The Vattenfall Energy Award 2012

Solar Receiver Design and Verification

for

Small Scale Polygeneration Unit

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Motivation

- **Our world's climate is changing.**
- The release of the greenhouse gas CO_2 into the atmosphere from burning fossil fuels is the largest known human contribution to climate change.
- Solar thermal power is one of the most promising options to move electricity production towards reliable, clean and climate-friendly solutions.
- Small-scale modular solar power plants, such as solar dish systems, can be installed close to the demand, providing an indigenous source of electricity.
- The solar receiver, which converts the solar energy into useable heat, is one of the limiting components in contemporary solar power plants and innovative new designs are required.
- The solution proposed in this thesis satisfies the requirements of robustness and low cost while maintaining high performance.
- Improvements and cost reductions in this key component will allow increased deployment of solar thermal power, and thereby reduce our dependence on fossil fuels and the associated emissions of CO_2.

Thesis Work

- This thesis addressed the design of a solar receiver for a hybrid micro gas-turbine solar dish system (Fig 1), and the trade-offs between efficiency, material utilization and economic design. Significant challenges were the high flux intensity, high temperatures, and material stresses.
- A preliminary heat transfer analysis found volumetric receivers to be the only applicable receiver concept capable of withstanding the expected flux levels.
- With volumetric receivers selected as the receiver type, a receiver model was evaluated using a 2D MATLAB based numerical heat transfer model coupled with a multi-objective optimization tool based on advanced evolutionary algorithms. This resulted in a set of Pareto-optimal solutions (Fig 2) that confirmed the trade-off between pressure drop in the receiver and critical material temperatures.
- Based on this first investigation, a parameter study was conducted to improve specific aspects of the design using a coupled CFD/FEM approach (COMSOL, Fig 3). The performance of the selected final design was then confirmed using ANSYS FLUENT.

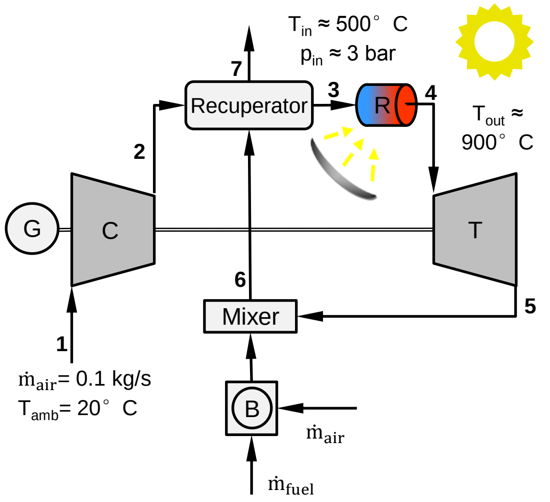

Fig 1. Hybrid Solar Micro Gas-Turbine Unit Layout

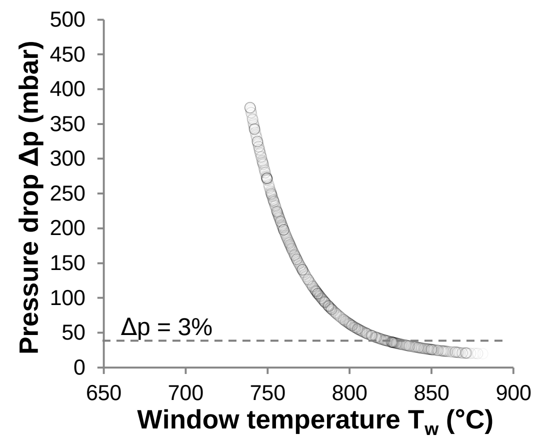

Fig 2. Pareto-optimal Solutions

Results

- A low-cost, robust, and modular **prototype** for integration into a hybrid micro gas-turbine solar dish system was **successfully designed** (Fig 4). It was shown that the design is able to operate under the highly non-uniform solar flux conditions expected, while maintaining material temperatures and stresses below permissible limits.
- Two different hybridization schemes were evaluated. It was shown that pressurized receiver configurations clearly outperform atmospheric configurations with significantly smaller pressure drops: a key performance factor for gas-turbine systems.
- The use of **volumetric solar receivers** to provide heat input to micro gas-turbine systems was shown to be a **promising solution**. The design work undertaken highlights the feasibility of the concept and no major hurdles were found.
- The receiver design simultaneously provides low costs and high performance, which will facilitate the deployment of solar thermal power, reducing our worldwide dependence on fossil-based fuels.

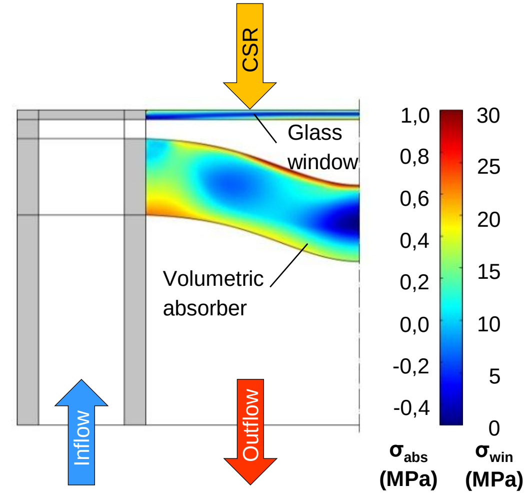

Fig 3. Coupled CFD/FEM Model (Material stresses)

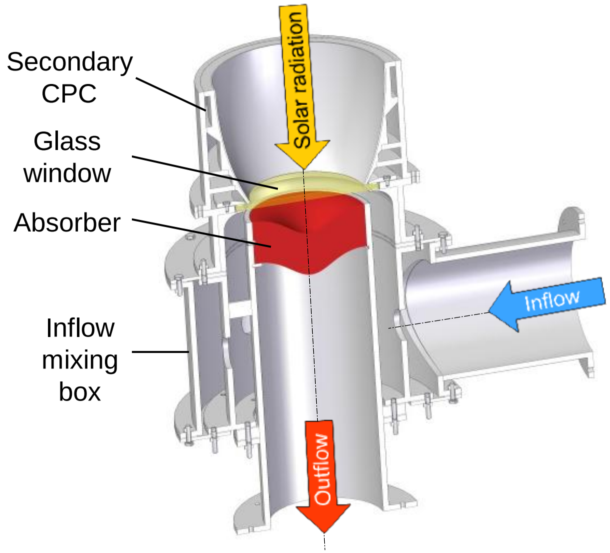

Fig 4. Prototype