Feasibility Study of Combining the Stirling Cycle With the Solar Calcium-looping Integration for Thermochemical Energy Storage

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Introduction

The problem of storage is one of the most important challenges in contemporary renewable energy engineering. A chemical storage option is offered by the conversion of calcium carbonate in to calcium oxide and carbon dioxide which can be brought together in an exothermic reaction to power a thermodynamic cycle. The feasibility of integration depends virtually solely on the effectiveness of the heat transfer scheme from the exothermic reactor to the power cycle. This work studied the integration of a 1 kW beta type Stirling engine with the thermochemical energy storage scheme.
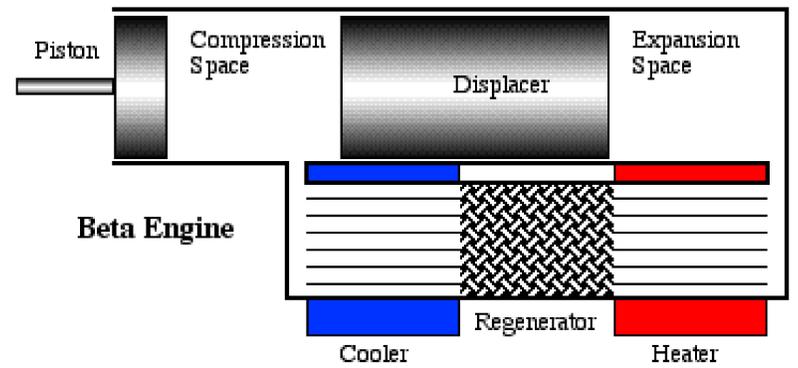

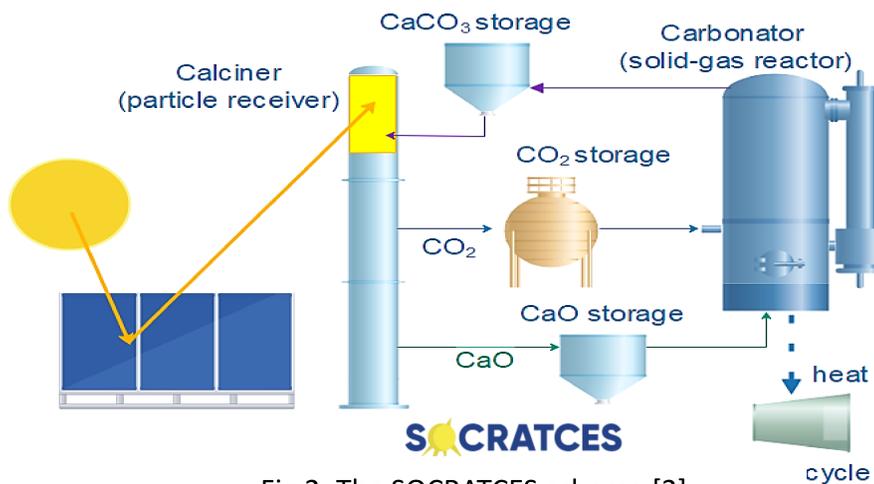Fig 1: A Beta-type Stirling engine's schematic diagram [1]

Fig 2: The SOCRATCES scheme [2]

SOCRATCES PRINCIPLE

a. A solar reactor (calciner) breaks $CaCO_3$ in to constituents CO_2 and CaO.
b. The stored CaO and CO_2 are brought together when solar power is no longer available to produce $CaCO_3$ producing temperatures in excess of 800 °C in a reactor called Carbonator.
c. The heat liberated in the carbonator is delivered using a heat transfer fluid to the Stirling engine to produce electricity

