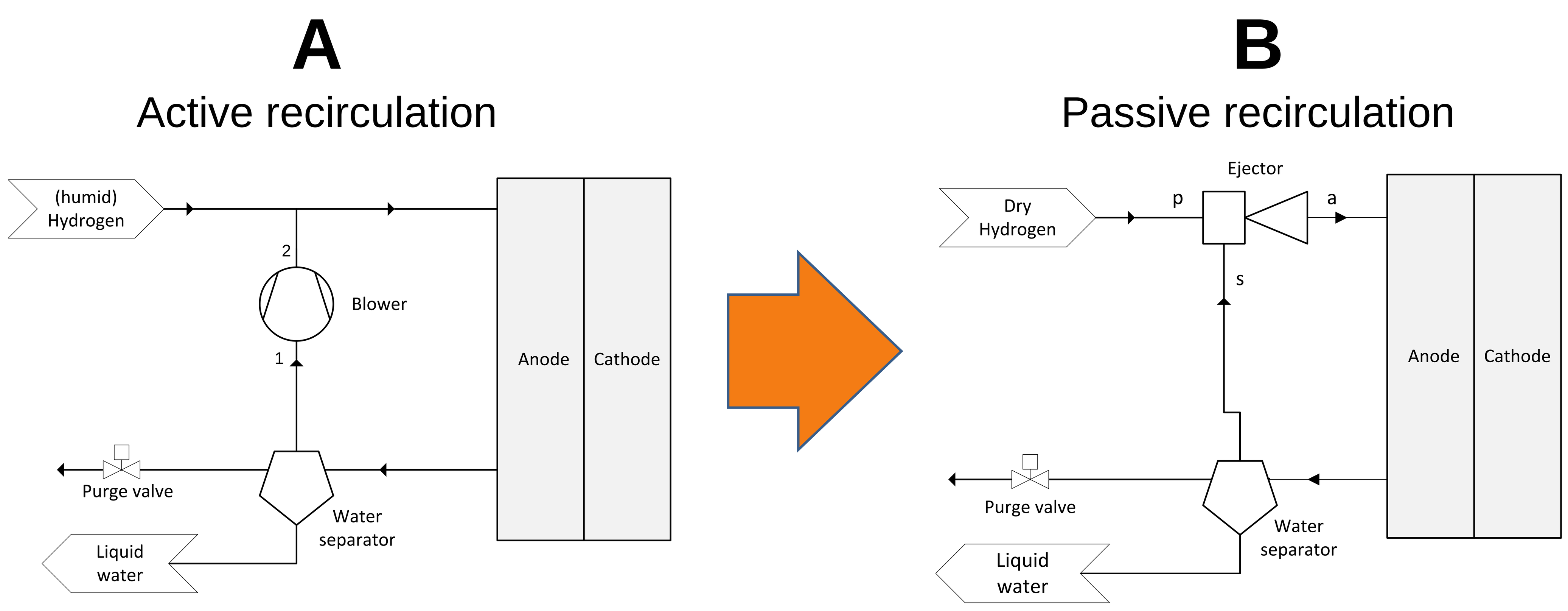
How ejectors increase efficiency

EFCF 2023

- Operation of PEMFCs with $\lambda_{H_2} > 1$ requires a recirculation of the unconsumed hydrogen to achieve high fuel utilization efficiencies [1]
- Substituting active recirculation with a blower (Figure 1, A) by passive recirculation with an ejector (Figure 1, B) saves electrical power → the system efficiency increases



Maximum increase of the system efficiency if only hydrogen is recirculated:

$$\eta_{increase} = \frac{(\lambda_{H_2}-1)\cdot\frac{\kappa}{\kappa-1}\cdot\frac{R_m}{M_{H_2}}\cdot(T_2-T_1)}{H_u} \approx \begin{cases} 0{,}12\,\% \ @\ \lambda_{H_2} = 1{,}5 \\ 2{,}7\,\% \ @\ \lambda_{H_2} = 12 \end{cases}$$

→ Dependent on the choice of λ_{H_2}

Figure 1: Schematics of the anode circuit: Active recirculation (A) vs. passive recirculation (B)

