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 processes 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.

![Thermochemical water-splitting cycle diagram](image)

Boiler
- Inlet mass flow rate – 0.34×10⁻³ kg/s
- Inlet temperature – 473 K
- Solid – SiC
- Operating pressure – 101325 Pa

Results
- Pressure drop ∆P = 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

Results
- Pressure drop in decomposer ∆P = 512.59 Pa
- % decomposition of SO₃ - 61.97%

Future work
- Multiphase fluid flow can be considered in the future for the whole geometry.
- Recuperator can also be modeled and analyzed.
- Numerical analysis with turbulent flow can be carried out to find the decomposition percentage of SO₃.

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Meshing and grid independent study
- Meshing was done in Gambit
  - Boiler – 48000 cells and 49319 nodes
  - Superheater – 48735 cells and 49760 nodes
  - Decomposer – 73872 cells and 76137 nodes

Parametric studies
- Results for different pressures and flow rates
- Parametric study for different pressures
- Parametric study for different flow rates

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.

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

![Boiler diagram](image)