FONaR: Flux-Optimised Sodium receiver

Multi-objective and evolutionary approach to geometry optimisation

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Raising the temperature of operation of solar receivers presents some interest in improving the efficiency of the subsequent power block. High temperature receiver design is challenging and multidisciplinary: increased emissive losses significantly impact the efficiency, thermo-mechanical stress affects numerous design options, the cost of materials rises, etc.

Design by multi-objective optimisation is a promising way of taking into account all constraints to produce more robust and efficient receiver designs.

Influence of receiver geometry on performance

Optimal temperature of photo-thermal conversion

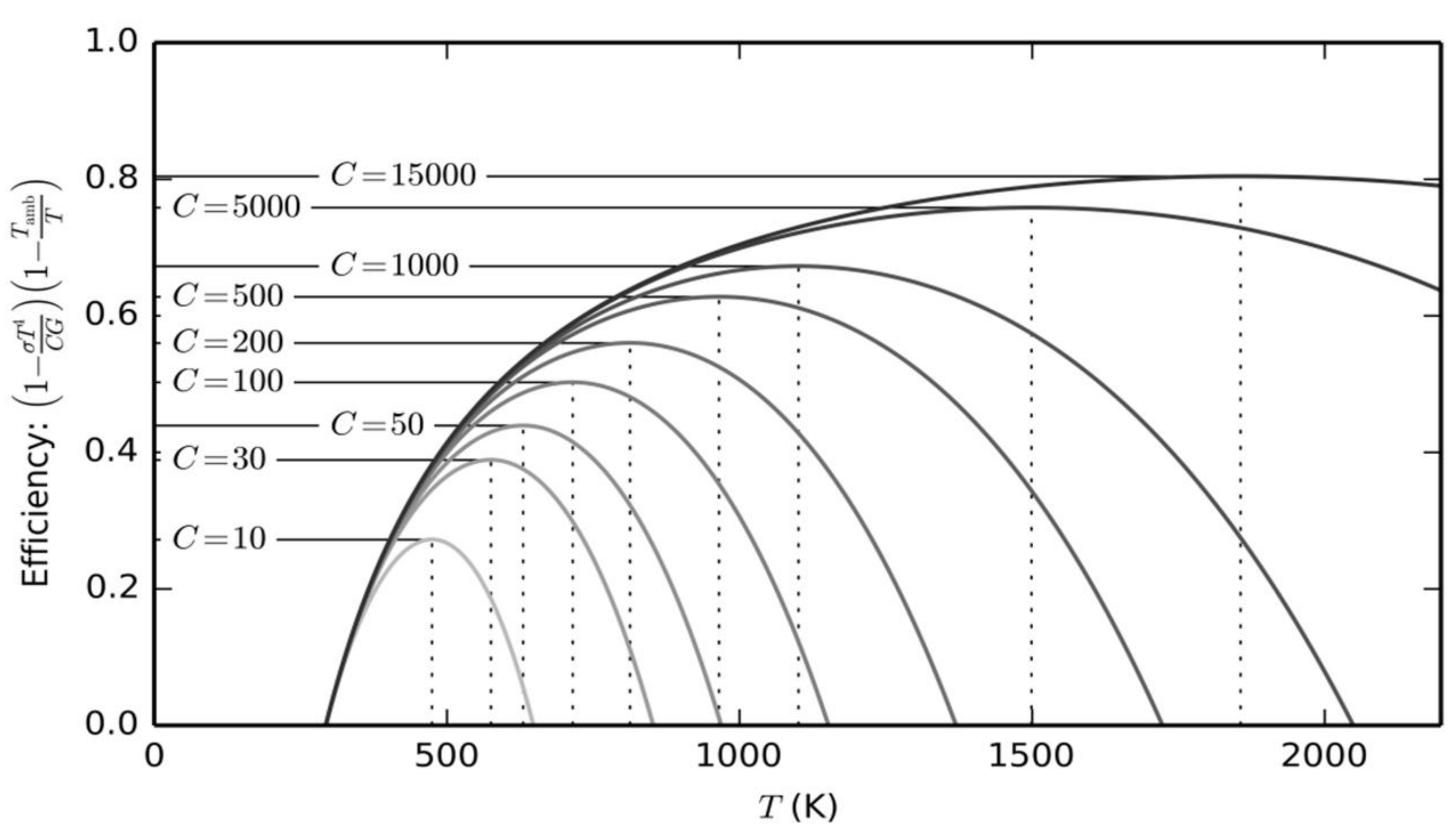

Figure 1: Efficiency of conversion of radiation into work as a function of temperature for a series of optical concentrations

The **optimal temperature** of photo-thermal conversion depends on the **incident flux**.