Model setup and results

- Thermodynamic analysis of a single choking ejector with convergent primary nozzle → see Figure 2
- Implementation of a stationary, 0-D and single-phase model in Matlab®; consideration of a fixed geometry ejector
- Calculation of pressure, temperature, velocities, relative humidity and diameter at each specified state point

→ The ejector performance - in terms of the achievable ejector outlet pressure - depends on the operating parameters of the FC stack

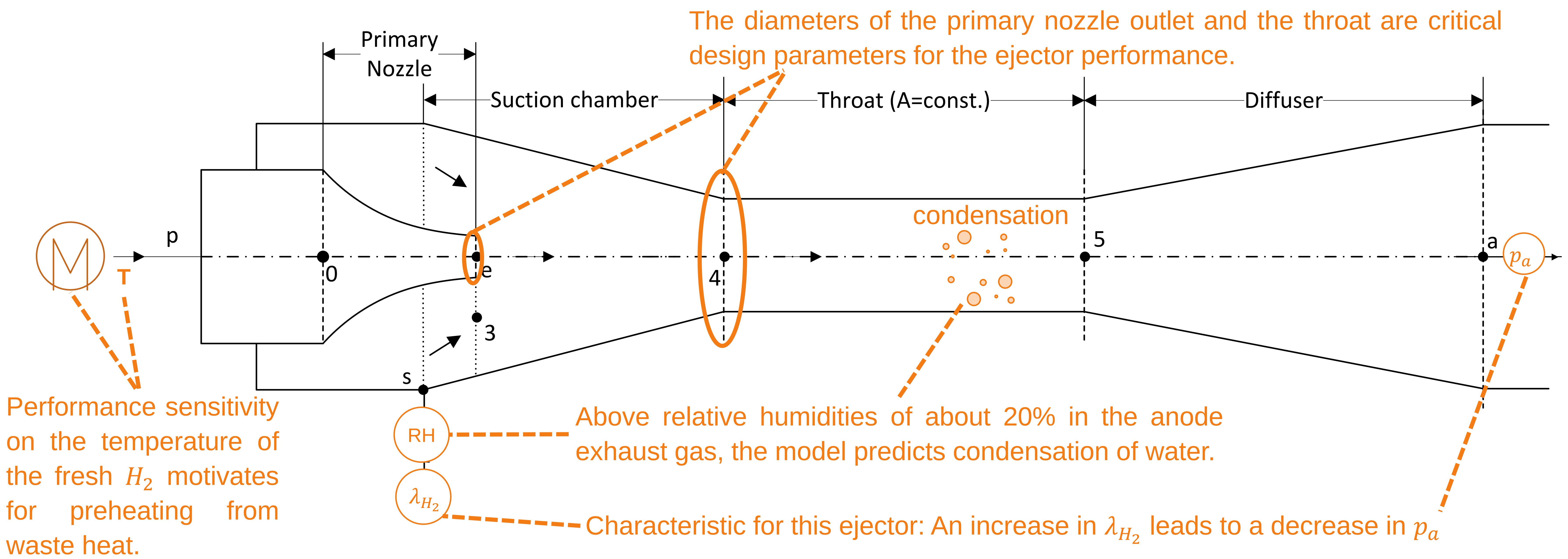


Figure 2: Simplified sketch of the single choking ejector (according to [5,6,11]). Inserted are the specified state points at which the ejector is calculated. Relevant simulation results are highlighted in orange.

Initial values used for the sensitivity analysis

Parameter	Value	Parameter	Value
T_0	$300{,}15\,K$	T_s	$353{,}15\,K$
RH_s	$15\,\%$	p_s	$2{,}3\,bar$
$\dot{m}_{N_2}$	$10\,\frac{g}{s}$	λ_{H_2}	2
i	$1{,}3\,\frac{A}{cm^2}$	d_e	$3{,}4\,mm$
A_{cell}	$300\,cm^2$	$\eta_{s,PNZ}$	$90\,\%$
N_{cell}	400	p_a	$2{,}65\,bar$

Changes of state:

0 → e: Reversible adiabatic accelerated flow of the fresh H_2

s → 3: Reversible adiabatic accelerated flow of the anode exhaust gas (expansion to the pressure at state point e)

e + 3 → 5: Adiabatic mixing of primary and secondary flows

5 → a: Reversible adiabatic decelerated flow

Consideration of flow losses by isentropic efficiencies

- Sensitivity analysis based on a high-load operation of the FC stack
- The percentage change of the parameters does not correspond to the same absolute values

