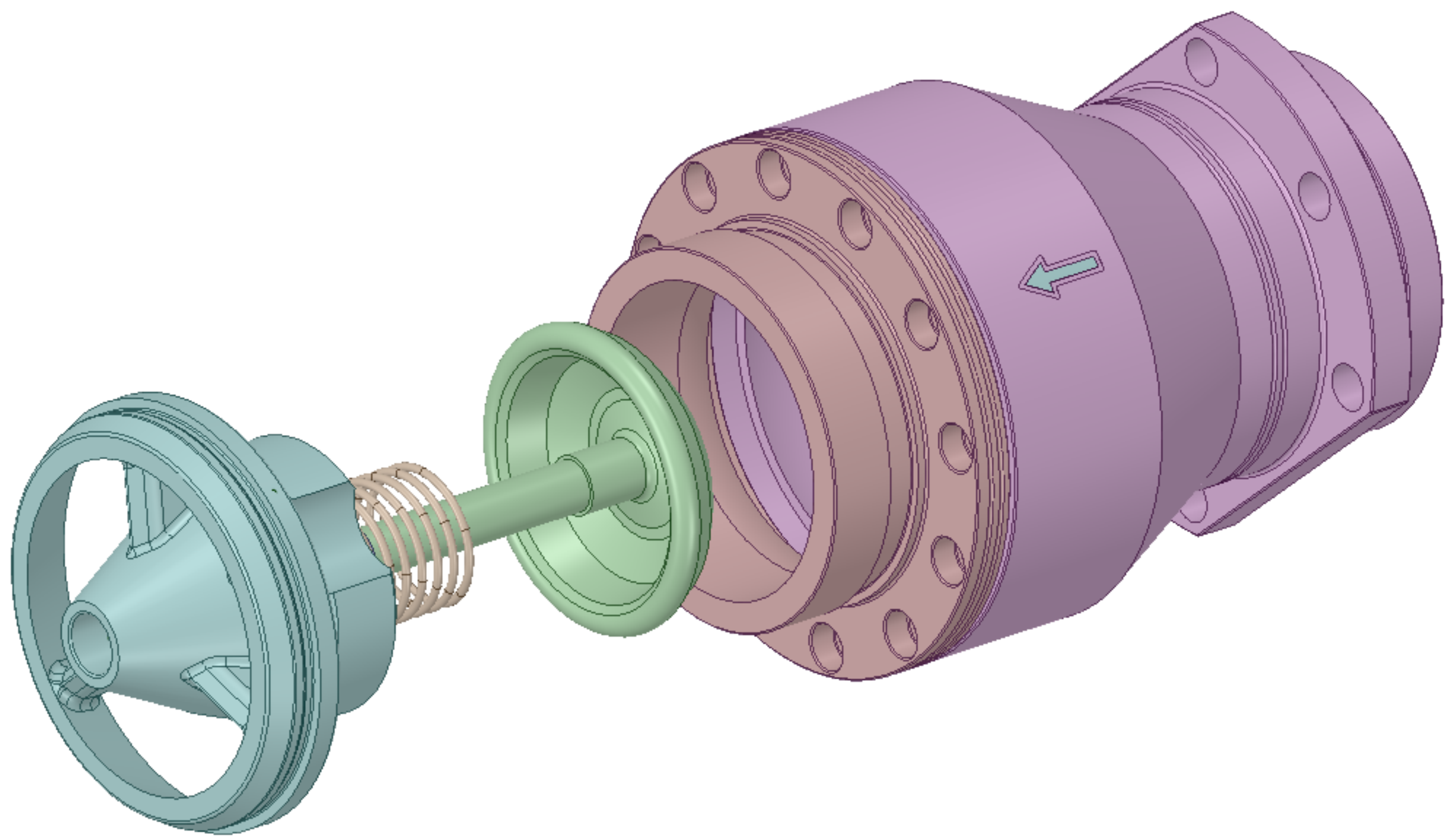


Poppet Valve Optimization

CAESES® and SimericsMP®

OMIQ srl Via Serviliano Lattuada 31 - 20135 Milano - info@omiq.it - www.omiq.it

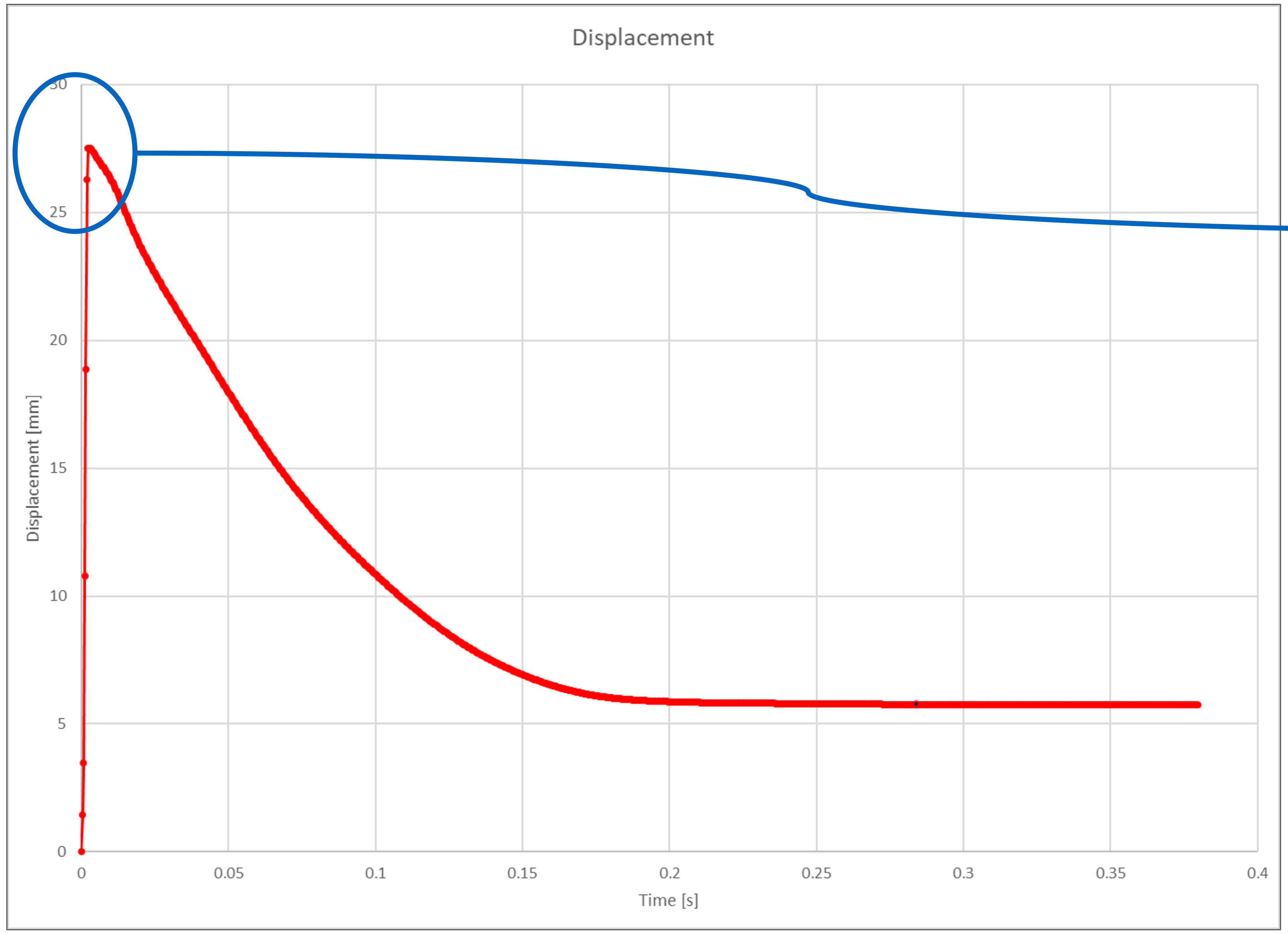
Introduction

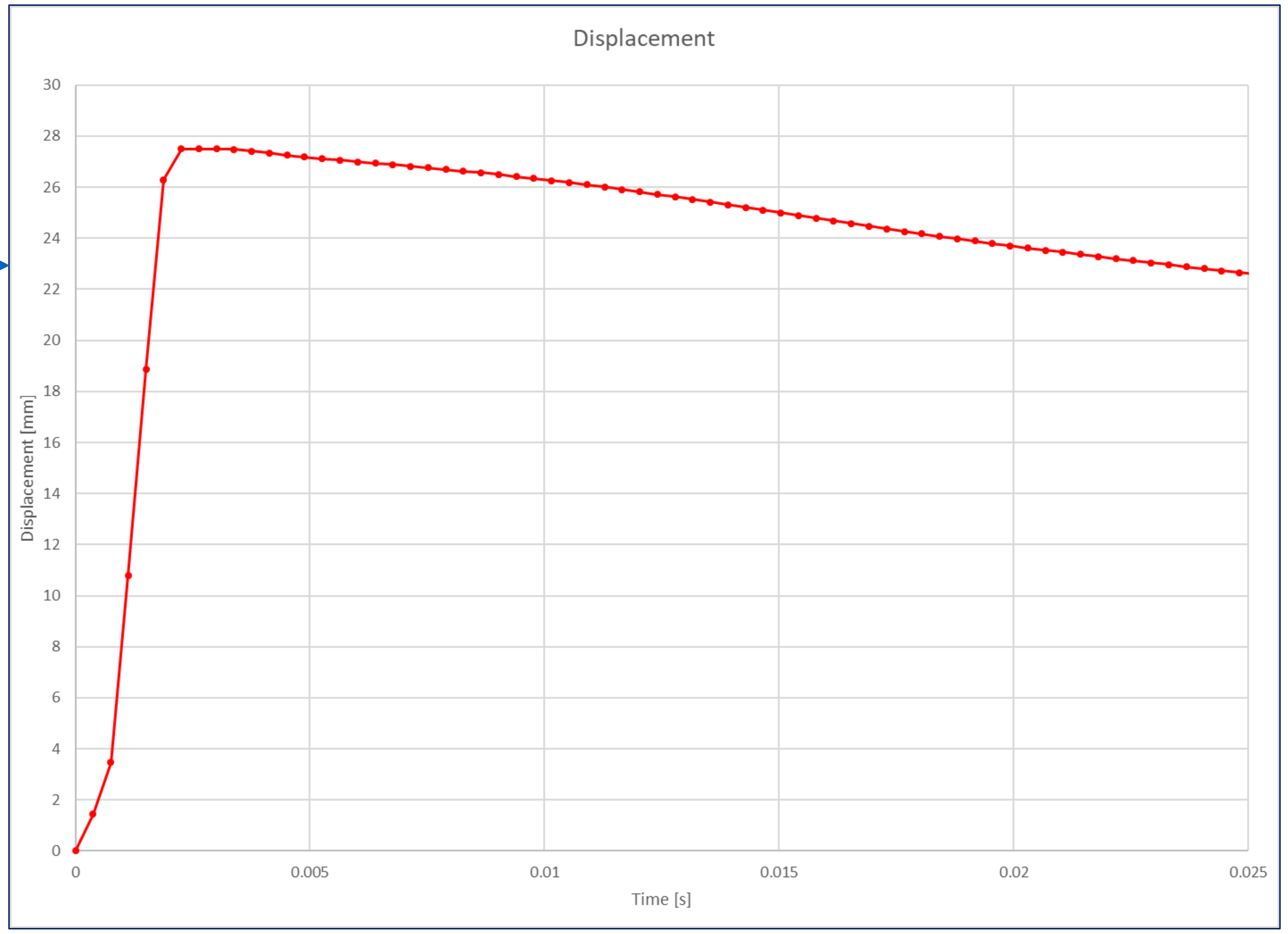
- ✓ This presentation introduces a methodology for the optimization of the dynamic behavior of a poppet valve.
- ✓ The project was carried out in collaboration with Danfoss High Pressure Pumps.
- ✓ SimericsMP® (Computation Fluid Dynamics calculation) and CAESES® (geometry optimization) were combined to solve the problem.
- ✓ It all started on the test bench, where the valve, once opened, showed an instable behavior. We were then asked by Danfoss HPP to investigate the issue and find a solution.
- ✓ The valve dynamics was studied with SimericsMP®. Based on the results obtained, the poppet geometry was optimized with CAESES®.

