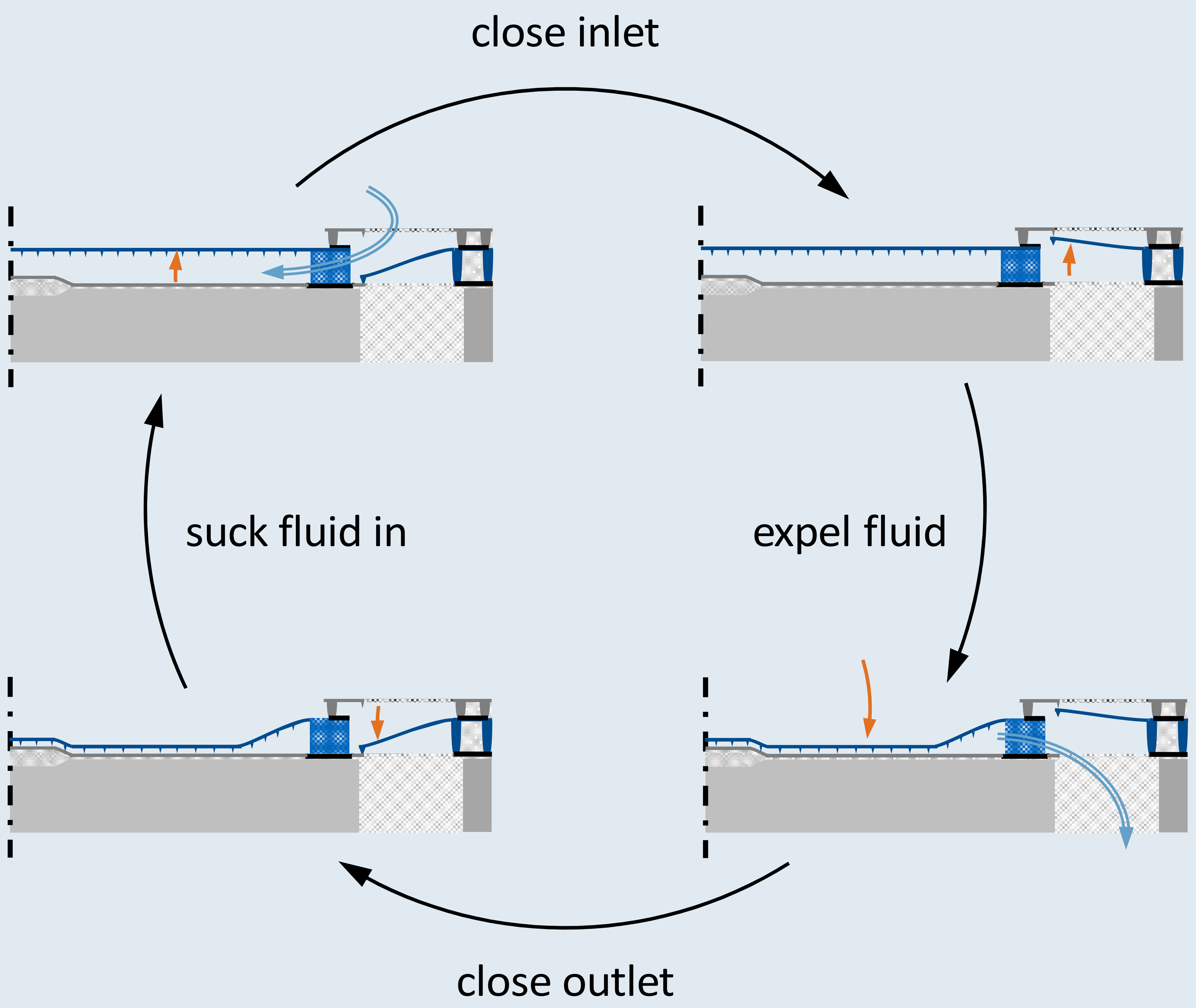

Fully-Coupled Transient Modeling of a Highly Miniaturized Electrostatic Pull-In Driven Micropump

The combination of electrostatic pull-in and mechanical contact in a transient fluid-structure interaction FEM simulation poses a hard-to-solve problem. We developed a problem-adapted finite element model, which overcomes the numerical singularities, drastically improving convergence.

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Introduction & Goals

We developed a new type of electrostatically actuated, monolithic MEMS membrane pump [1]. It is based on a radial design with an annular valve ring. The pump and valve membranes are actively steered and equipped with anti-sticking structures to prevent adhesion at pull-in. First prototypes show promising results. However, further improvement necessitates deeper insights into the internal behavior of the system.

