optiSLang in functional development of hydraulic valves

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07.06.2019

dynardo | presented at the 16th Weimar Optimization and Stochastic Days 2019 | Source: www.dynardo.de/en/library

Presentation Overview

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3. Simulation task
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5. Summary

Hilite simulation department and optiSLang

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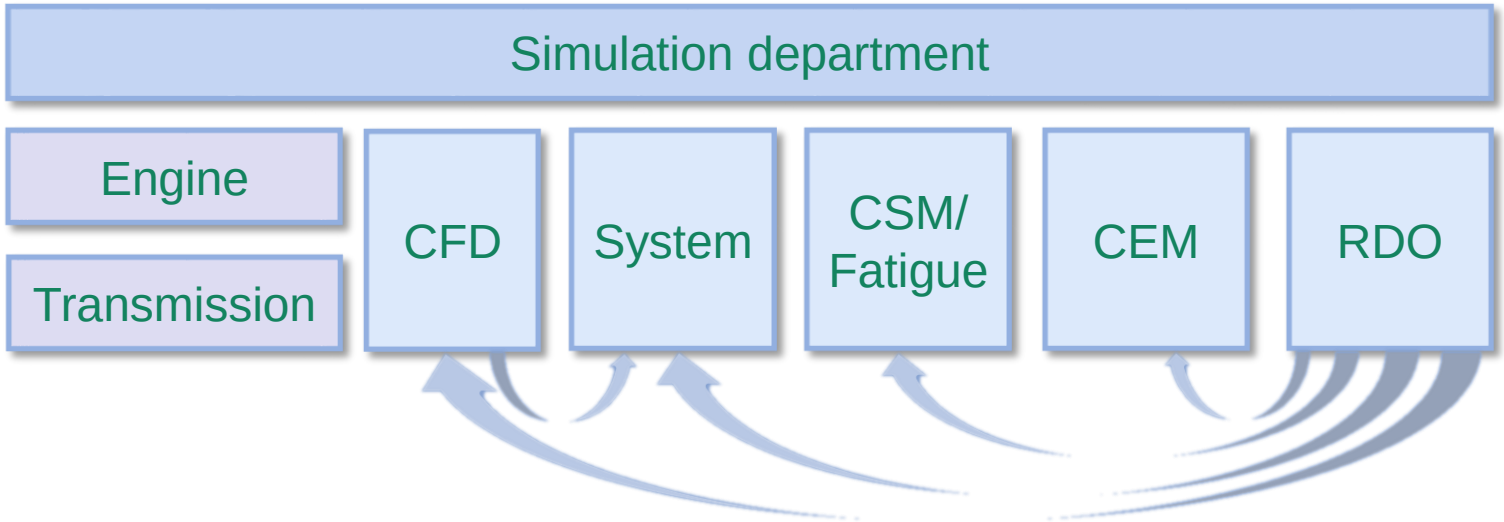

Hilite simulation department and optiSLang

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- Examples of projects using optiSLang
  - to calibrate system simulation components
  - combined with CFD to optimize the flow rate / jet force curves
  - to define tolerance classes
  - combined with system simulation to reduce scrap by manufacturing tolerances
  - to optimize electromagnetic force-curves of the actuator
  - to investigate the magnetic properties (B-H-curves) of materials after manufacturing
  - combined with CSM to reduce press fit force
  - combined with CFD and system simulation to optimize the system behaviour of our products