Results on the original geometry

Valve results

- A dynamic analysis with SimericsMP® was performed on the original configuration of the valve.
- Results obtained from this analysis showed that the valve, once opened (maximum displacement 27.5 mm), tended to close back and stabilized on a final position, more or less half-way between full opening and full closing.





Optimization strategy

CAESES®

- The original geometry was used as the baseline for the optimization with CAESES®.
- CAESES® is a geometry optimization tool that can be easily automated and integrated with simulation software.
- CAESES® generates geometry variants and automatically drives the CFD solver (SimericsMP® in this case) .
- In this specific valve case, the geometry changes were determined considering 4 "main geometric parameters", that were identified as follows:

1. Axial translation
2. Radial translation
3. Angle circle
4. Axial translation bottom

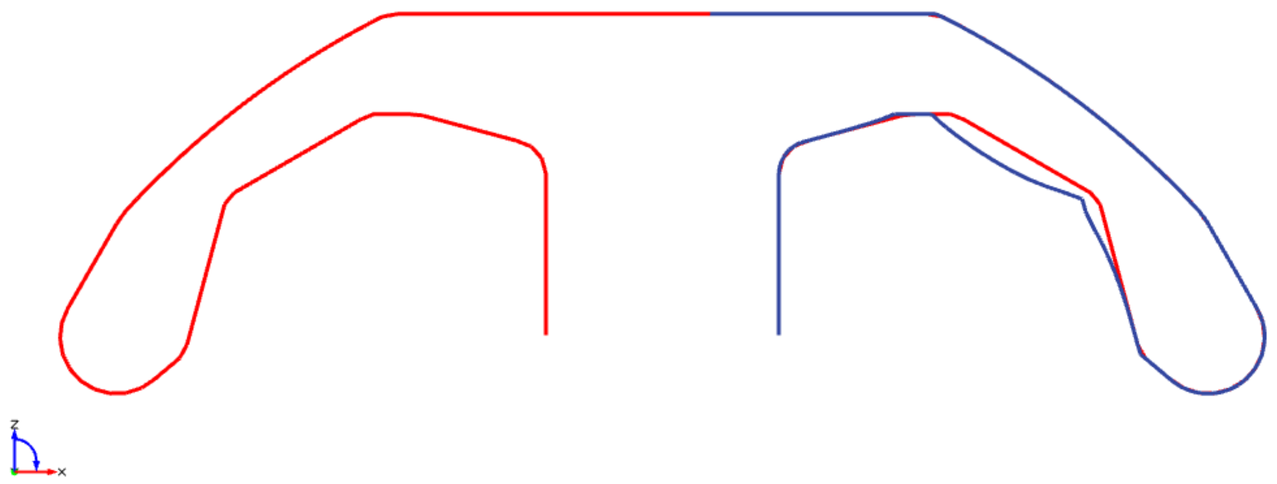
All these changes were limited with a lower and an upper value in order not to modify the distance between the poppet and the support when the valve is fully open. It was decided to work on the internal part of the poppet because this is where baseline CFD results showed high values for the pressure forces pushing the poppet to close back.

In the next slides, the geometry modifications are shown. The red line is the original geometry, the blue line shows the variants.