Modelling Challenges:

- FSI + electrostatics + moving mesh
- Singularity in the electrostatic actuation force
- Contact forces
- Tiny time steps
- Convergence difficulties

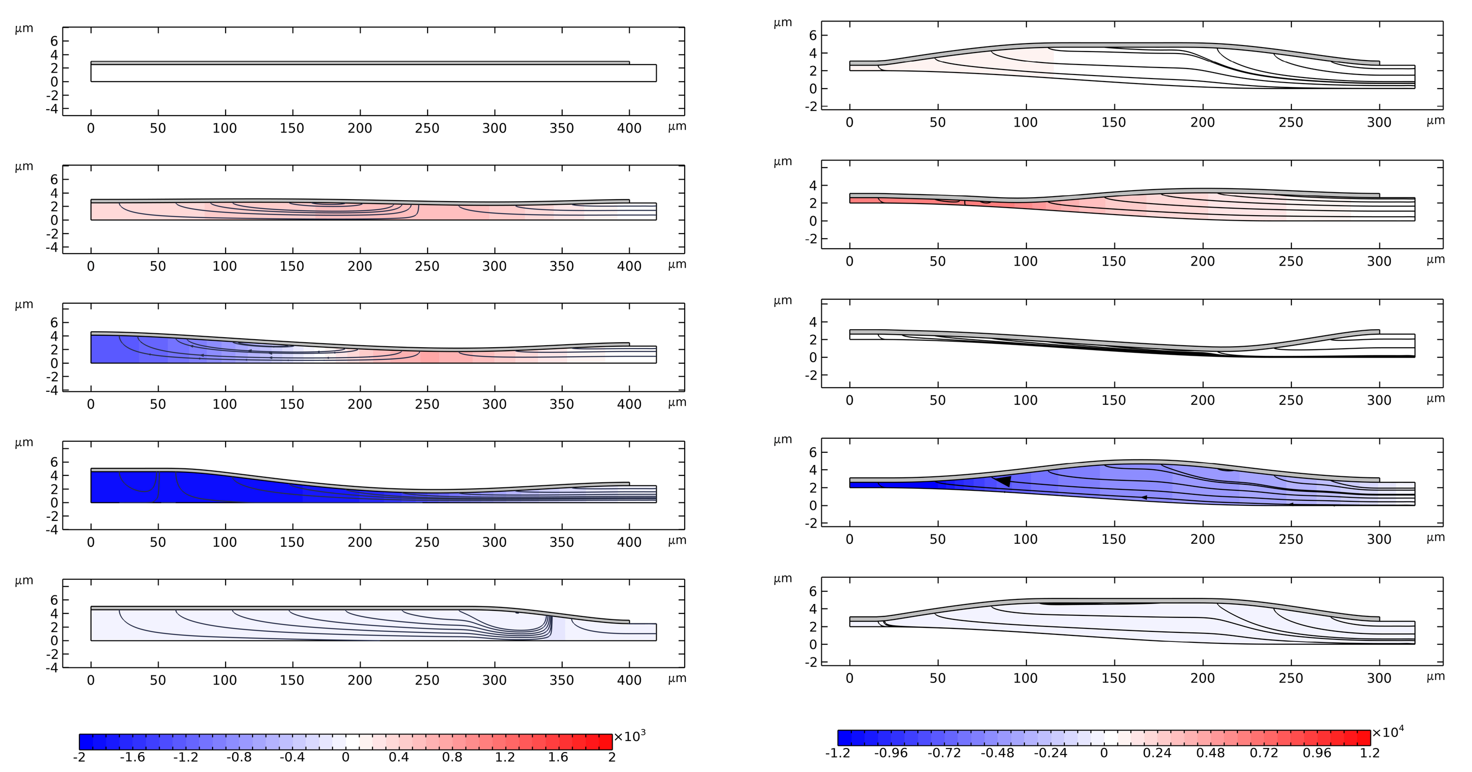


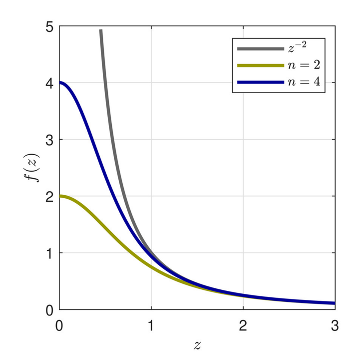
FIGURE 1. Results of pump cycle simulations. Left: standard pump chamber. Right: optimized pump chamber geometry.