Simulation task and general approach

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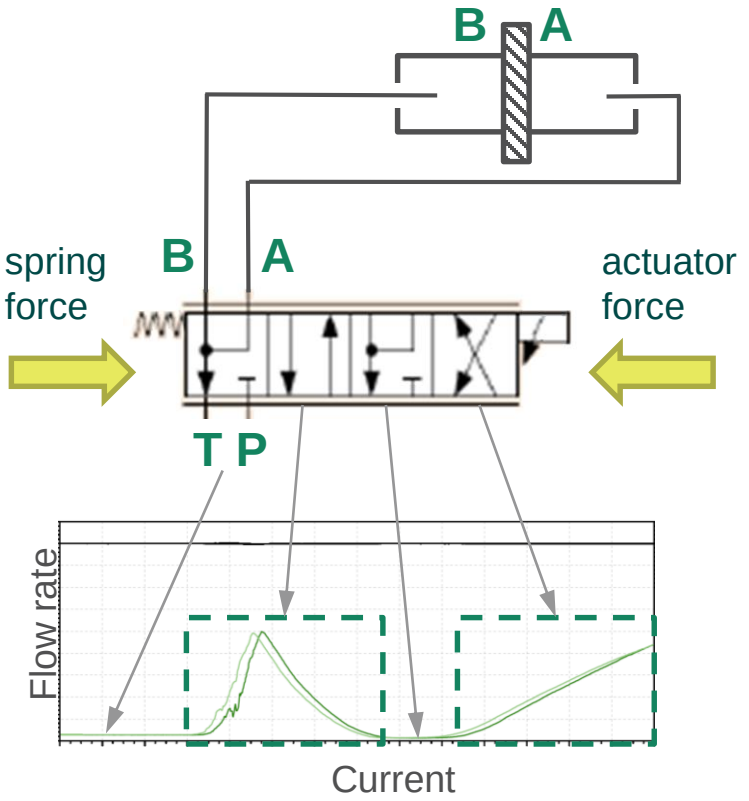
- Operating mode of a directional valve (4/4)
  - electro-magnetic actuator creates a force controlled via TCU* current
  - the spring force acts against the magnetic force to reach a static equilibrium
  - the spool position controls the opening of the ports and the flow rate
  - TCU* can control the flow rate
  - challenge: flow generates a significant force

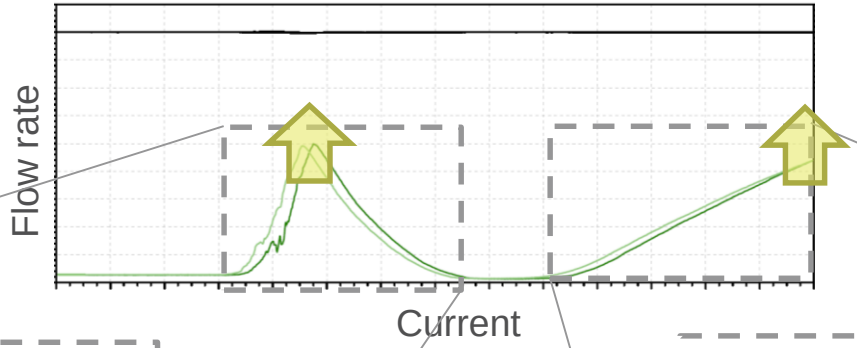


*: Transmission Control Unit

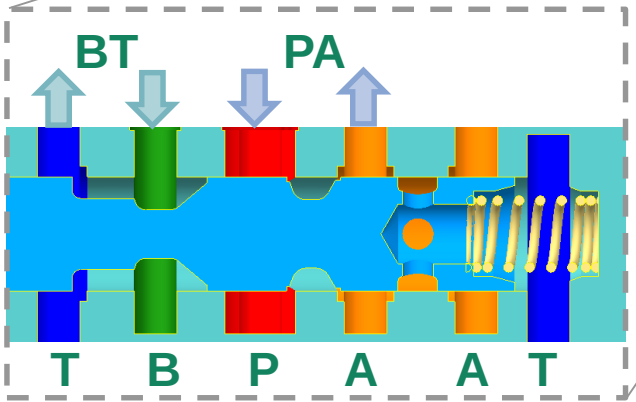
3 Simulation task and general approach

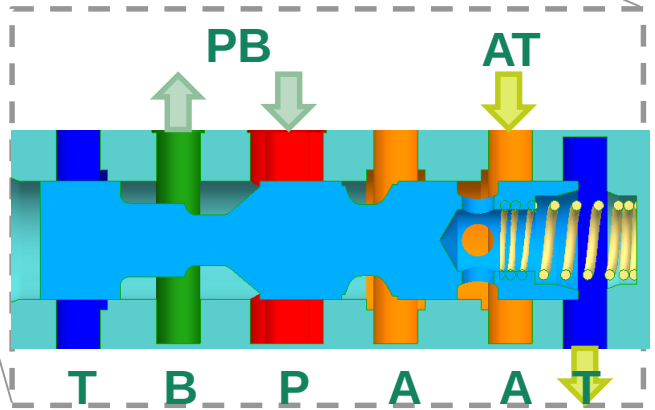
Task:
- increasing the flow rate on the A- and B-side

