Let it flow
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Deformations caused by hydraulic pressure differences between flow battery half-cells

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BACKROUND & MOTIVATION

- Dynamic viscosity of anolyte and catholyte differs with temperature and state of charge (SOC) (shown in figure 1)
- Intensity of viscosity differences is depending on electrolyte composition (shown in table 1)
- Direct proportionality between viscosity and pressure losses lead to pressure differences between half-cells
- Deflections of flexible membranes und bipolar plates can be expected
- Deflections may vary over SOC and therefore cause plastic deformations of graphite felt electrodes
- Important impact on the design of large-scale flow battery cells

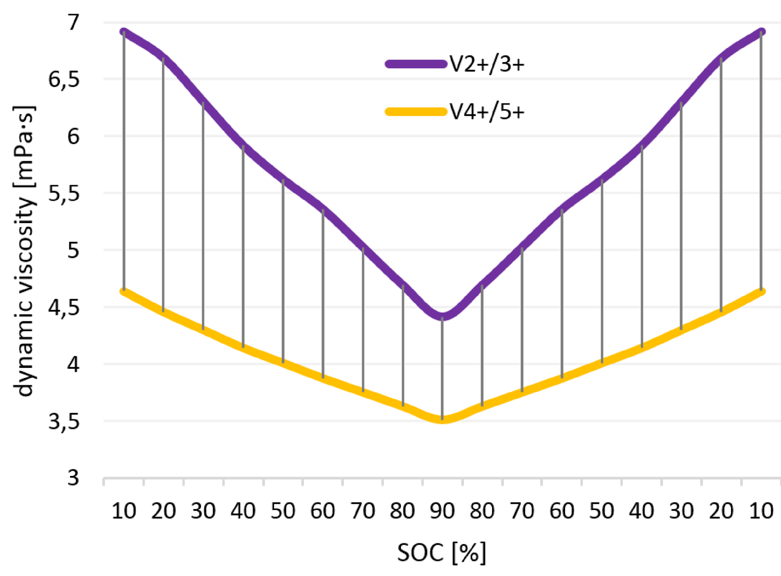

Fig. 1 *Varying dynamic viscosity of $V^{2+/3+}$ and $V^{4+/5+}$ electrolyte depending on SOC, 1.8 mol/L V, 2.7 mol/L H_2SO_4, 30 °C [1]*

Composition	$V^{2+/3+}$	$V^{4+/5+}$
2 mol/L V, 5 mol/L H_2SO_4	3.80 mPa*s	2.90 mPa*s
1.6 mol/L V, 2.6 mol/L H_2SO_4	3.96 mPa*s	3.57 mPa*s
1.8 mol/L V, 2.7 mol/L H_2SO_4	5.36 mPa*s	3.88 mPa*s

Tab. 1 *Dynamic viscosity of electrolytes at 30°C and 60% SOC [1;2]*

APPROACH

- Model design of the assembly: graphite felt – bipolar plate – graphite felt
- Deflections can be simulated using a modificated Kármán theory for nonlinear large bending of thin plates
- For determining the forces involved, the cell is separated in segments (shown in figure 2)
- Solving of the displacement function for finite matrix points
- Computation loop for the dependencies: felt compression – pressure loss
- Graphite felt electrodes can be assumed as nonlinear elastic-plastic spring assembly