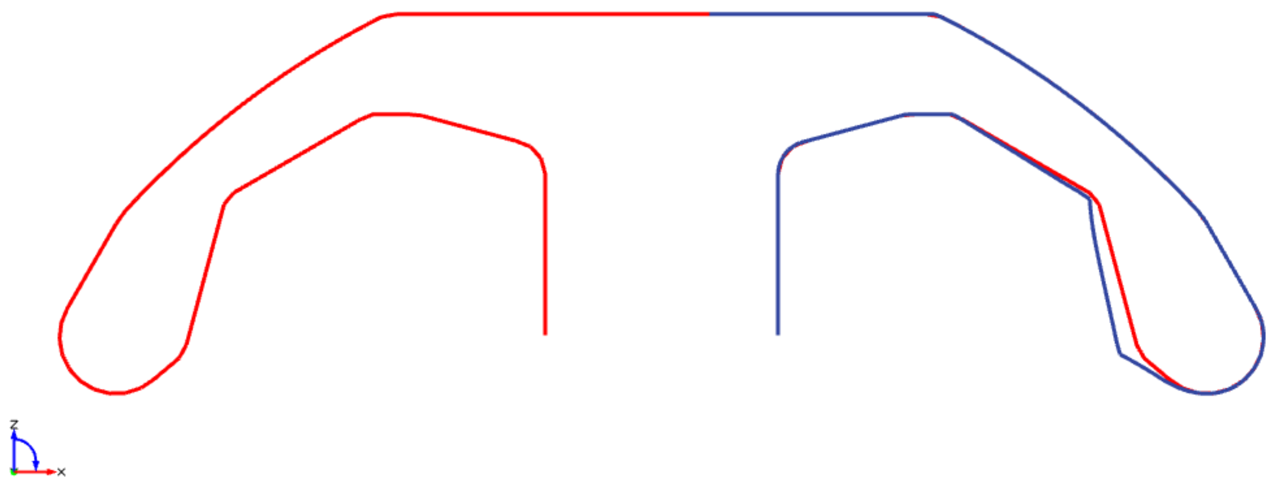
Optimization strategy

CAESES®

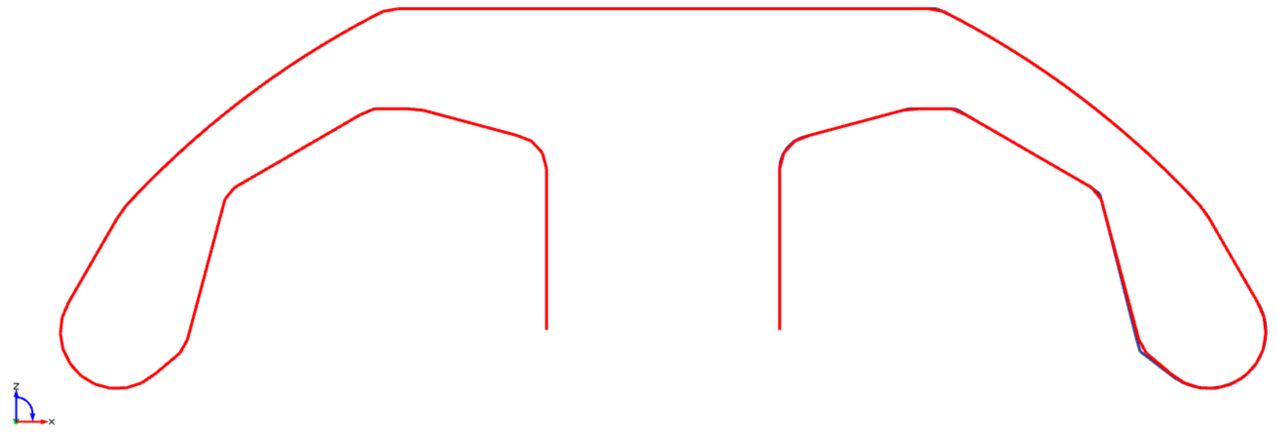
1. Axial translation



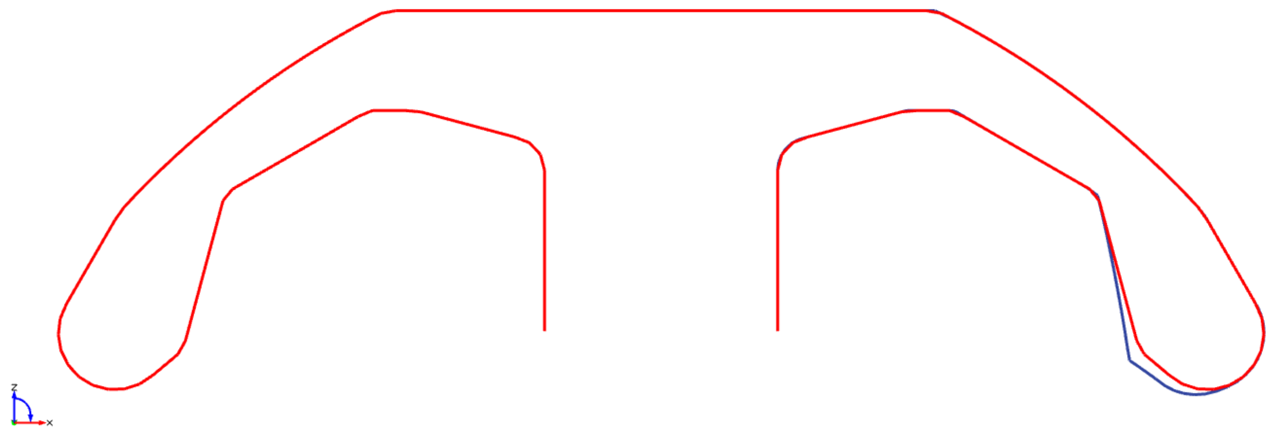
2. Radial translation



3. Angle Circle



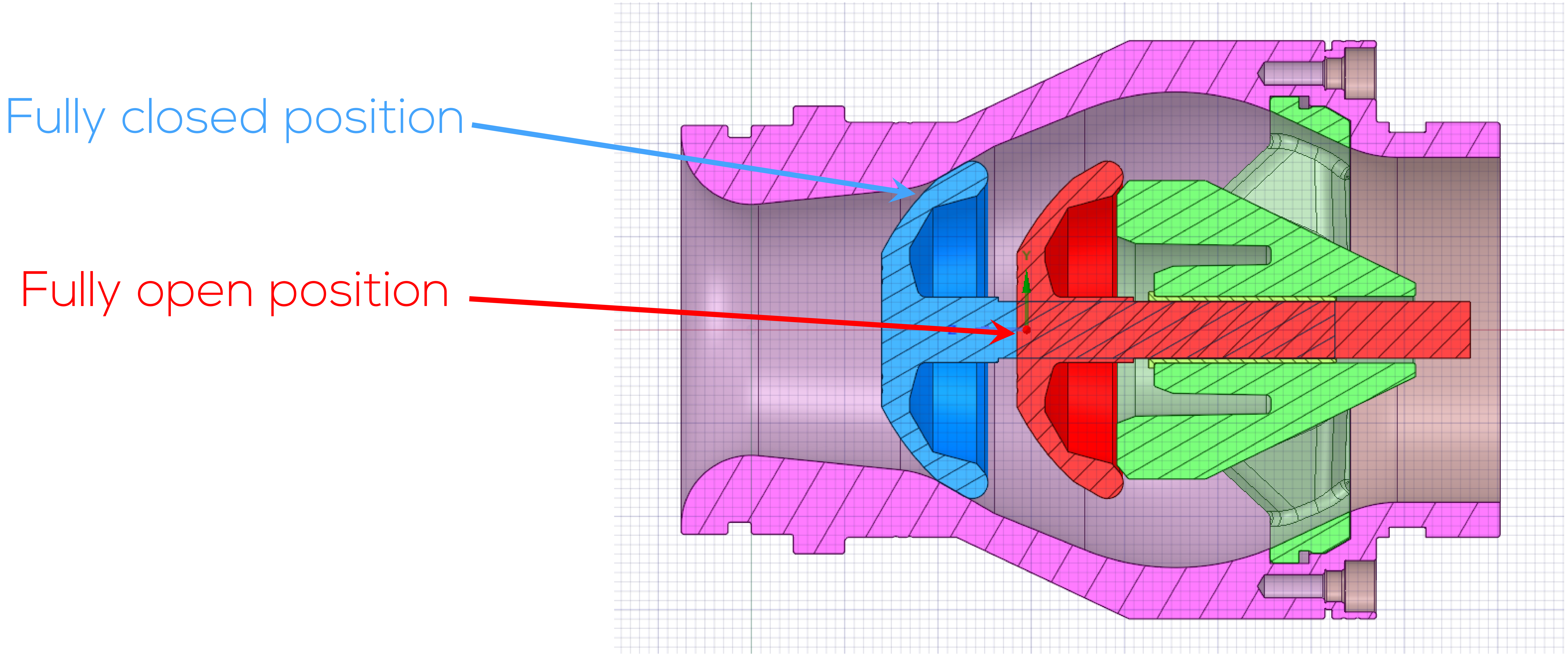
4. Axial translation bottom



Optimization strategy

Fully open position

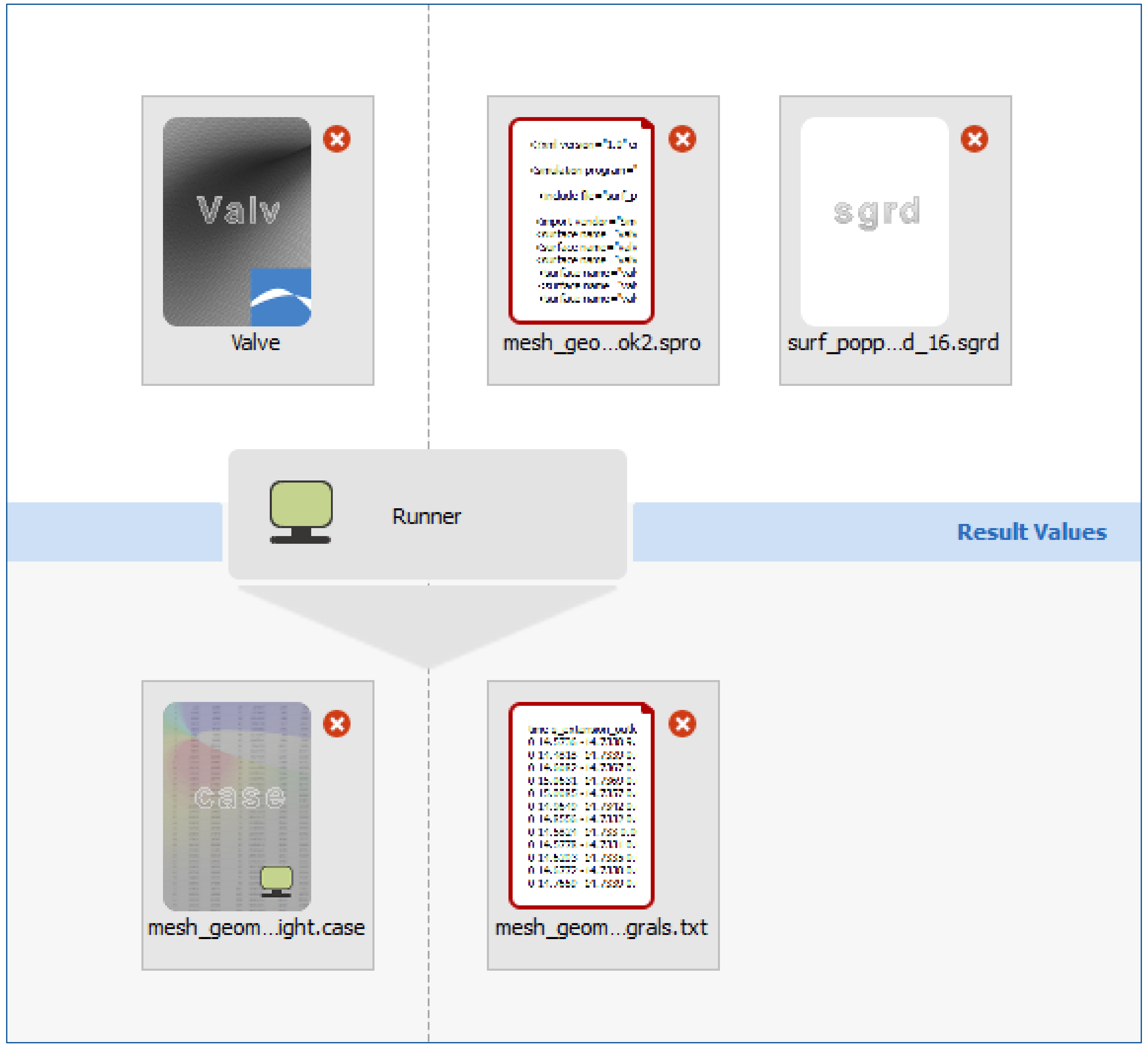
- To speed up the optimization procedure, steady state simulations with the poppet in fully open position were used.
- This approach would not affect the optimization results as the fully open position is where pressure forces should be maximised to avoid the poppet closing back.



Optimization strategy

CAESES® - SOBOL

- CAESES® can generate new geometry variants, as indicated in the previous slides, and consequently export them in STL format to SimericsMP® for meshing.
- Based on the variation of the above-mentioned parameters, we defined in CAESES® a Sobol DOE (Design Of Experiments) sequence.
- CAESES® automatically sets up the geometries and runs the SimericsMP® calculations.
- A baseline model with the original geometry in "fully open" position was also calculated in order to have a starting point to investigate the new configurations.



