Numerical modeling of high temperature bayonet heat exchanger and decomposer for decomposition of sulfur trioxide

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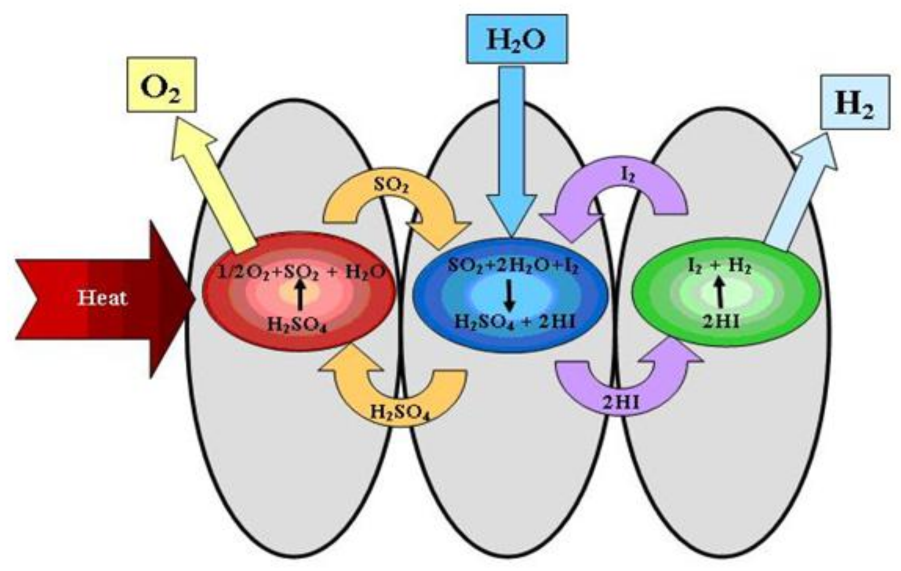
Motivation

- Hydrogen is an attractive energy carrier in the future energy technology.
- Hydrogen is produced from splitting of water through various process namely electrolysis, photo-electrolysis, photo-biological production and thermochemical water-splitting.
- The aim of this study is to numerically investigate fluid flow, heat transfer and chemical reaction in bayonet high temperature heat exchanger and decomposer.
- Parametric studies are performed to achieve maximum decomposition with less pressure drop.