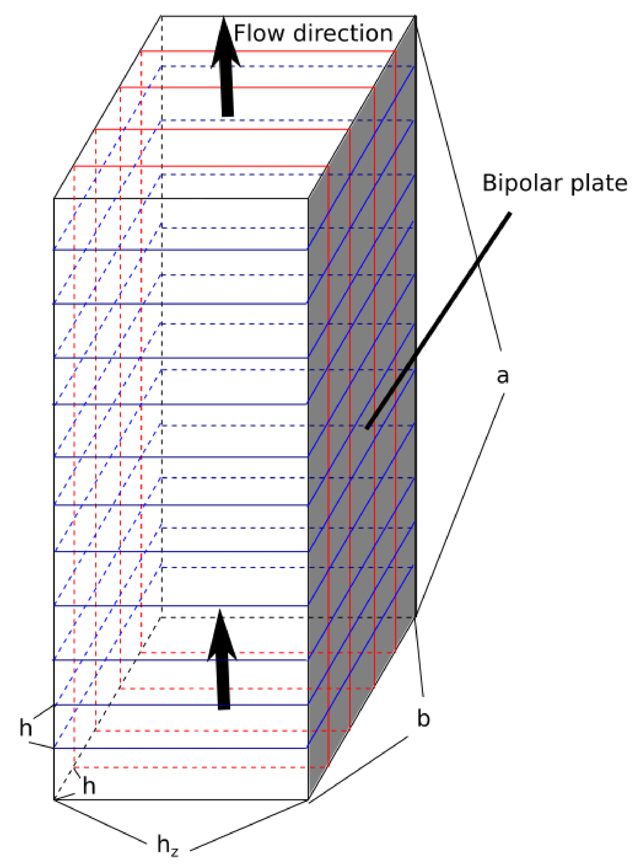

Fig. 2 *Flow direction and pressure segments of a model half-cell*

AIMS

- Establishing a theoretical computation basis
- Visualization of the shape and variance of thin plate deflections

RESULTS

SOC dependent deflections of the bipolar plate in the assembly graphite felt – bipolar plate – graphite felt for an all-vanadium flow battery cell with 135 cm² active area

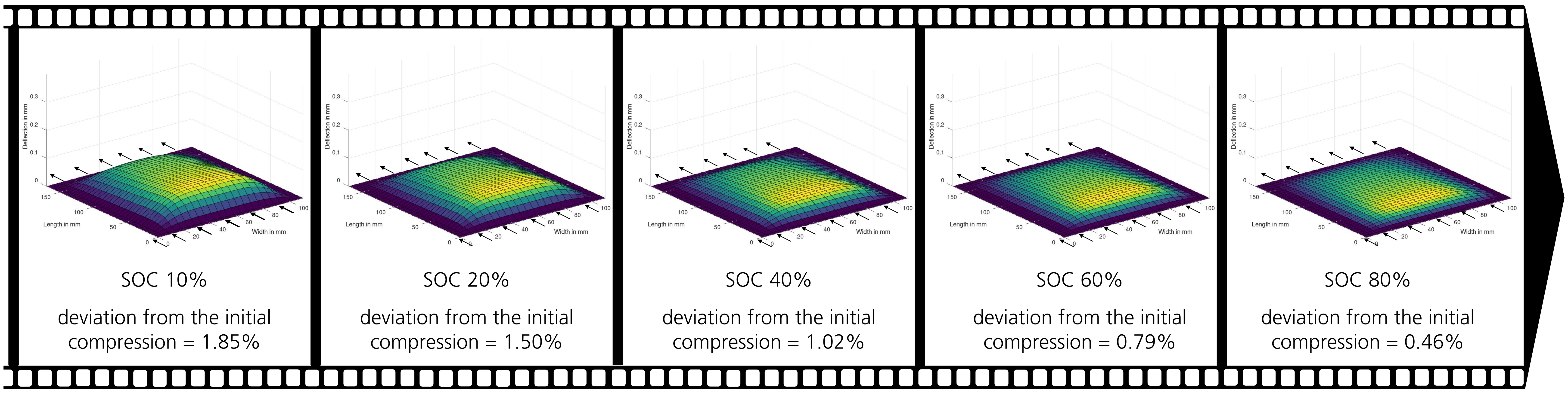

Fig. 3 *Deflections of the bipolar plate in the assembly graphite felt – bipolar plate – graphite felt, GFD 4.6 with 13% initial compression, 1.8 mol/L V, 2.7 mol/L H_2SO_4, 30 °C*

CONCLUSION

- Pressure differences between flow battery half-cells cause deflections of flexible membranes und bipolar plates
- Deflections vary over the state of charge
- Contrary to the originally expected pear-shaped deformation (by the triangular load distribution), the actual deflection is more evenly distributed

OUTLOOK

- The simulation model will be adapted for the computation of larger flow battery cells, as much higher deflections are expected
- The deformation behavior in a battery stack will be investigated

DEDUCTIONS

SOC-dependent variance of membrane and bipolar plate deflections will intensify with

- increasing pressure losses by increasing volumetric flow, viscosity and flow length as well as decreasing flow area and felt permeability
- plastic deformations of graphite felt electrodes by fiber breakage

References
[1] Li, X.; et al.: Investigation of the use of electrolyte viscosity for online state-of-charge monitoring design in vanadium redox flow battery; Applied Energy, 2018
[2] Skyllas-Kazacos, M., et al.: Vanadium electrolyte studies for the vanadium redox battery - a review; ChemSusChem, 2016