Workflow

CFD based mathematical modeling	Interface and module design	Building and testing
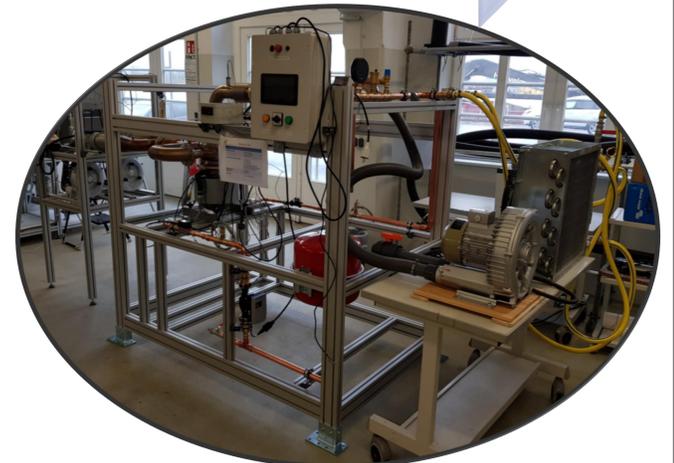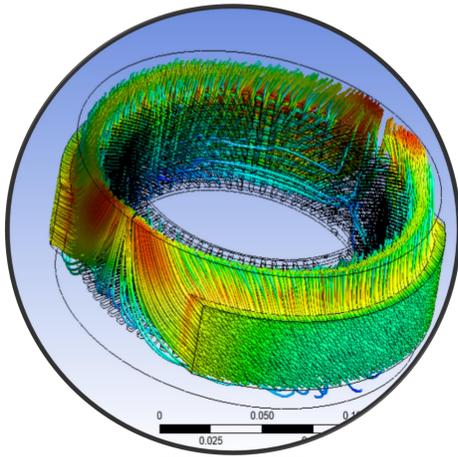
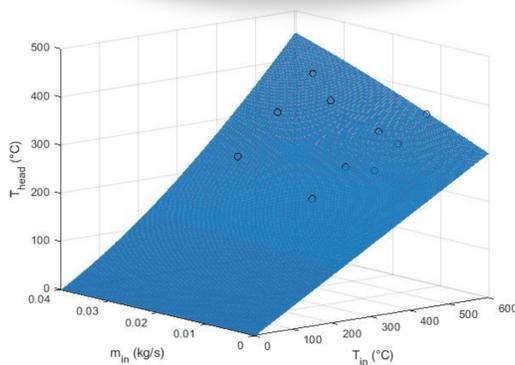

Results and conclusion

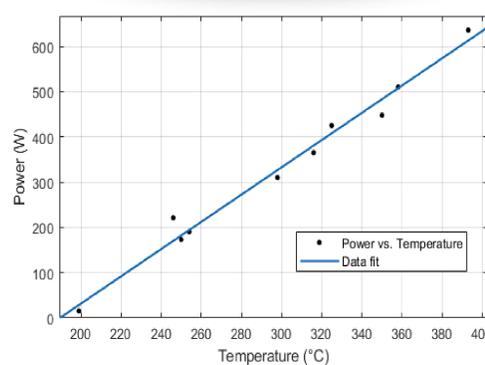Fig 3: Engine's head temperature with respect to air mas flowrate and incoming temperature

Fig 4: Power versus engine head temperature

a. The engine was able to produce ~ 700 W at about 25% overall conversion efficiency with T_{in} = 556 °C at a flowrate of 0.032 kg/s.
b. The Stirling engine is not able to absorb enough heat without impractically large heat exchangers, thus having high thermodynamic efficiency at low temperatures is not very useful.
c. The hot-side internal temperature of the engine is too low for it to be a feasible solution.
d. The power/weight ratio is poor, with other cycles showing much better conversion efficiency

The theoretical model's prediction is in very good agreement with the experimental data with only slight deviations

References

1. I. Urieli, "Chapter 2b - Beta Type Stirling Engines," 2020. [Online]. Available: https://www.ohio.edu/mechanical/stirling/engines/beta.html.
2. C. Ortiz, "SOCRTACES," 2020. [Online]. Available: https://socratces.eu/the-project/

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