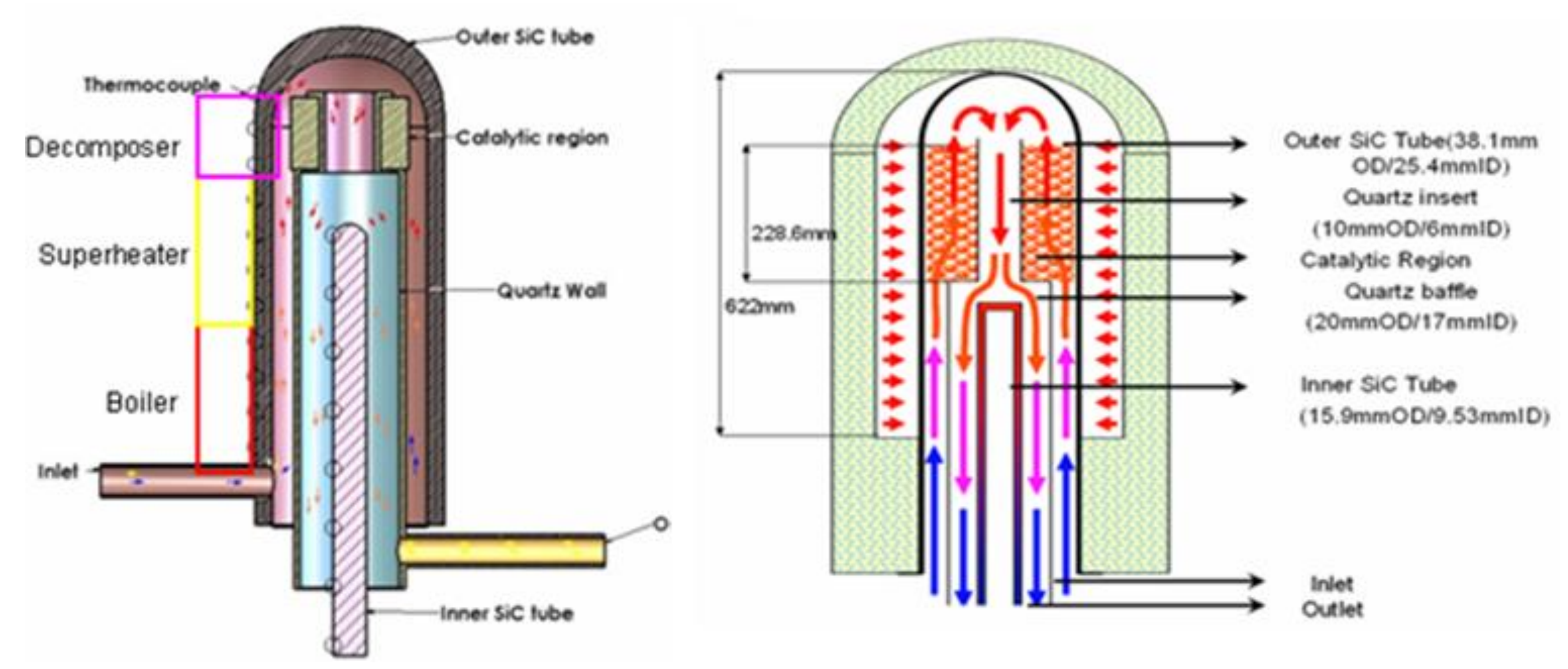
Thermochemical water-splitting cycle

- The sulfur-iodine (S-I) cycle was developed by General Atomics (GA) for large scale hydrogen production



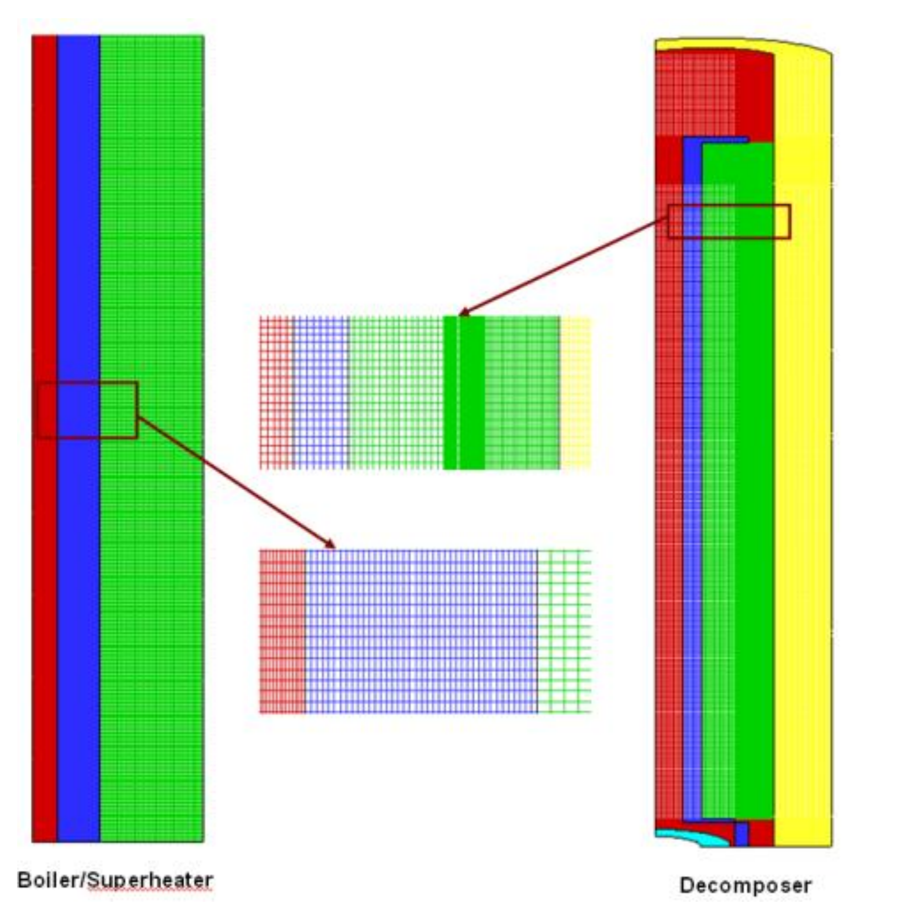
Picard, P., Presentation for Project PD27 , "DOE Hydrogen Program Review for Sulfur-Iodine Thermochemical Cycle" Sandia National Lab, May 25, 2005.

