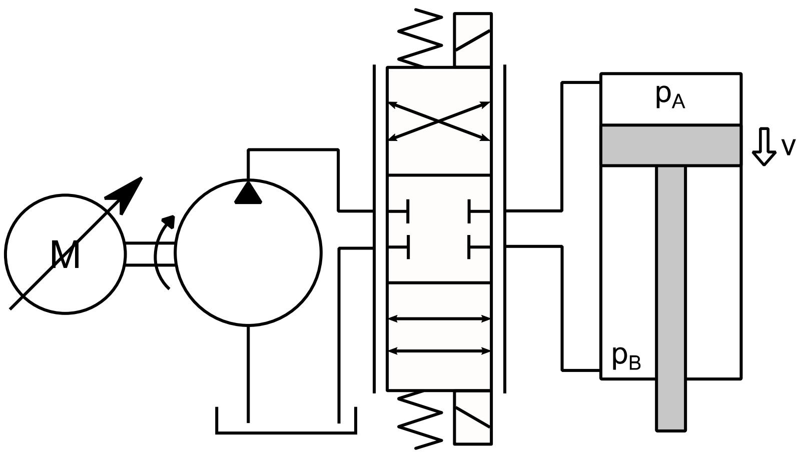
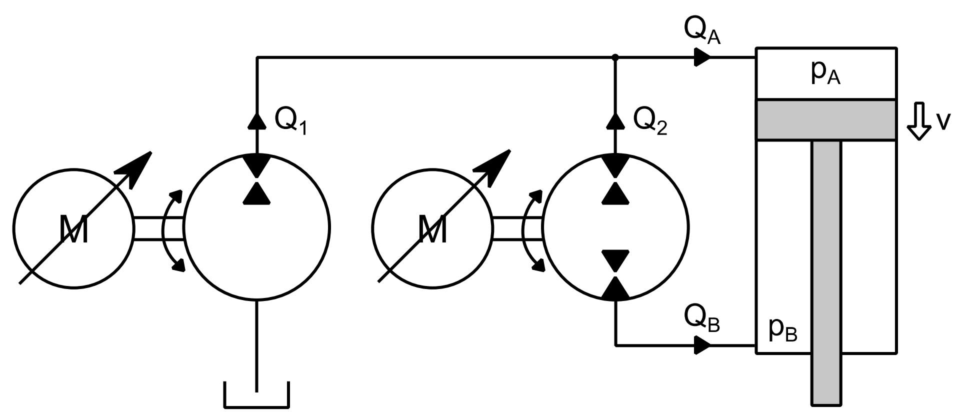
- Two systems with the same requirements for actuator force and velocity
- Hydraulic machines work in different number of quadrants and different drive cycles!

Conventional system

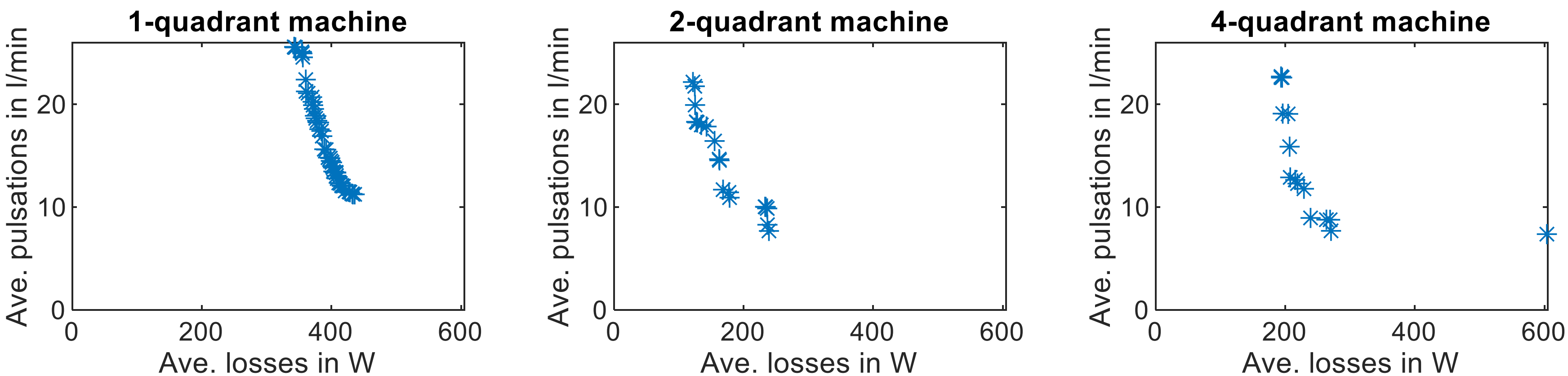


Electro-hydraulic actuator (EHA) system



Results for hydraulic machines

- Combined losses and pulsations for EHA machines in same magnitude as for conventional system
- Potential for increased system efficiency by recuparation



	1-quadrant machine	2-quadrant machine	4-quadrant machine
Displacement [cm^3/rev]	42.0	29.9	35.3
Total average power [kW]	18.6	15.3	16.1
thereof pump mode [kW]	18.6	9.9	10.5
thereof motor mode [kW]	0	5.4	5.5

Conclusion

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- Methodology for pressure relief groove optimization has been presented
- 4-quadrant operation comes with increased losses and flow pulsations
- EHA system: no significant penalty on machines' pulsations and losses despite large potential for energy savings on the system level

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