→ optimization PA, PB, AT, BT flow



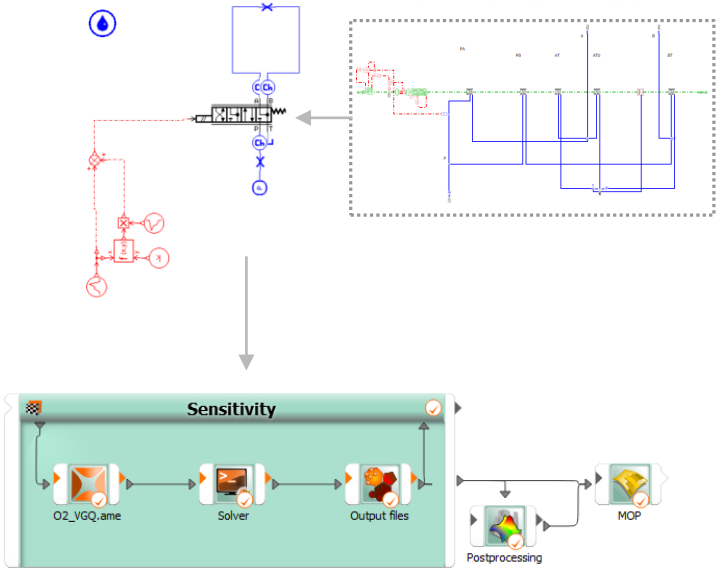
Challenge:
order the part within 3 weeks





4.1 Potential analysis / System simulation

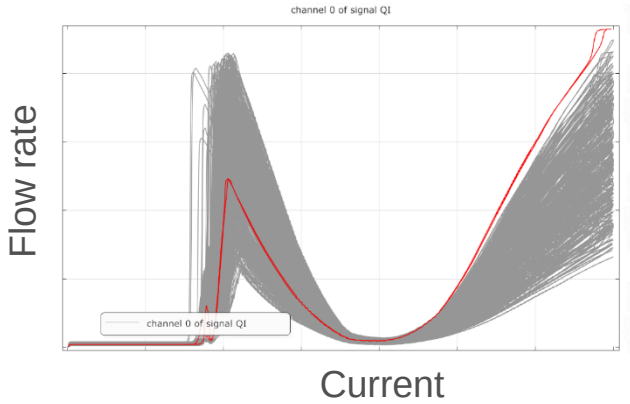
- **First step**: Potential analysis → which port flow do I have to change in order to increase the flow rate in the A- and B-side
- Creation of the system simulation model which contains
  - CFD-fields for all port flows
  - fields for the magnetic curves (force vs. stroke)
  - the AMESim component is modified to allow to scale the field input
  - this scale factor is used as an input in optiSLang

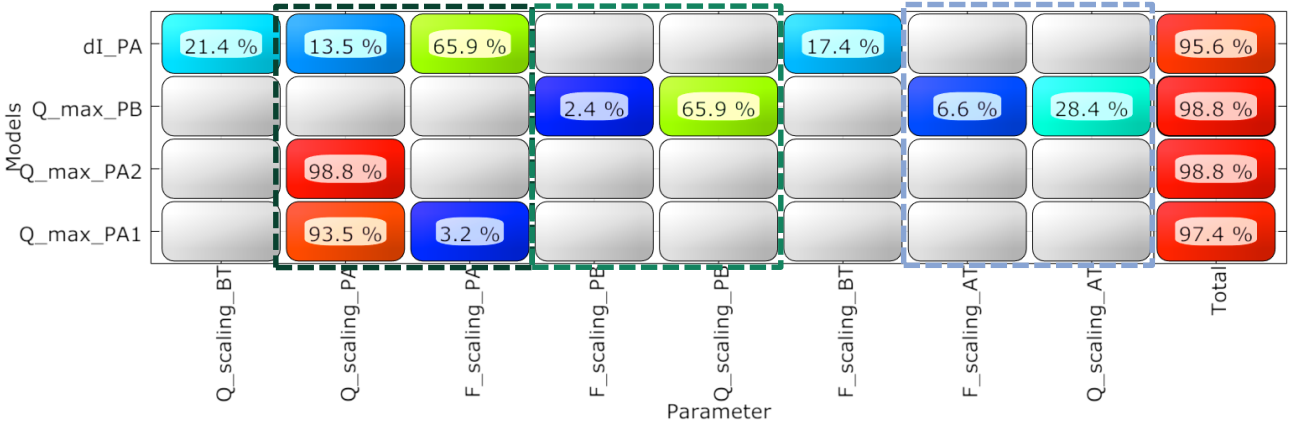


8 scaling factors, 300 design point (ALHS), 4 output parameters, 20 runs in parallel