Optimization strategy

Optimization criteria

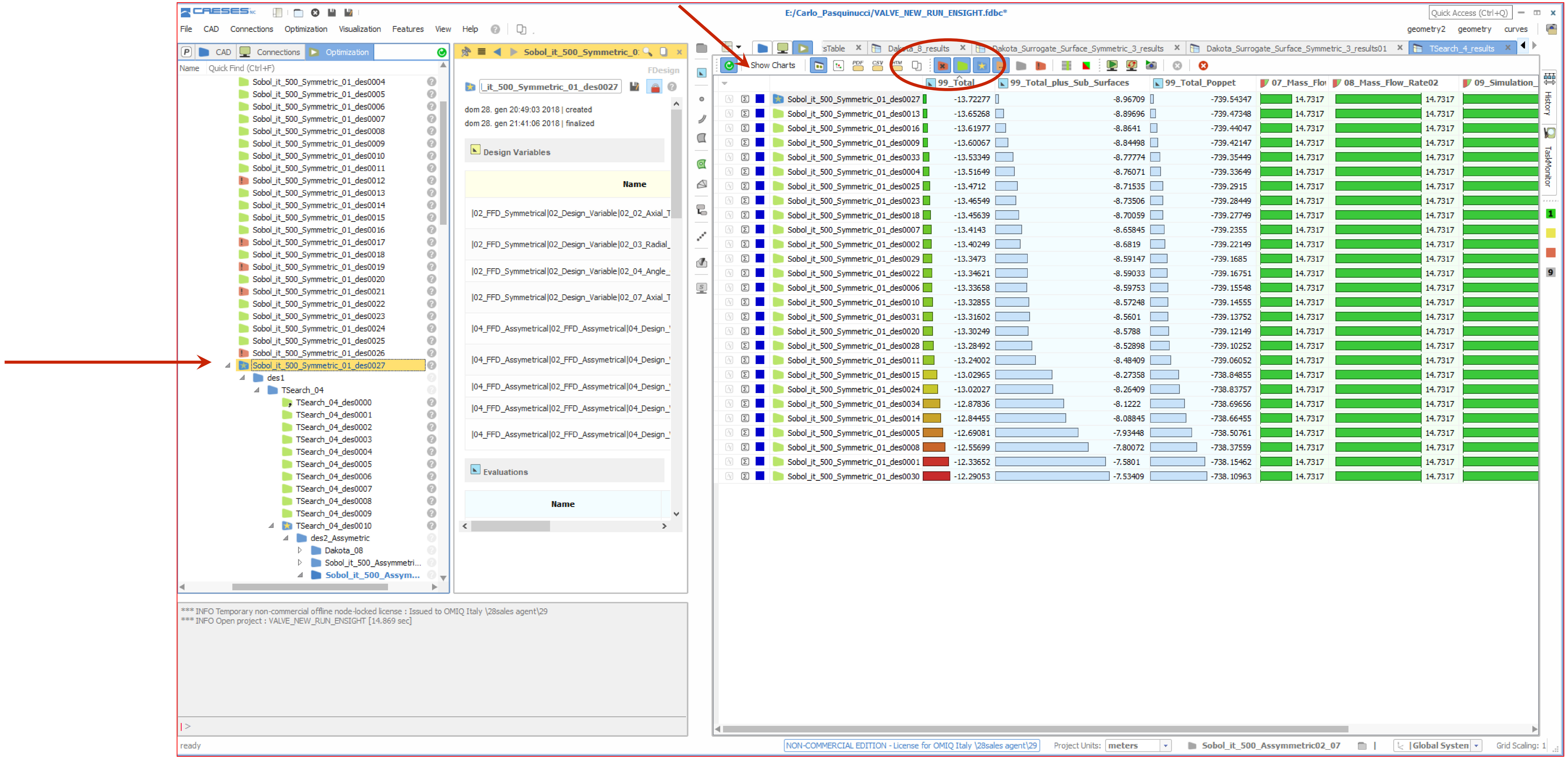
- Aim of this optimization process was to improve the shape of the poppet so that the valve would not close back, once opened, considering a volumetric flux of 53 m^3/h.
- From the baseline calculation, it is possible to calculate the value of the spring force when the valve is fully open, that is 12.64 N.
- This value was considered as a reference for the optimization. If the fluid force acting on the whole poppet was higher than this value, then the valve would stay open. The variation of the force value had also to be kept lower than 17 N, that is the value of the spring force when the valve is in contact with its back support.
- During the DOE sequence calculations, results that were significant for convergence and optimization, were monitored, that is

1. Mass flux: to evaluate the quality of convergence.
2. Distance of the poppet to the support, in order to check the existence of a fluid gap between the poppet and the support itself (i.e the poppet would not touch the support).
3. Value of the Force acting on the poppet.

Optimization

Optimization results

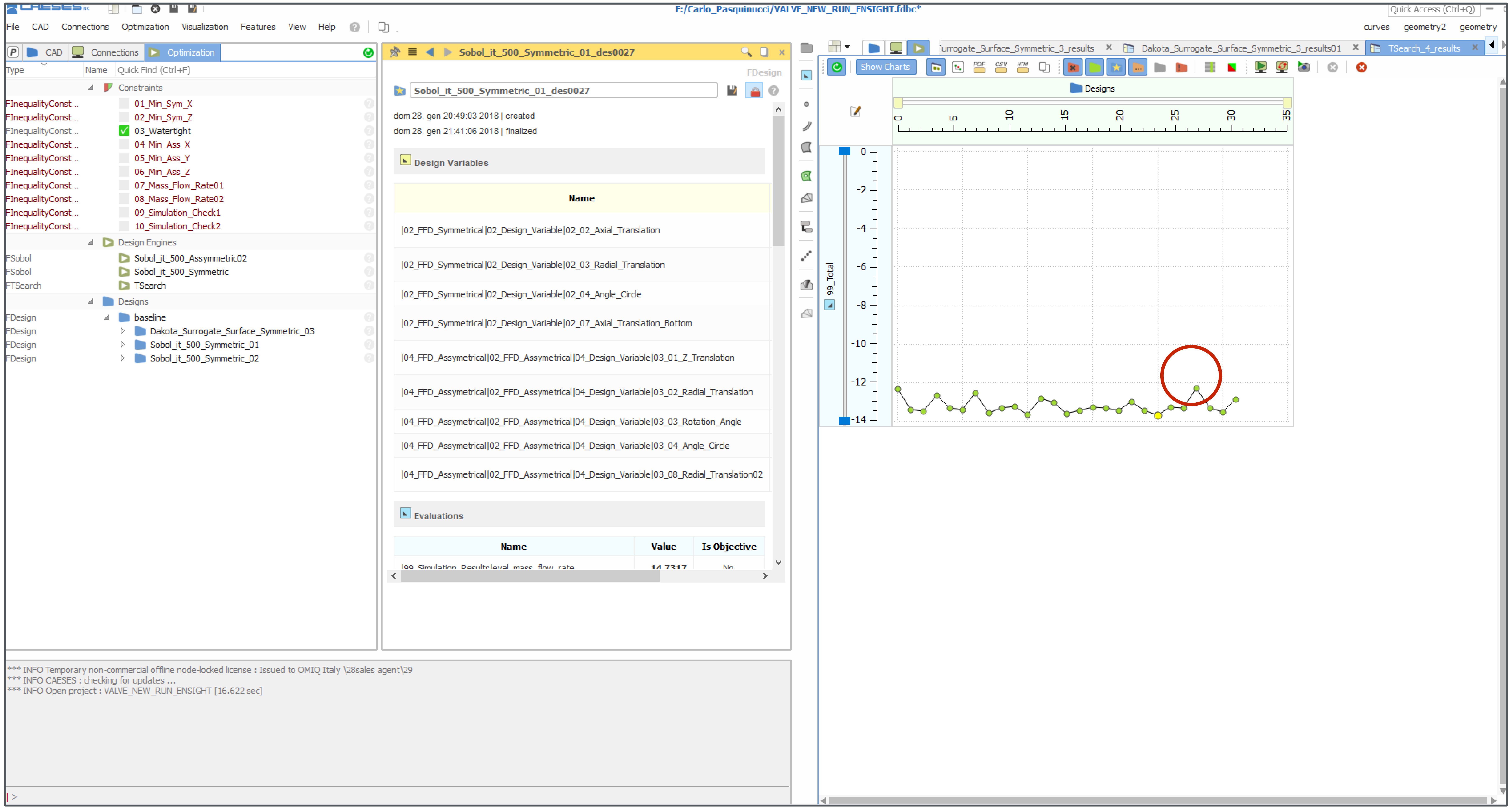
- Once the DOE sequence calculations were completed, CAESES® also selected the "best solution" of the DOE set.



Optimization

Optimization results

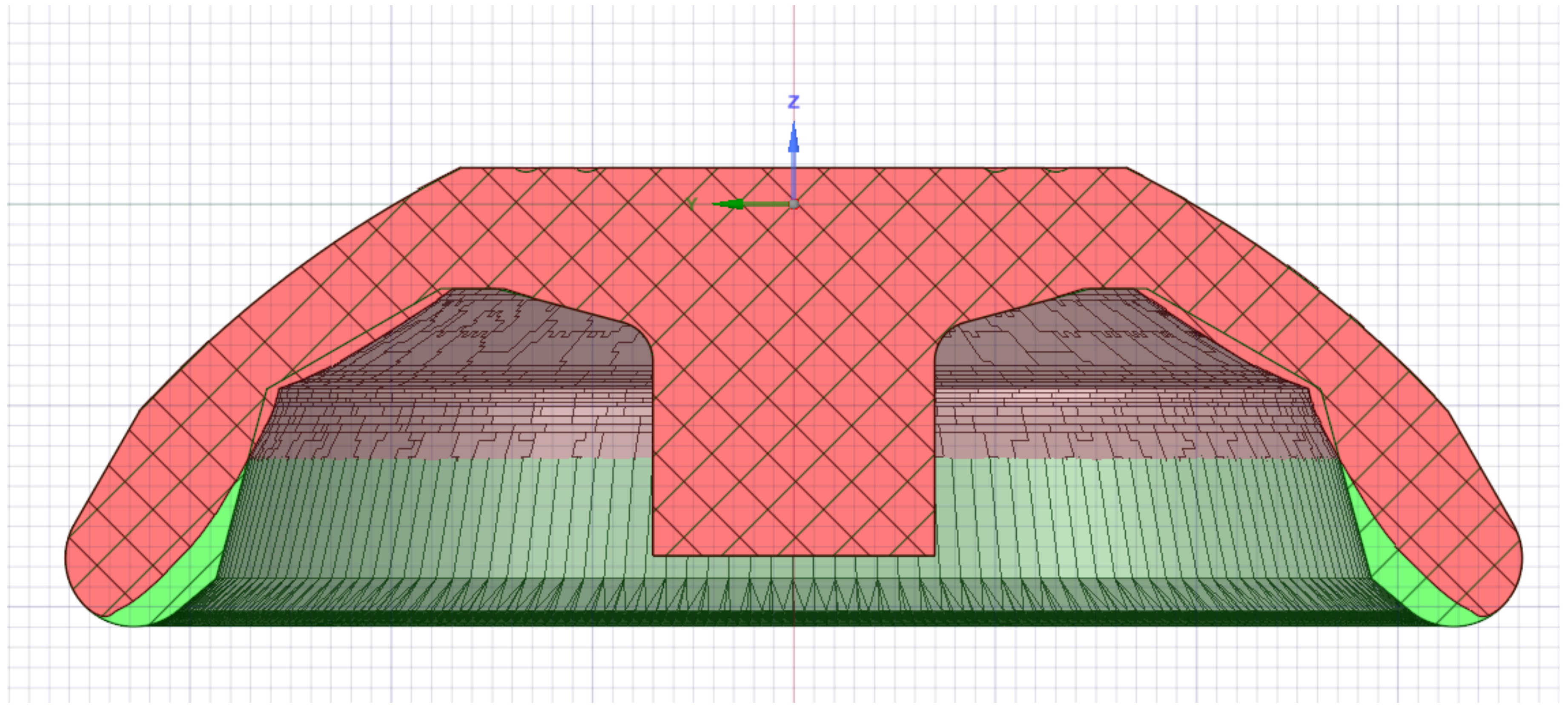
- The "best solution" was defined as the geometry configuration that provided the maximum fluid-force acting on the whole valve poppet surface.