Flux distribution on receiver surfaces

The incident flux on a receiver is imposed by the optics. The geometry has a strong influence on the receiver flux distribution [1].

Optimal geometry of receivers

Considering a **given optical concentrator**, there is an **optimal receiver geometry** that **maximises the amount or work** that can be extracted from the concentrated solar radiation. This geometry is also influenced by:

- The thermo-mechanical limits of the materials constituting the receiver.
- Economical constraints such as materials and manufacturing cost.

To study the optimal geometry for a set of constraints, **the receiver geometry is parameterised** and multi-objective optimisation is applied to it.

ASTRI P12: Sodium receiver concept

Sodium as a heat carrier

- Very good conductivity = very good heat transfer coefficient
- Liquid and stable at high temperature, in absence of oxygen or water
- Demonstrated high flux receiver operation capability

Flux-Optimised Sodium (Na) Receiver: FONaR

Sodium gives more freedom in the selection of the geometry of the heat carrier circuit and is therefore suitable for receivers with **non-conventional, flux-optimised geometries**.

Optimisation of tower receiver geometry

Receiver Energy balance

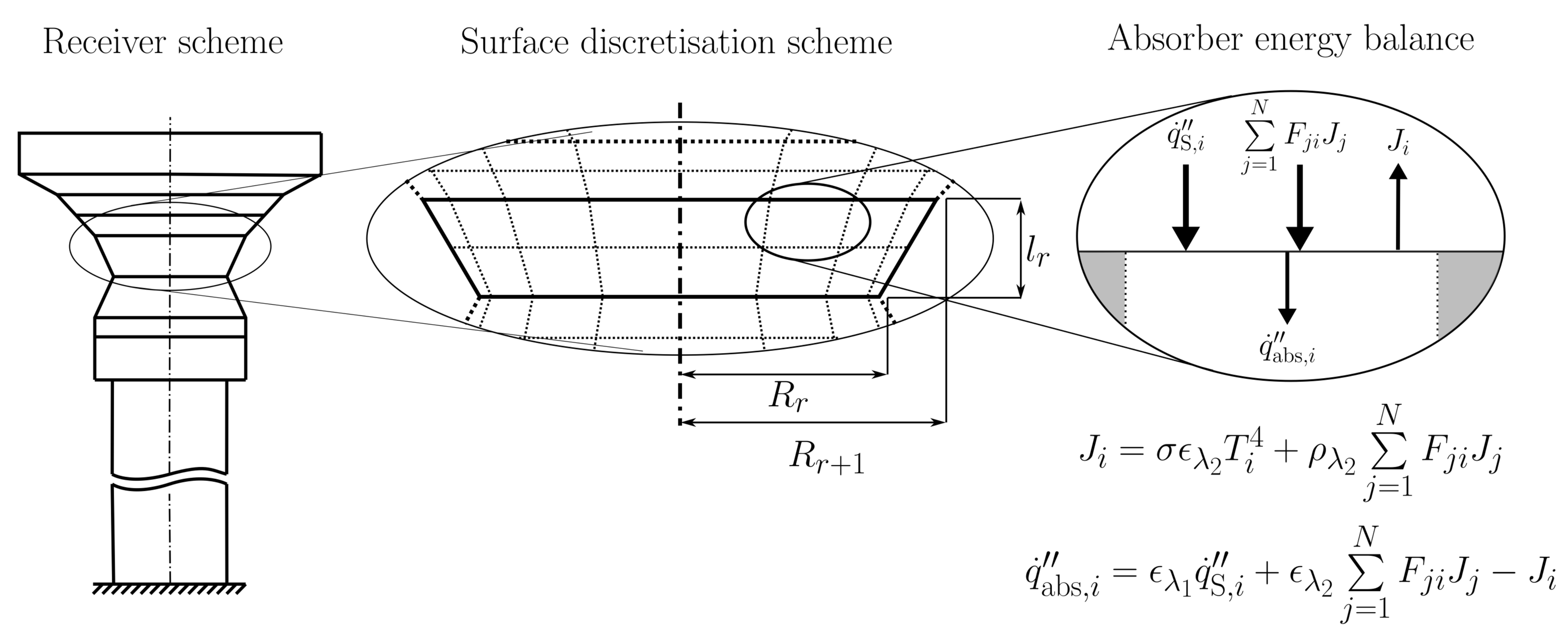

Figure 2: Tower receiver geometry class example with variable geometry parameters and wall energy balance scheme.