4.1 Potential analysis / System simulation

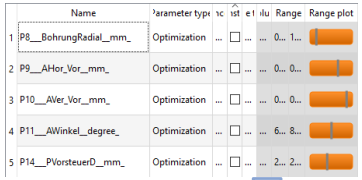
- the results are not actual geometries but show the potential of a change, e.g. to increase the PB flow rate, also the AT flowrate need to be increased
- port flow to optimize: PA, PB, AT





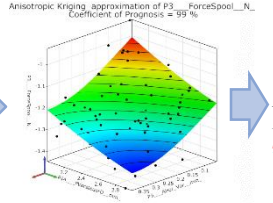
4.2 Simulation approach

geometrical input parameter set

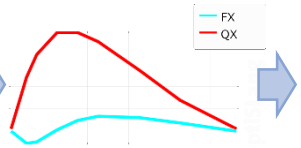


not accurate enough

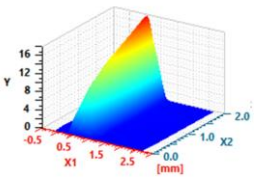
MOP Interpolation (CFD-results)



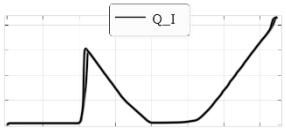
curve generation



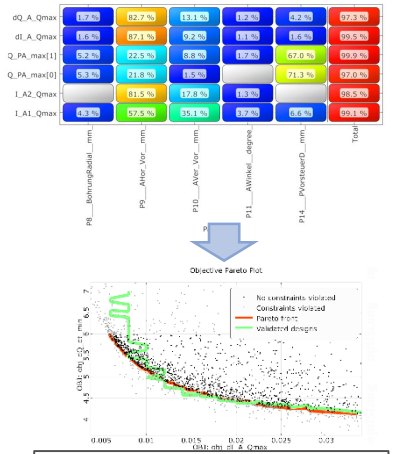
field generation



system response (Q-I-curve)



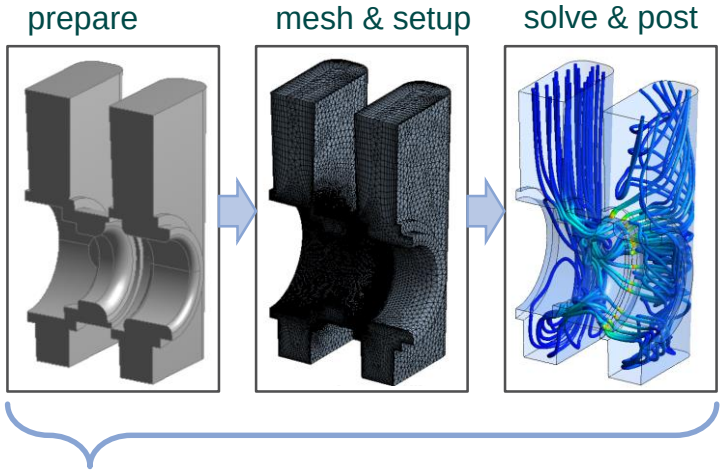
input / output correlation (sensitivity)

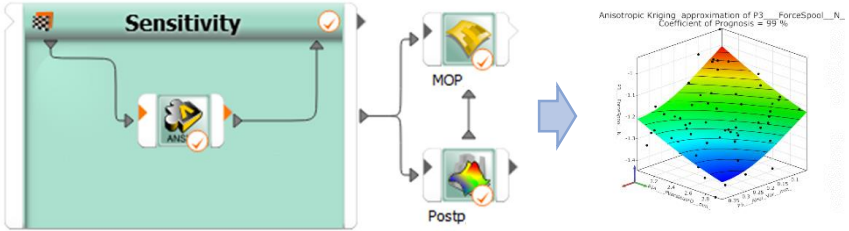


optimization and reevaluation

4.3 CFD-simulation with optiSLang

- the potential analysis shows which port flow is important; now we need to find the geometrical parameters to achieve these changes
- the AT- improvement requires a design concept change → optiSLang is not used here
- for PA and PB parametric sensitivity analysis with CFD-simulations are performed
- PA: 80 design point per stroke; 560 in total