Methodology

Numerical Stabilization Measures

- Non-singular regularized electrostatic interaction

$$z^{-2} \rightarrow f_n(z) = \sum_{k=1}^{n} \frac{1}{(z^2+1)^k}$$



- Regularized contact force by a smoothening spring
- 2D axisymmetric computational model

Results

- Long anti-sticking structures create a dead volume and decrease the compression ratio
- Short anti-sticking structures cause large flow resistance
- Parametric study shows optimum for the pump rate for specific combinations of each pump chamber radius and one corresponding height of the anti-sticking structures, respectively
- Simulation model allows to determine optimal application-specific geometric parameter sets

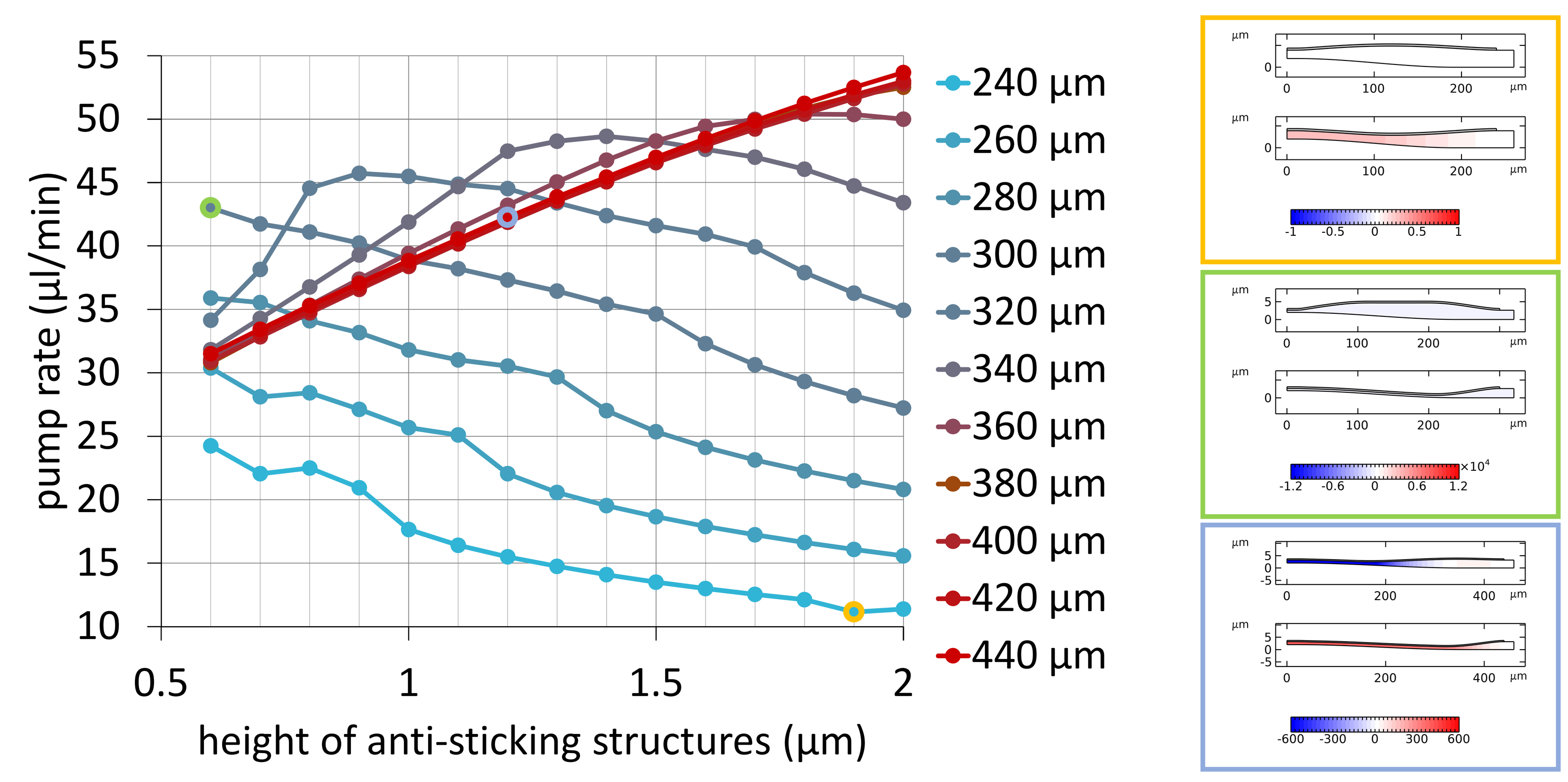


FIGURE 2. Results of parametric studies and selected combinations (pressure in Pa)

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