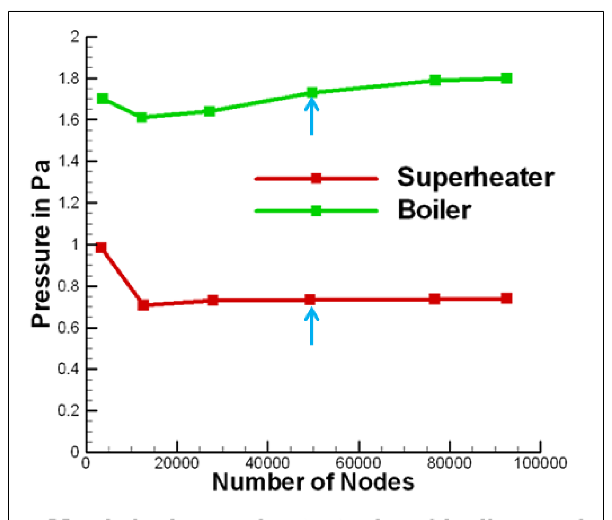
Bayonet type high temperature heat exchanger and decomposer



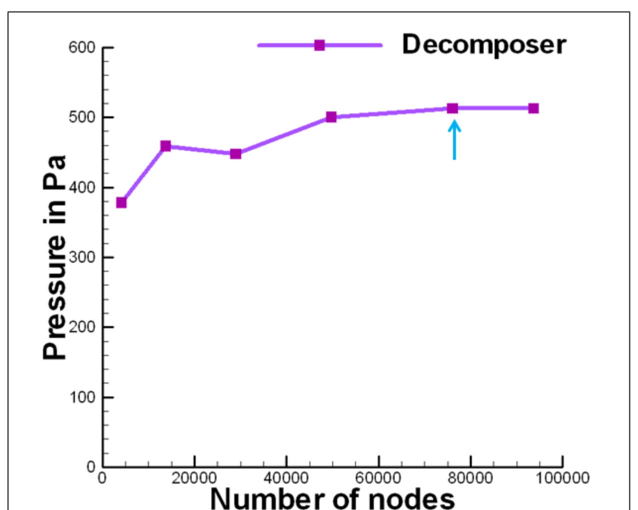
- SNL developed a lab scale model of the bayonet type heat exchanger and decomposer

Meshing and grid independent study





Mesh independent study of boiler and superheater



Mesh independent study of decomposer

Meshing was done in Gambit

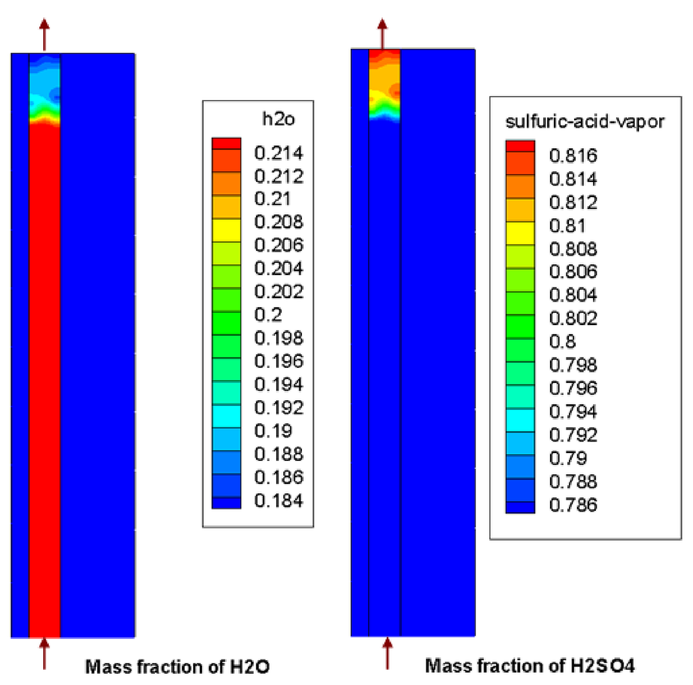
Boiler – 48000 cells and 49319 nodes
Superheater – 48735 cells and 49760 nodes
Decomposer – 73872 cells and 76137 nodes