4.4 System simulation based on CFD-MOP

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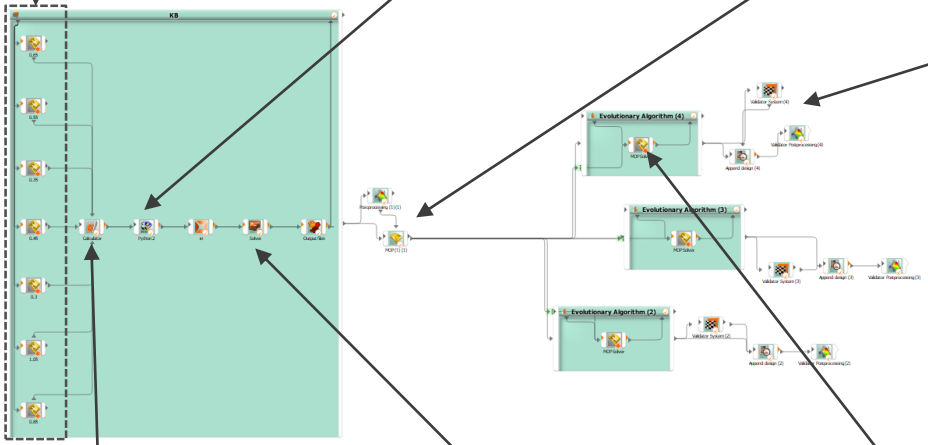
MOP Interpolation (CFD-results)

field generation

MOP of system response

re-evaluation and post processing



curve generation

system simulation (Q-I-curve)

optimization based on MOP

4.4 System simulation based on CFD-MOP

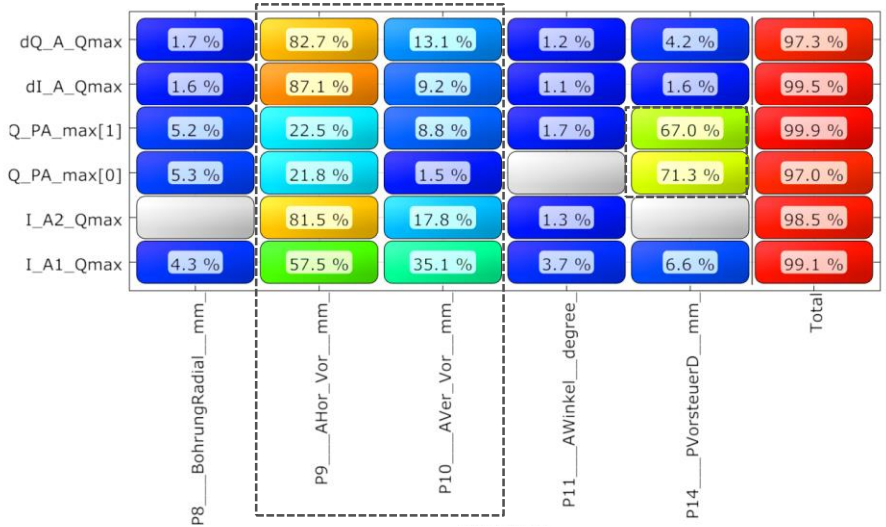
due to the new concept, MOP-results show that flow rate is not an issue any more
→ added as constraint