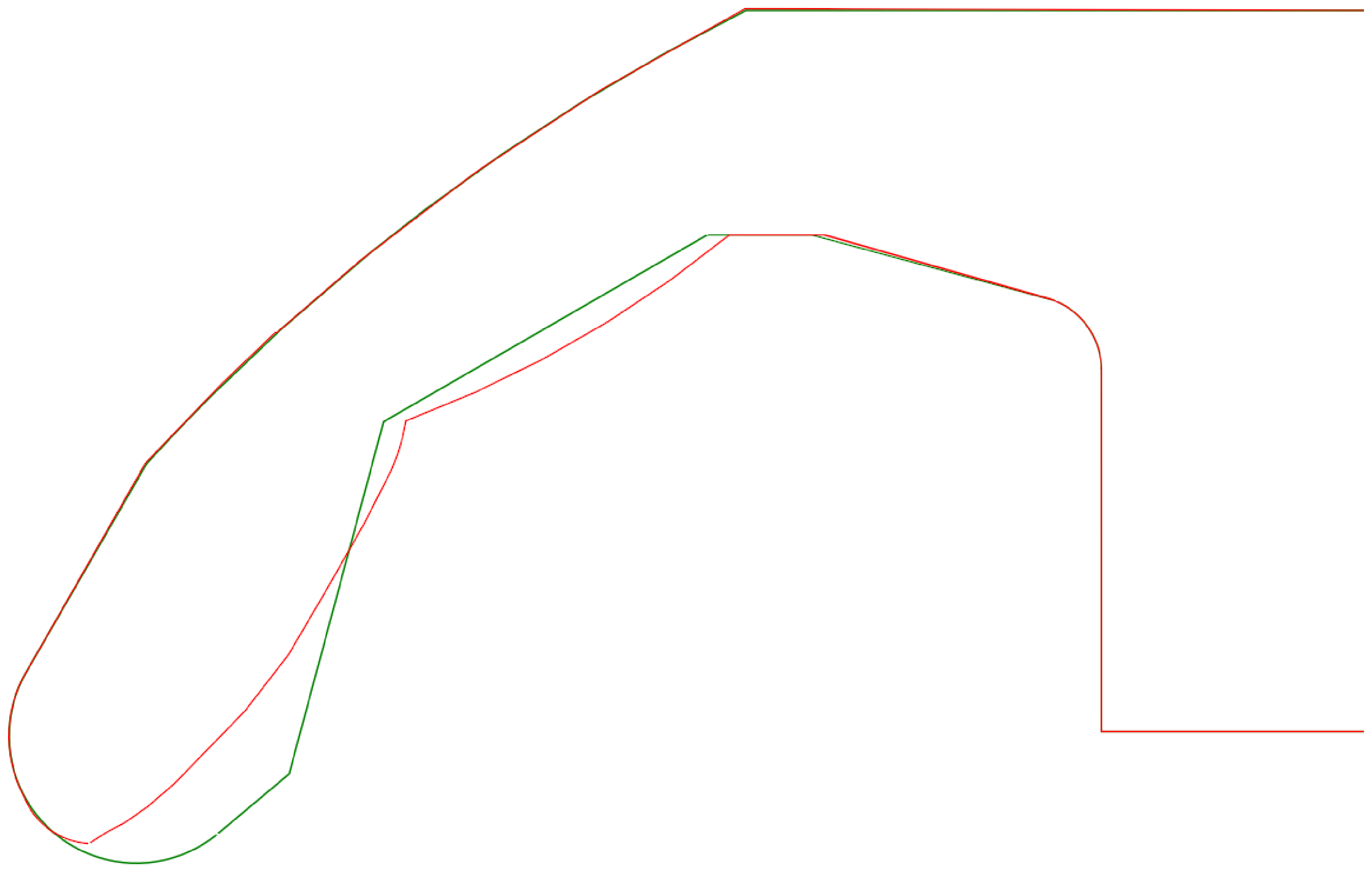


Optimization

Optimization step 2

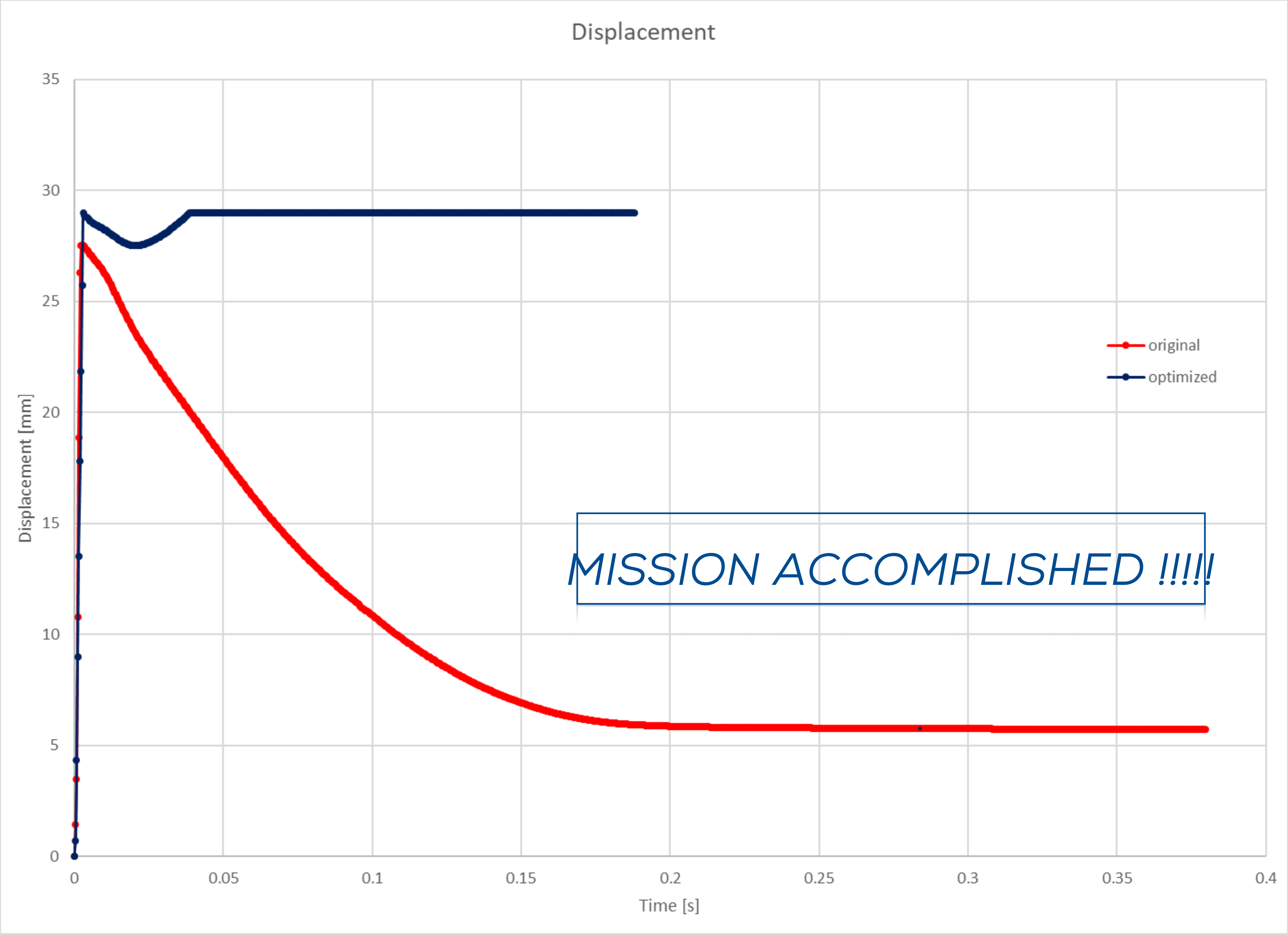
- The "best solution", identified by the DOE sequence, was then improved with a two-step local optimization (tangent method).
- The results were very close to the DOE sequence "best solution", probably because the DOE already considered more than 70 geometry variants, and the best solution was already in the first 30.
- Therefore, the DOE best solution was considered as the "optimal" solution for the defined problem.
- The best solution is represented in red in the images below (in green the original geometry)