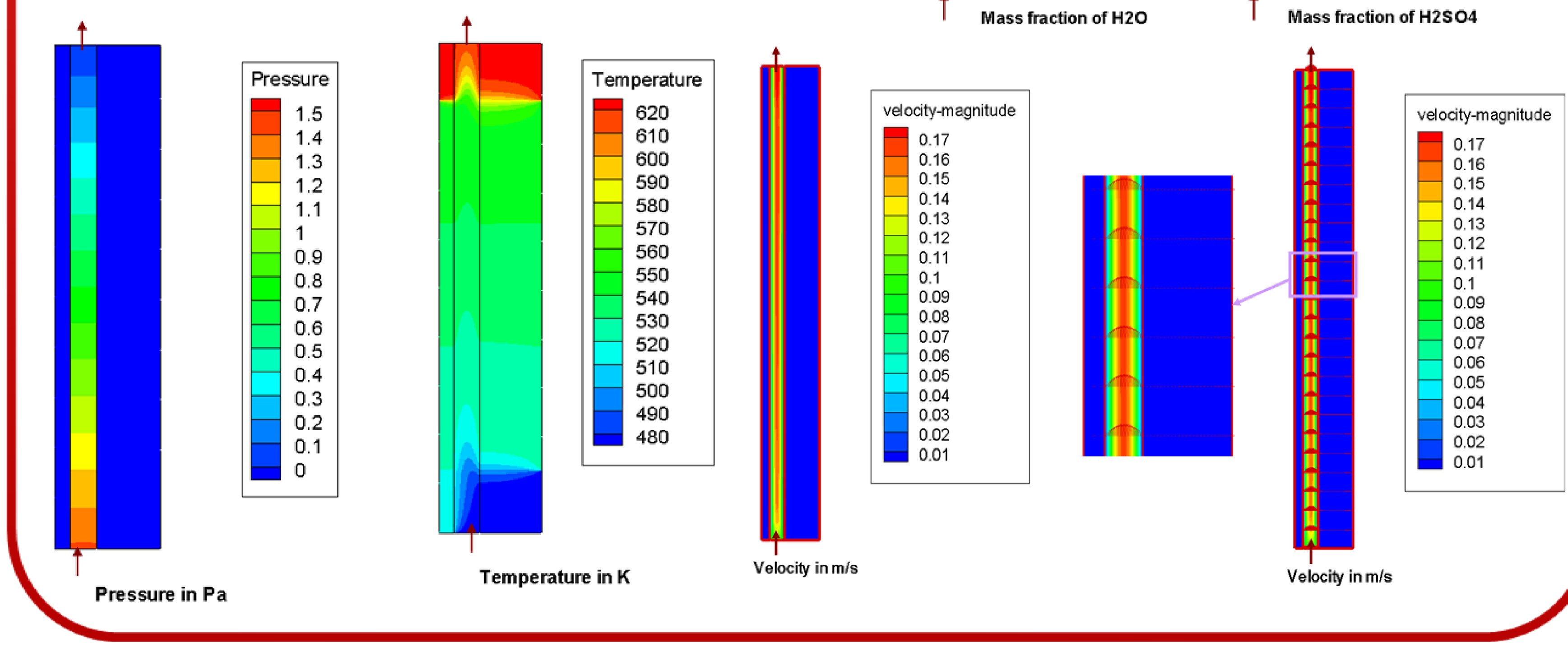
Boiler

Inlet mass flow rate – $0.34 \cdot 10^{-3}$ kg/s
Inlet temperature – 473 K
Solid – SiC
Operating pressure – 101325 Pa
$x_{H_2SO_4} = 0.784; x_{H_2O} = 0.216$