→ focus on the curve shape / slope of the curve

result parameter

important parameter

COP are very high

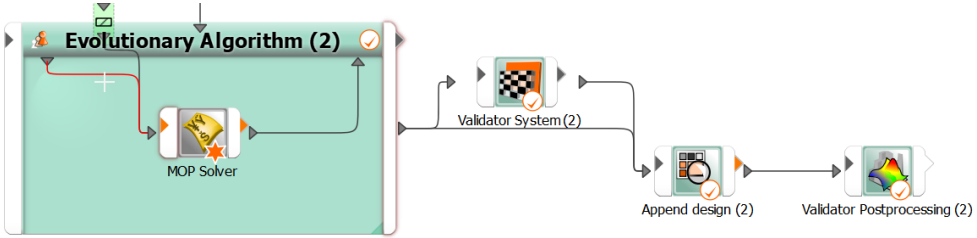


geometrical parameters

4.5 Optimization based on MOP

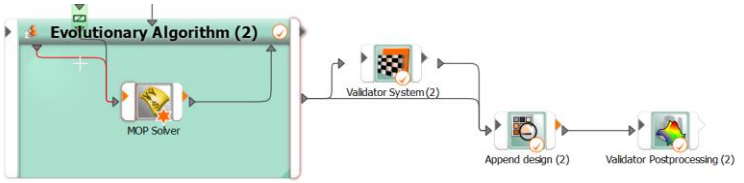
- MOP optimization is very fast
- testing different settings / optimization criteria

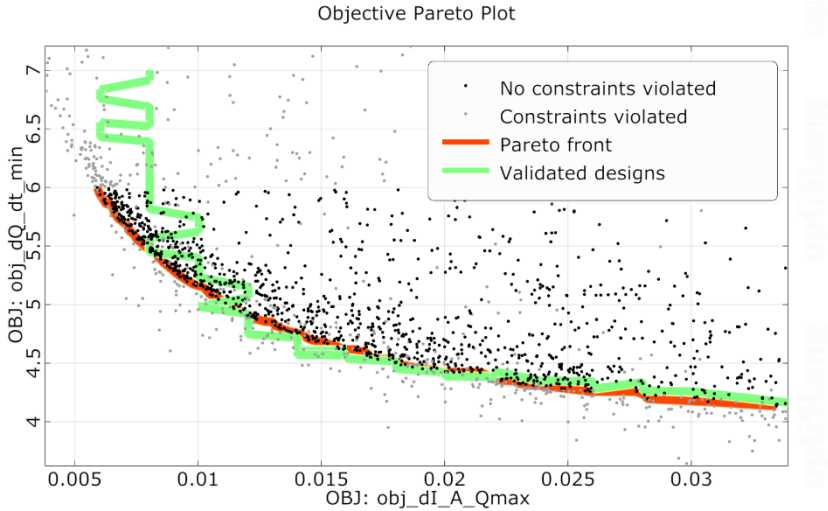
Optimization criteria:
-reducing hysteresis by reducing the slope of the Q-I-curve
-reducing the gap between the peaks
Constraint:
-maximum flow rate



4.6 2. Level - Re-evaluation

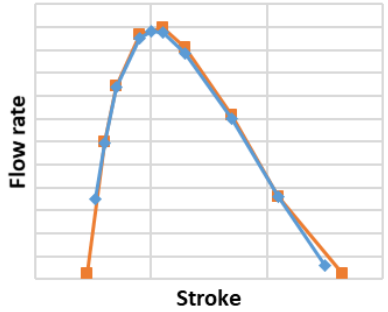
- the results are presented in a 2D-pareto front (2 optimization criteria)
- the optimization results (pareto front) can be validated with the validator system from the wizard
- the MOP pareto front shows a high quality for curves with lower slope
- the recomputed results are less smooth
- → the re-evaluated results need to be re-evaluated because the system simulation fields are based on MOP





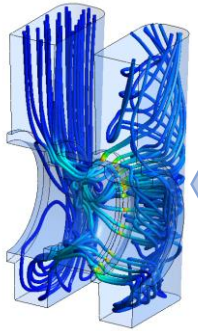
4.6 2. Level - Re-evaluation

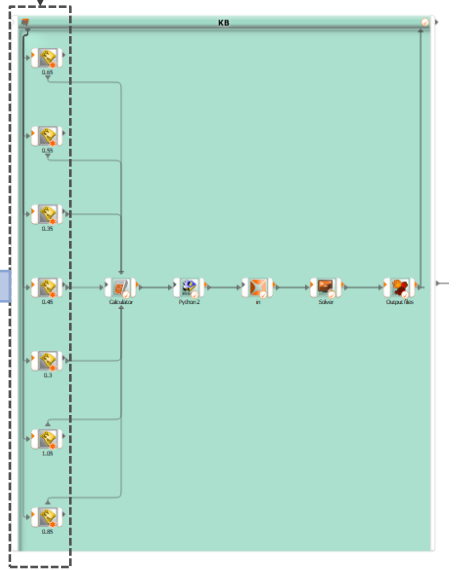
- the evaluation of the MOP based on CFD-results
- setting the geometrical parameters into the CFD system and rerun
- very small difference in flow rate, small difference in flow force



evaluation of MOP interpolation (CFD-results)