Semi-gray asumption is adopted. Radiative heat transfer is solved using Monte-Carlo Ray Tracing, "path tracing" (energy partitioning) with the "Tracer" in Python/Numpy for the visible part of the spectrum and a radiosity method using view factors for the thermal part.

Multi-objective optimisation

Table 1: Example set of objectives to maximise during the optimisation of a receiver geometry.

THERMODYNAMIC EFFICIENCY	AREA WEIGHTED TEMPERATURE UNIFORMITY	SURFACE AREA
$\eta_W = \frac{\sum_{i=1}^{N} A_i \dot{q}''_{abs,i}\left(1-\frac{T_{amb}}{T_i}\right)}{\dot{Q}_S}$	$\eta_T = \frac{1}{1+\frac{\sqrt{\overline{(AT)^2}-\overline{(AT)}^2}}{\overline{AT}}}$	$\eta_A = \frac{1}{1+A}$

The evaluation of a large number of geometries can lead to intractable simulation time. Two techniques are used to greatly improve the runtimes:

- **Evolutionary behavior** for geometry generation: The simulation learns about performing candidates.
- **N-dimensional Pareto front detection stochastic screen algorithm:** based on Asselineau et al. 2015 [2], underperforming candidates are removed from the simulation as soon as they are statistically unfit.

Sample results

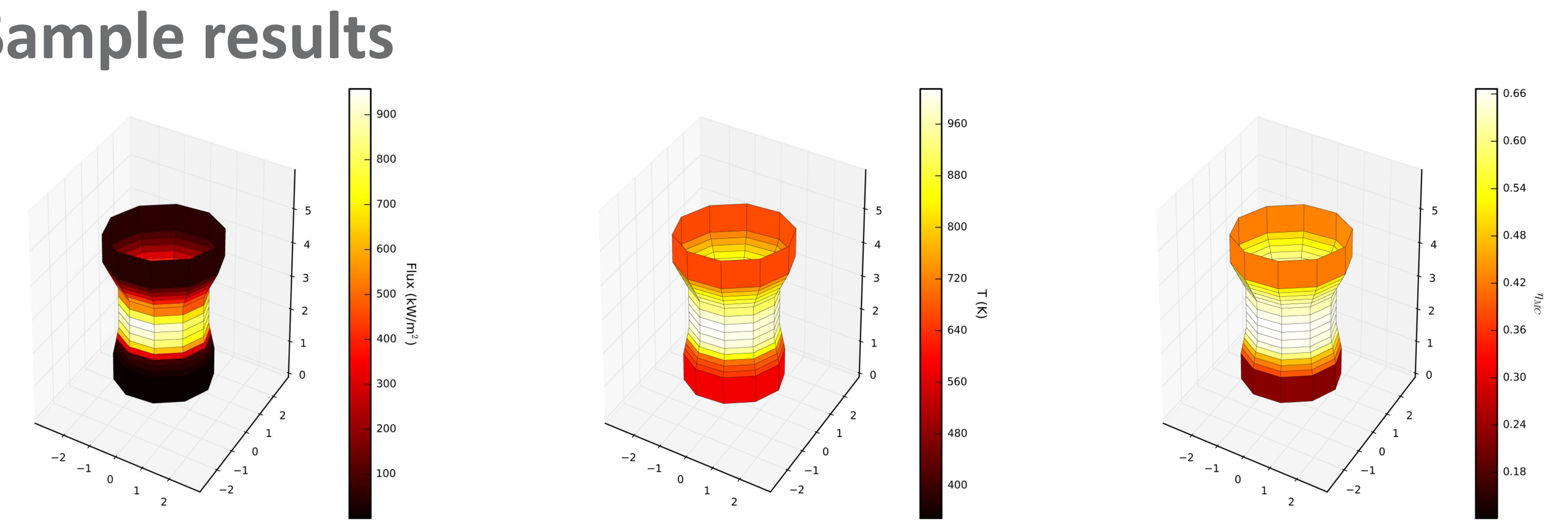

Figure 3: Sample flux, temperature and efficiency distributions for a candidate of a simple class of FONaR geometries.

Conclusions and outlook

A **new approach** to receiver design is proposed. A simpler version of this method was used with success in a previous project leading to a highly efficient Dish receiver. The method offers potential **receiver efficiency gains** as well as controlling the **inherent reliability** of the receiver from the design stage. Sodium circulation strategy will be implemented in further work.

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[1] Yong Shuai, Xin-Lin Xia, and He-Ping Tan. *Solar Energy*, 82(1):13 – 21, 2008.
[2] Charles-Alexis Asselineau, Jose Zapata, and John Pye. Opt. Express, 23(11):A437–A443, Jun 2015.

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