Results

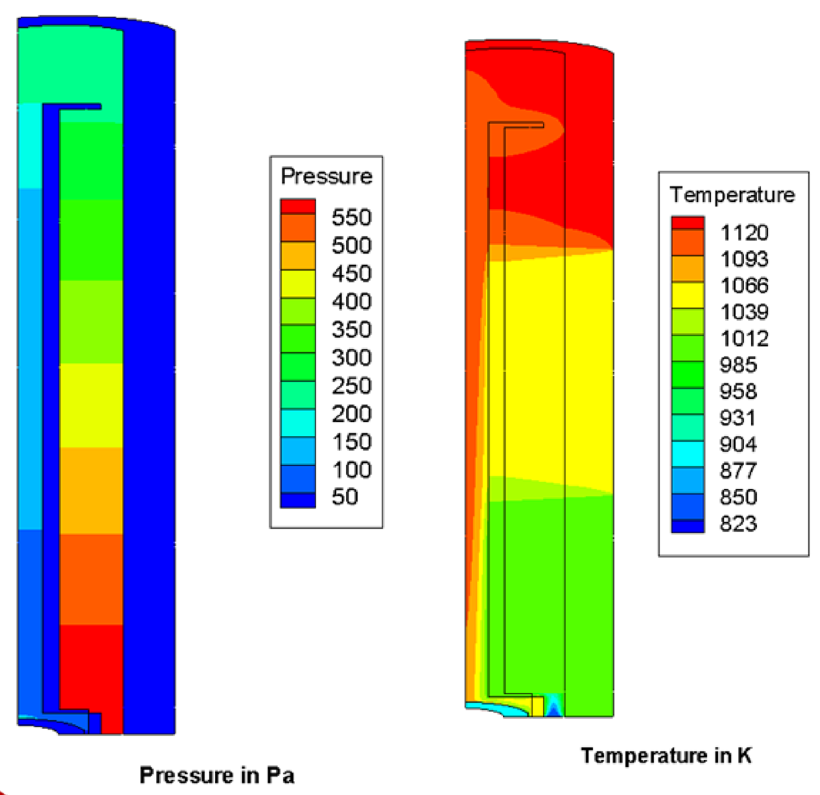
Pressure drop ΔP – 1.5 Pa
Friction factor – 0.128

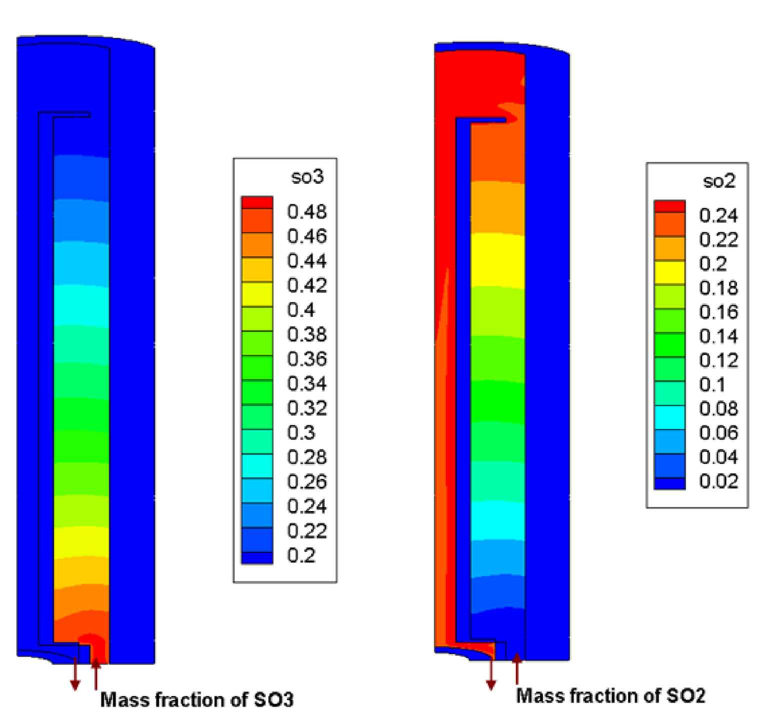




Superheater and decomposer

Superheater inlet temperature – 673 K
Decomposer inlet temperature – 973 K
Catalyst – Platinum
Porosity – 0.46
Surface to volume ratio – 128m^{-1}
$x_{SO_3} = 0.485; x_{H_2O} = 0.514$