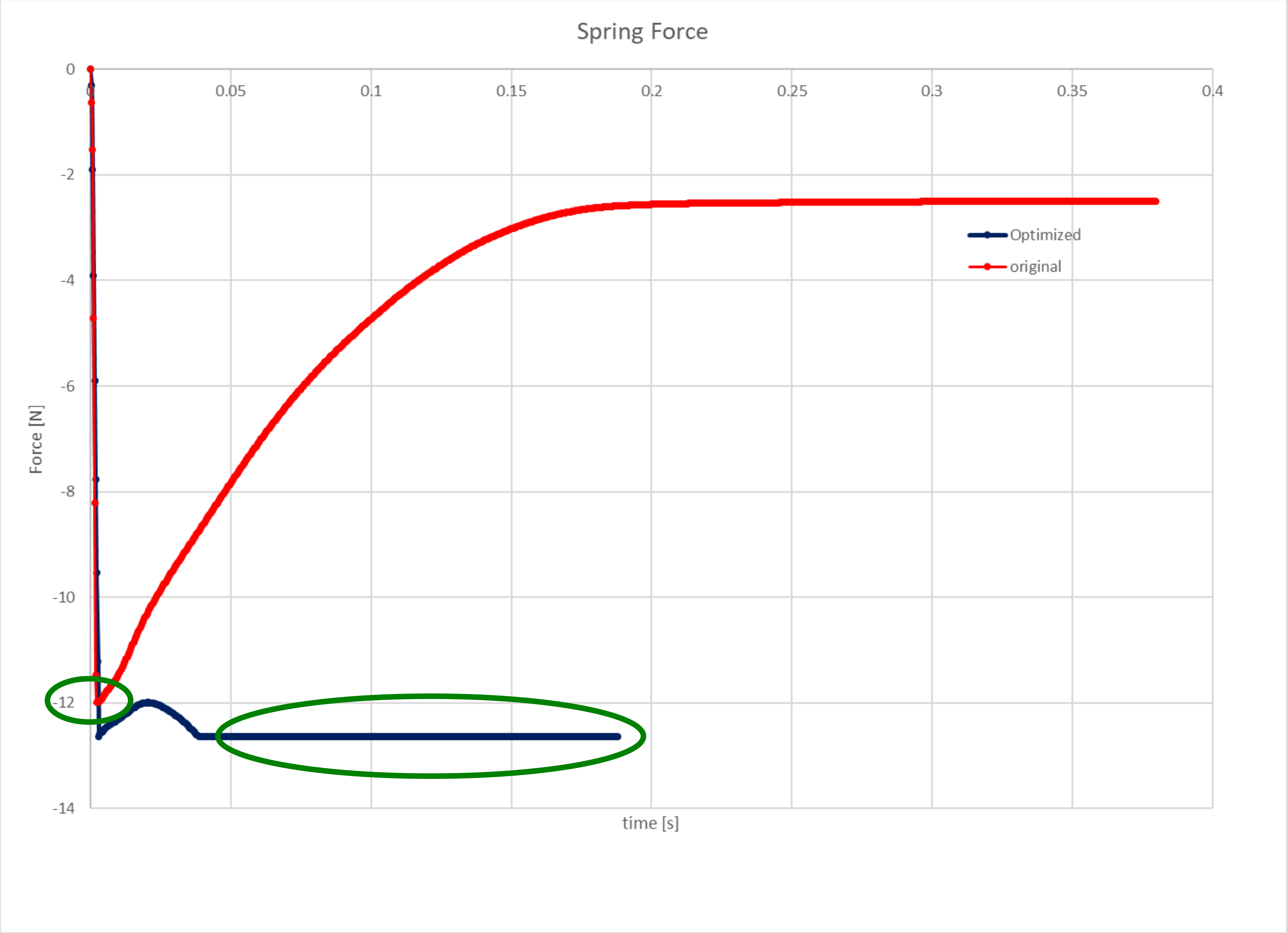
Dynamic Behavior Check

- We finally checked the dynamic behavior of the optimized valve.
- This graph represents the poppet displacement.
- While the original configuration opens up to 27.5 mm and then closes back, the optimized configuration, in 0.039 seconds opens up to 29 mm and then stays open.

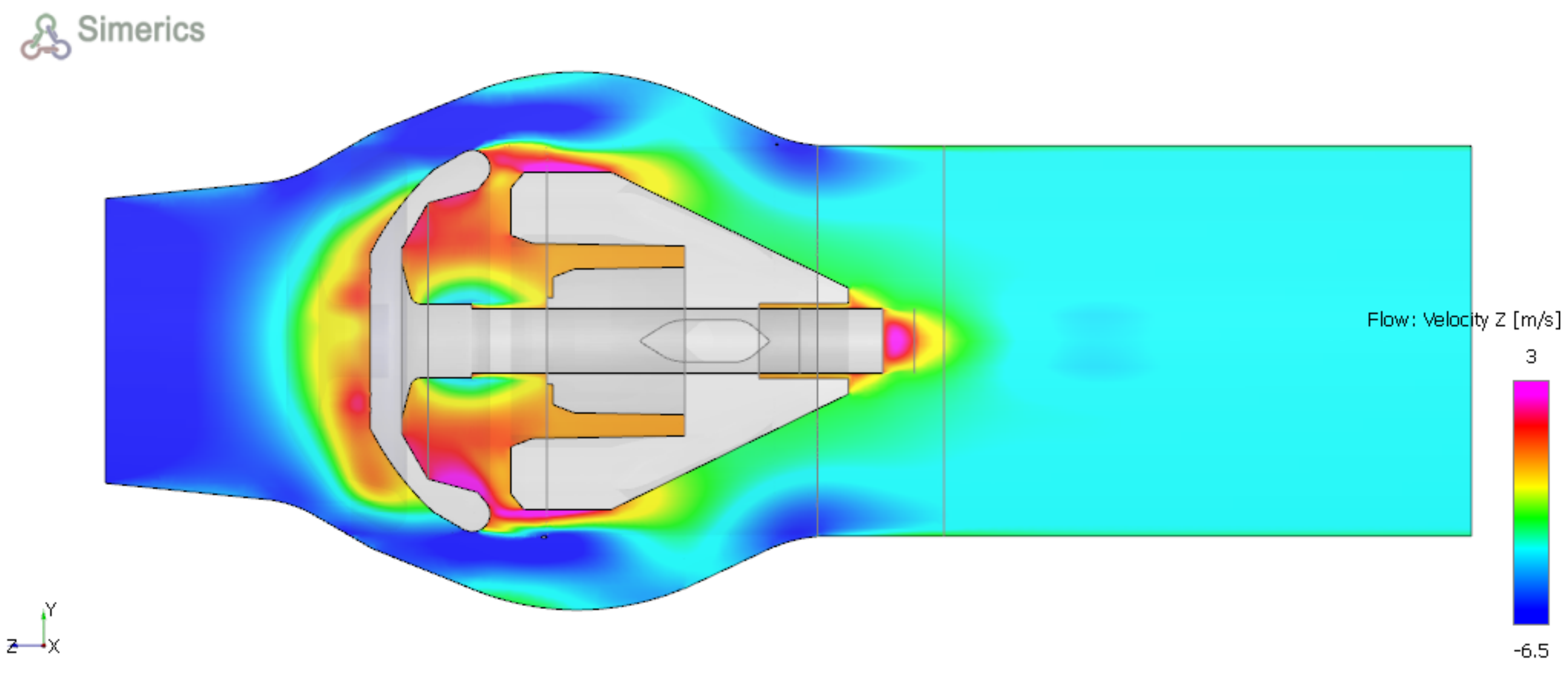


Dynamic Behavior Check

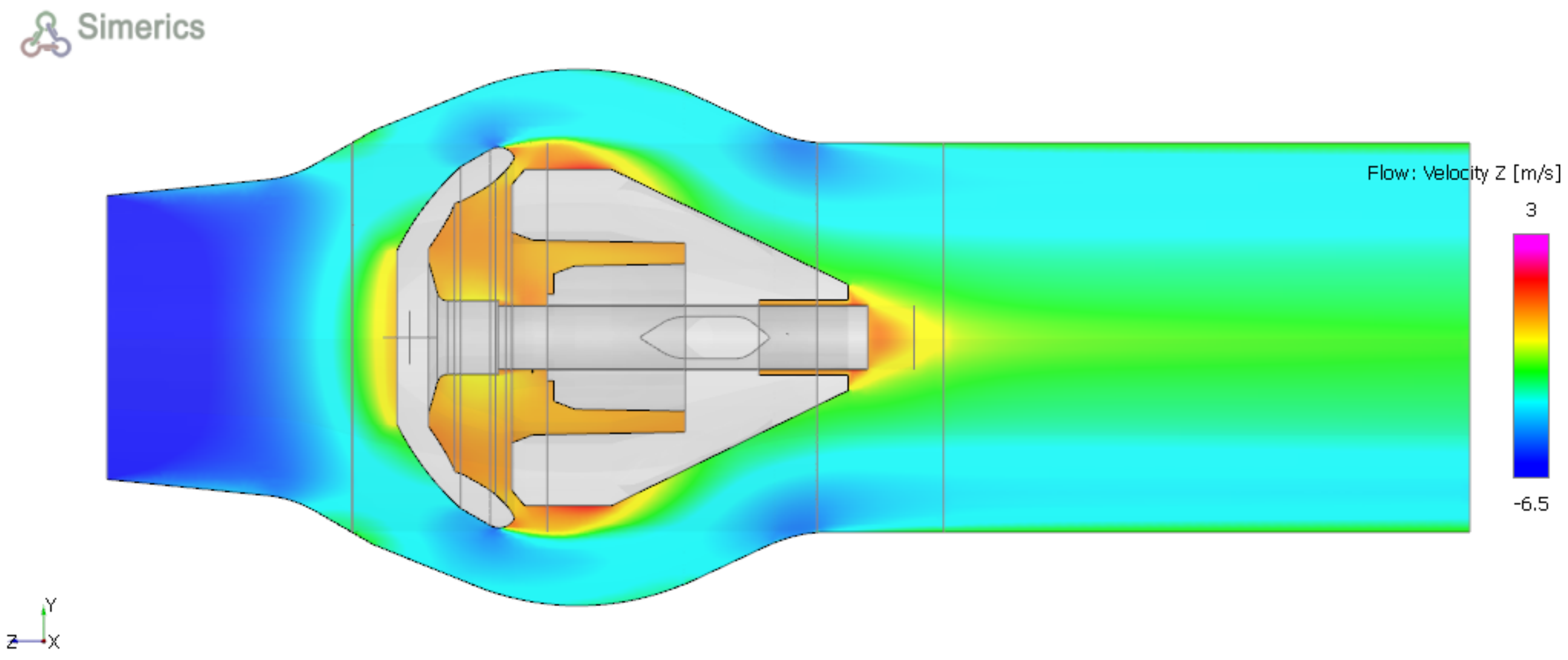
- A second check was done on the valve spring force, that should not exceed 17 N.
- The spring force is the force exerted by the spring: $F_{spring} = -K*X$ where X is the displacement.
- The spring force both in the original configuration and in the optimized one, followed the displacement trend.
- In the fully open position (green circles), the spring force value for the optimized configuration is well below the prescribed limit.
- The solution obtained is then compatible with the actual valve specifications.