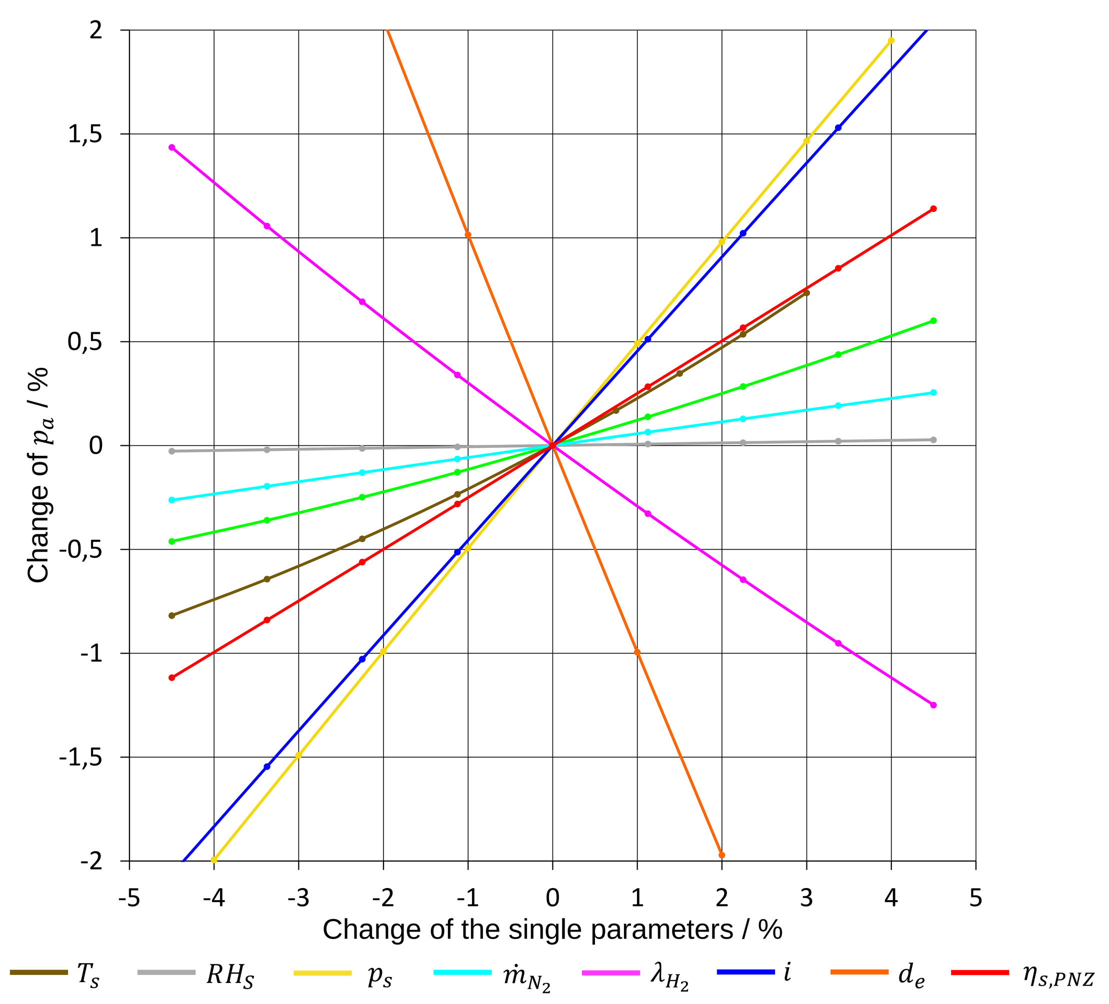


Figure 3: Sensitivity analysis: Percentage change of p_a at percentage change of different parameter values

Outlook

- Experimental validation of the simulation model on optically accessible ejectors → Integration of the experimental results in the model to obtain quantitatively exact simulation results
- Consideration of effects of liquid water in the ejector
- Identification of an ejector geometry with good technical feasibility and an suitable operating strategy