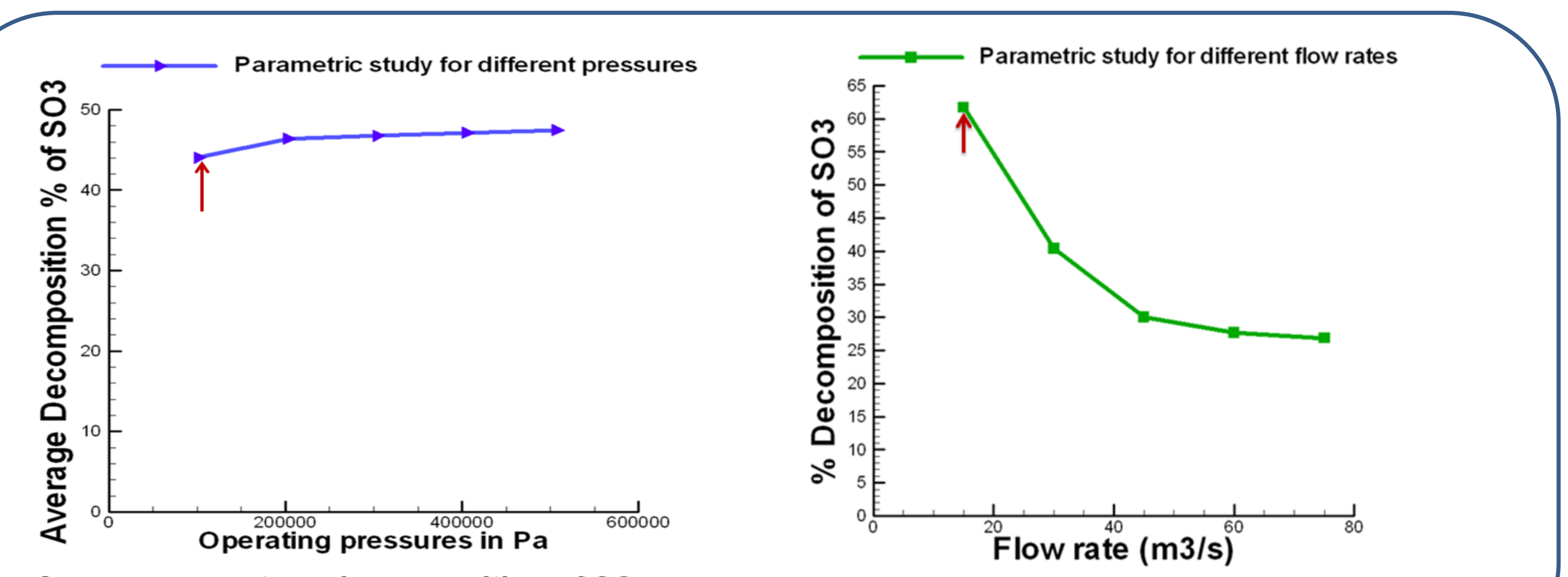




Results

Pressure drop in decomposer ΔP = 512.59 Pa
% decomposition of SO_3 - 61.97%

Parametric studies



Average percentage decomposition of SO_3 vs. operating pressure

Percentage decomposition of SO_3 vs. volumetric flow rate

Conclusions

- Percentage decomposition of sulfur trioxide obtained is 61.97%
- Numerical results agree closely with the experimental results from SNL
- Bayonet heat exchanger gives good decomposition rate with small pressure drop

Future work

- Multiphase fluid flow can be considered in the future for the whole geometry
- Recuperater can also be modeled and analyzed
- Numerical analysis with turbulent flow can be carried out to find the decomposition percentage of SO_3

Acknowledgement

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