Z velocity on X section

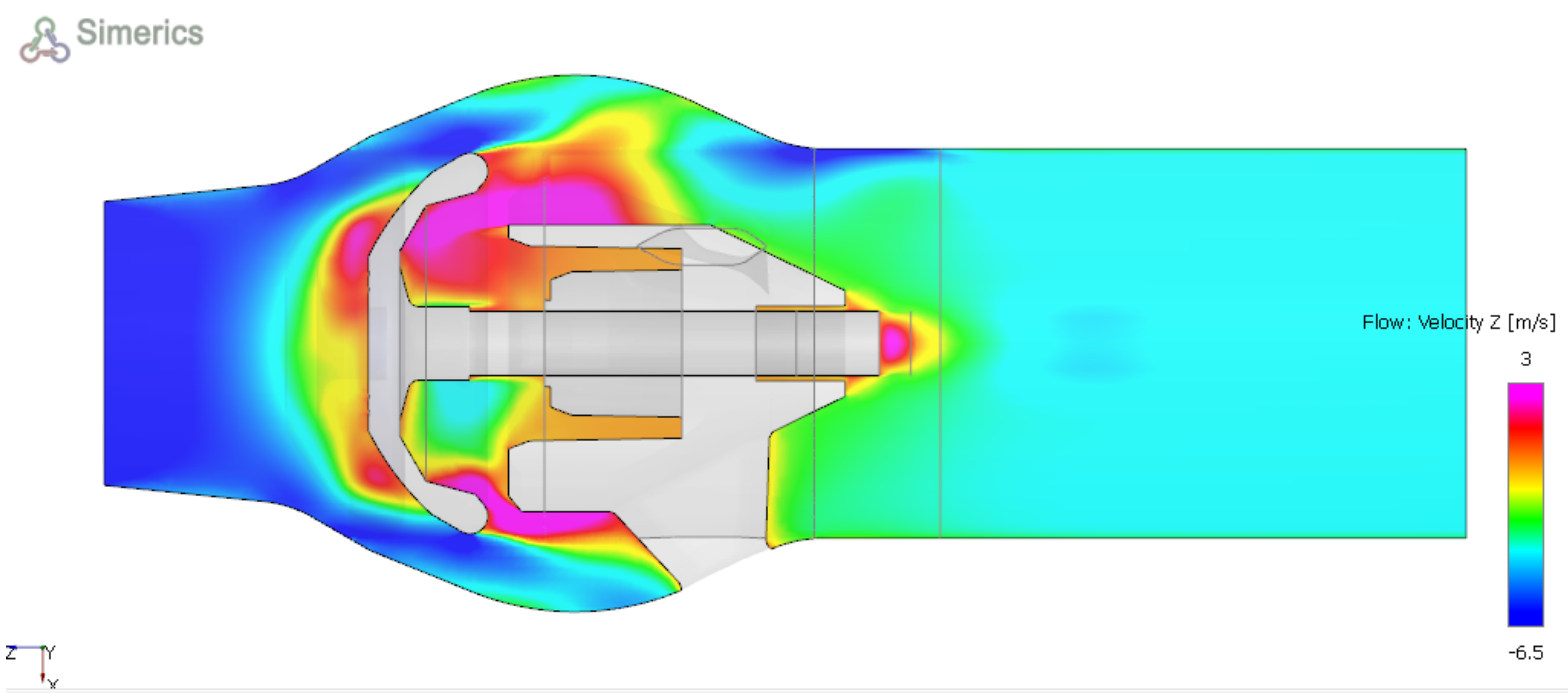


Original configuration @27.5mm

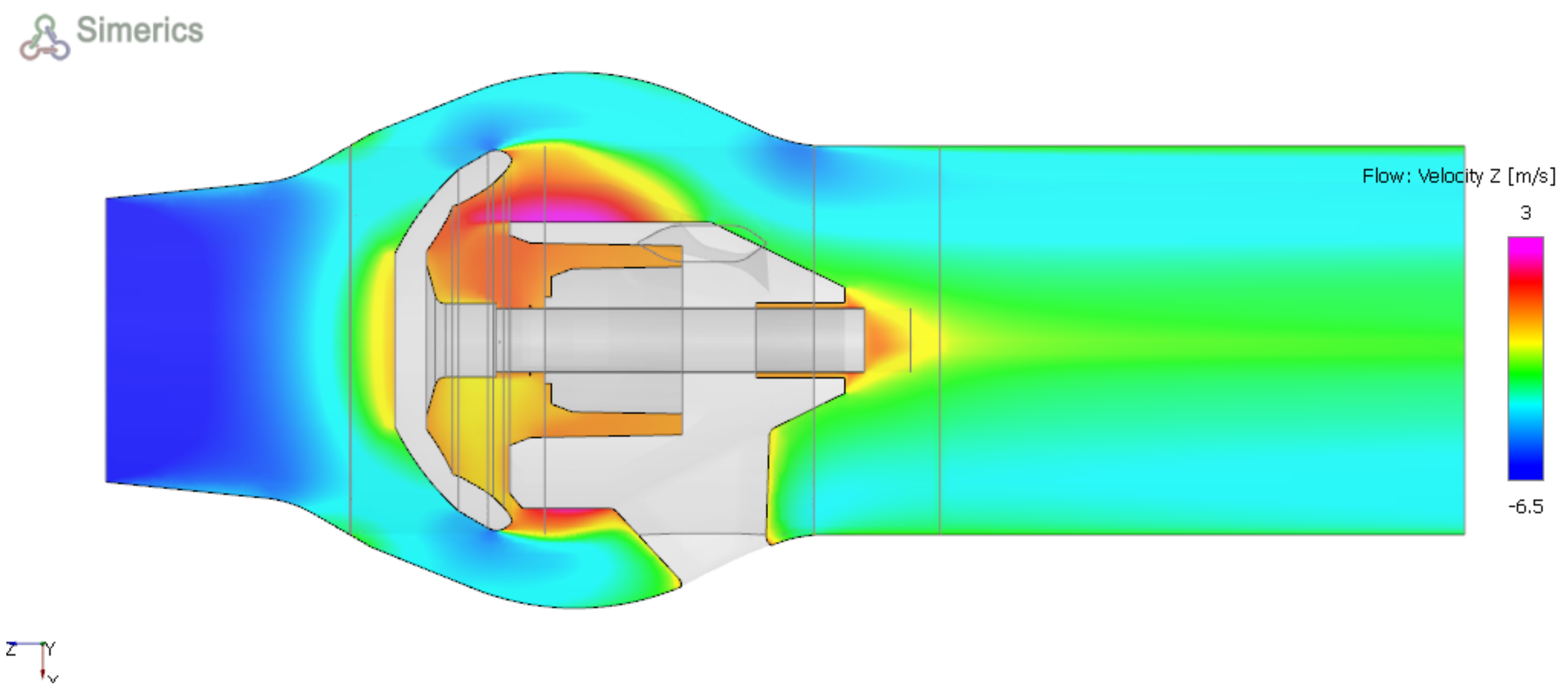


Optimised configuration

Z velocity on Y section

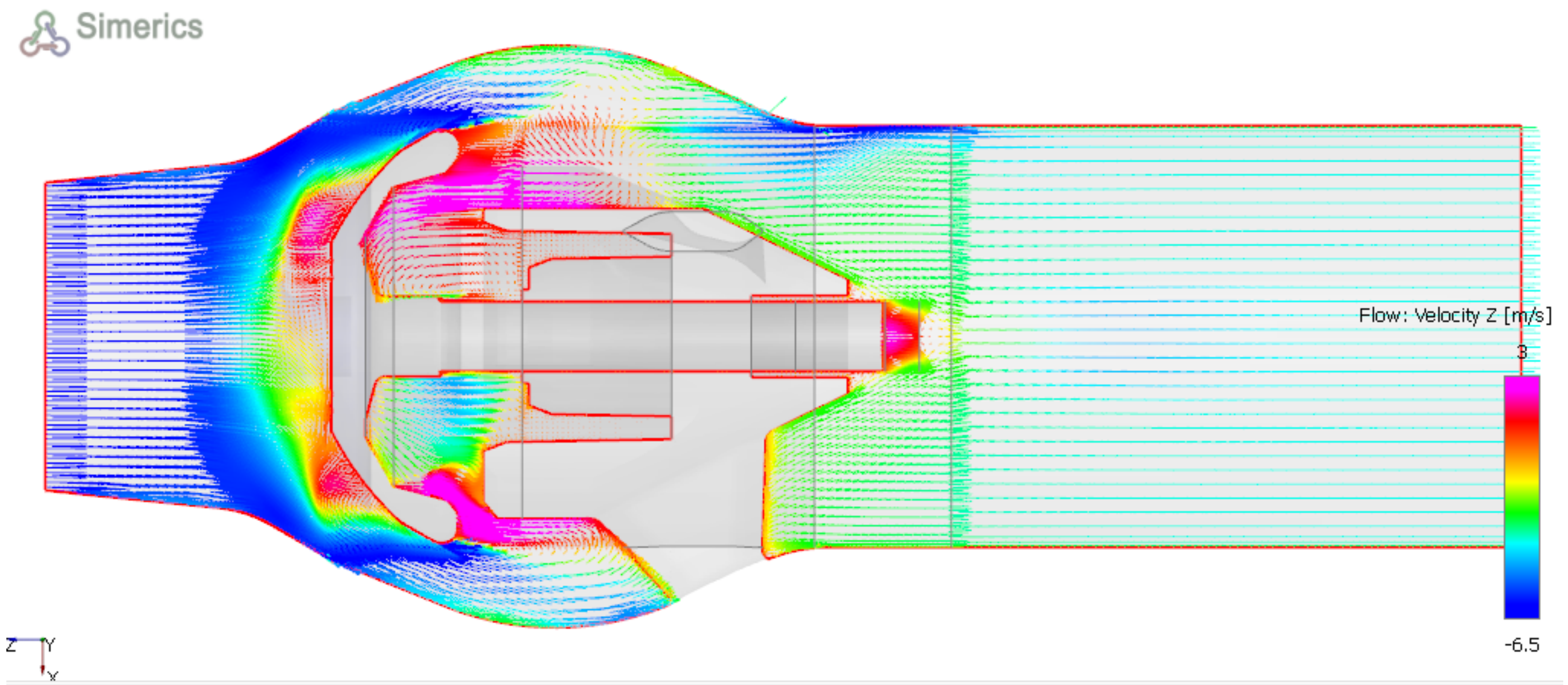


Original configuration @ 27.5 mm

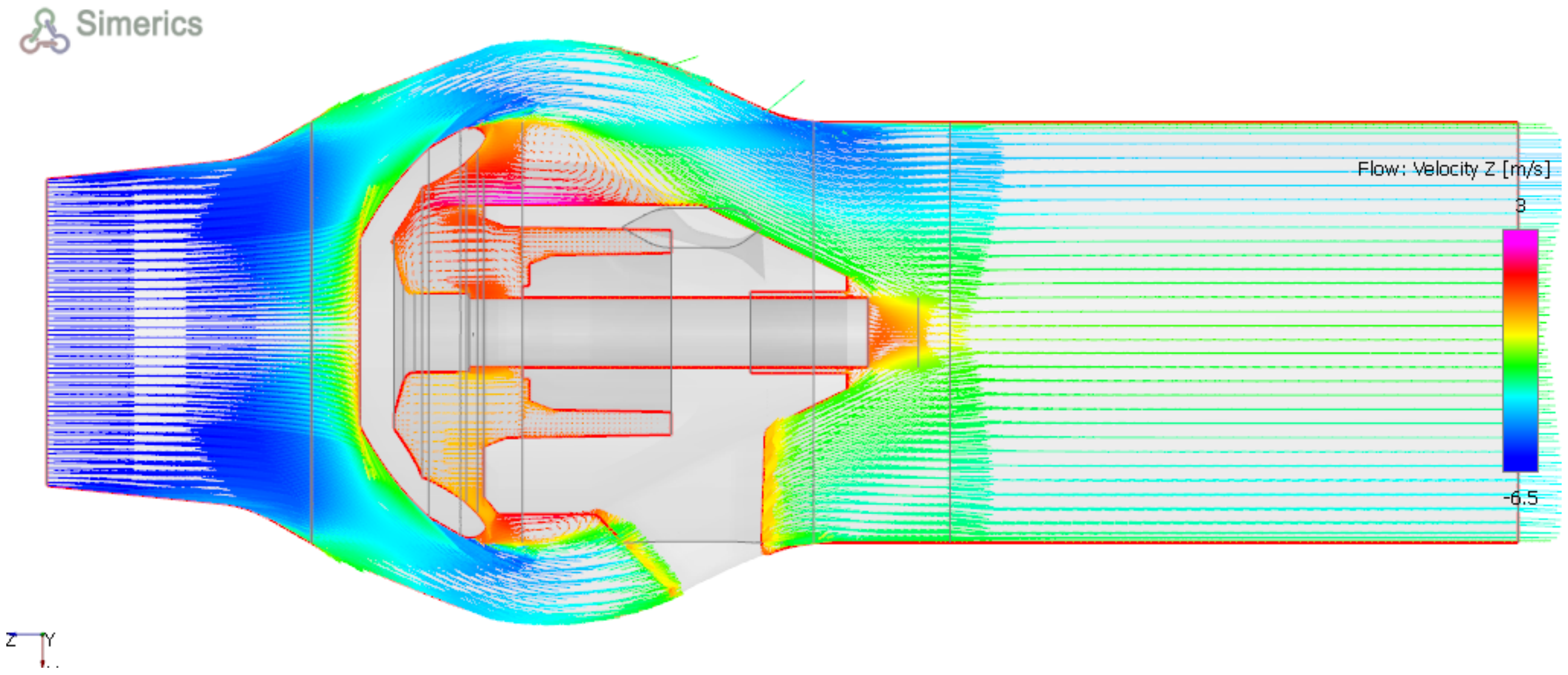


Optimised configuration

Z velocity on Y section, vectors

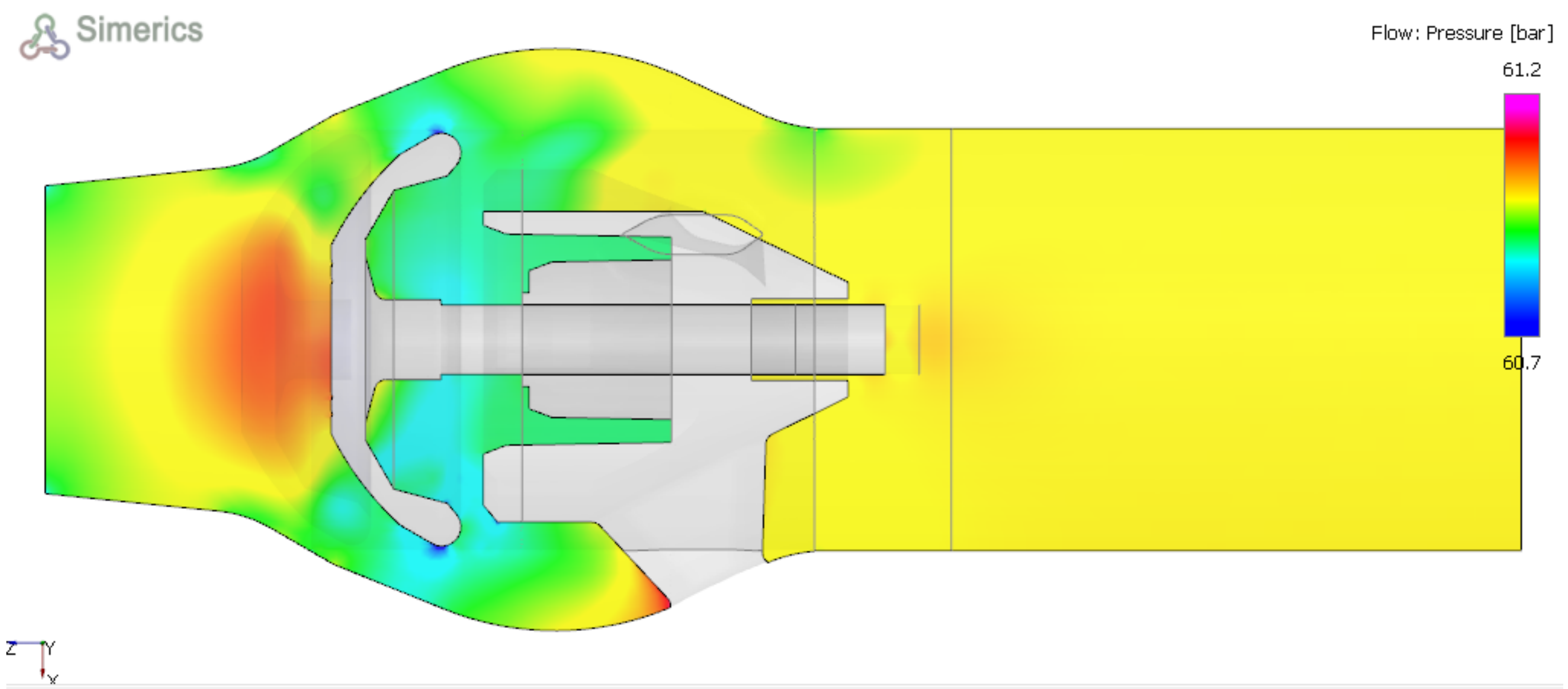


Original configuration @27.5 mm

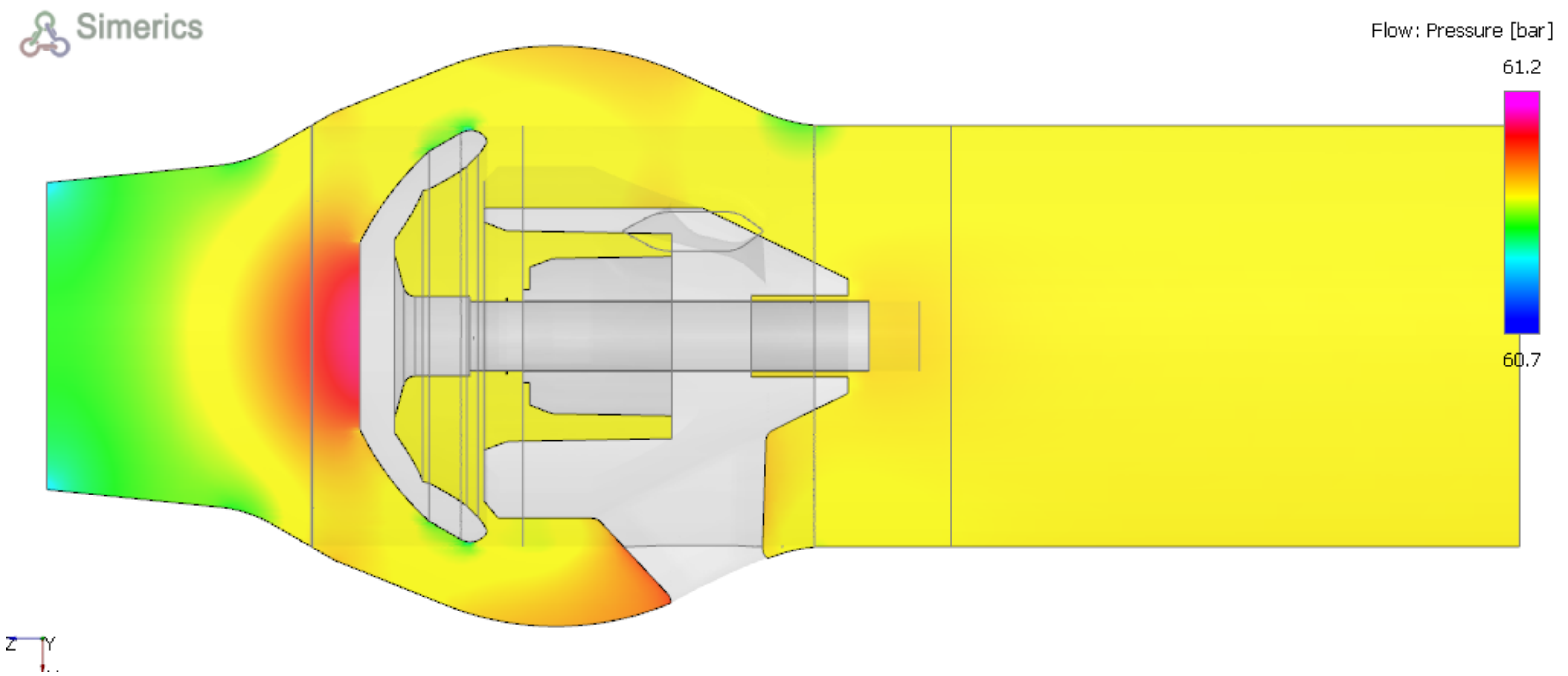


Optimised configuration

Pressure on Y section



Original configuration @27.5 mm



Optimised configuration

Conclusions

- ✓ Through steady state and dynamic CFD simulations, a problematic behavior of a poppet valve was studied. The simulations showed that the valve fully opens but doesn't maintain this position.
- ✓ A parametric geometry of the poppet was built with CAESES® and a DOE sequence defined.
- ✓ SimericsMP® steady state simulations were used to calculate the valve poppet forces for the DOE geometry variants.
- ✓ A "best solution" was identified and a dynamic CFD simulation was performed on the optimized geometry to validate the result.
- ✓ The CFD dynamic simulation proved that the new poppet geometry satisfied the manufacturer (Danfoss HPP) requirements.

We would like to thank Christian Svendsen of Danfoss High Pressure Pumps for the collaboration on this project.