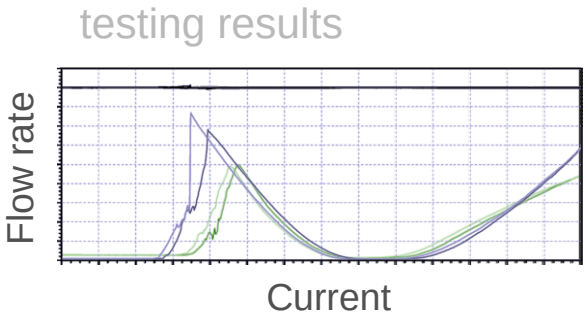
CFD-rerun





5 Summary

- optiSLang can be used for various tasks and simulation methods
- example: 4/4-directional valve:
  - system simulation and optiSLang: analyse the potential of the product and define where to start
  - coupling optiSLang with CFX and AMESim to connect geometrical parameters with a dynamic system response
  - first testing results validates simulation method/results
- next steps:
  - robustness analysis (RDO) based on manufacturing tolerances



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Simulation task and general approach

- Concept study:

  Concept 1: minimal changes in PA to reach the specification; reduce jet forces in PB and AT

  → **not possible**

  Concept 2: changing the opening in PA to increase PA, which decreases PB; add an annular gap to PB to increase flow rate PB again

  → **additional critical control edge, Q-I-edge**

  Concept 3: change the spool and block design, change the precontrol flow, change the PA opening, change the PB opening, change the AT flow

  → **new concept, many computations required, limited amount of time**

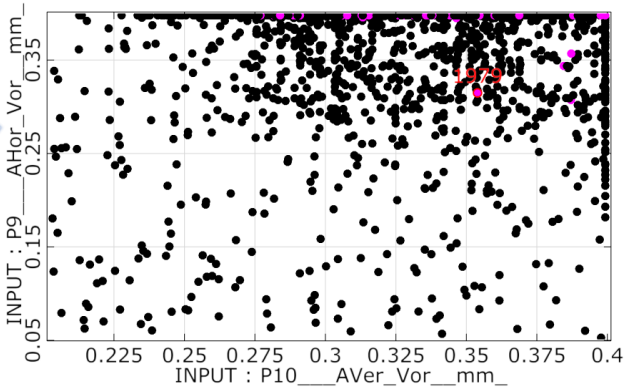
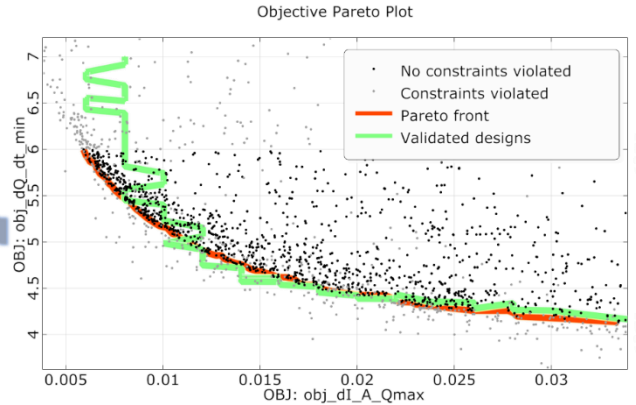
4.3 CFD-simulation with optiSLang

- MOP are created for each position
  - → *do not mix geometrical and operational parameters*
- **WHY?**
  - → the behaviour of the operational parameters (stroke, current, pressure difference) are known and have a wider range here than the geometrical influences
  - → leads to good high COP for the operational parameters and low COP for the geometrical parameters

it is also possible to create one MOP were the response is set for one specific stroke like e.g. flow rate at 0.3 mm stroke

Problem: ~~for one input set all CFD-computations must be feasible and successful~~

4.6 2. Level - Re-evaluation

- correlation between pareto front and geometrical parameters
- mark the optimal design
- look at the distribution of the important input parameters

- marked parameters are at range boundary
- → increasing the boundary as a possibility for next generation