Optimizing Geothermal Energy Production and Utilization Technology

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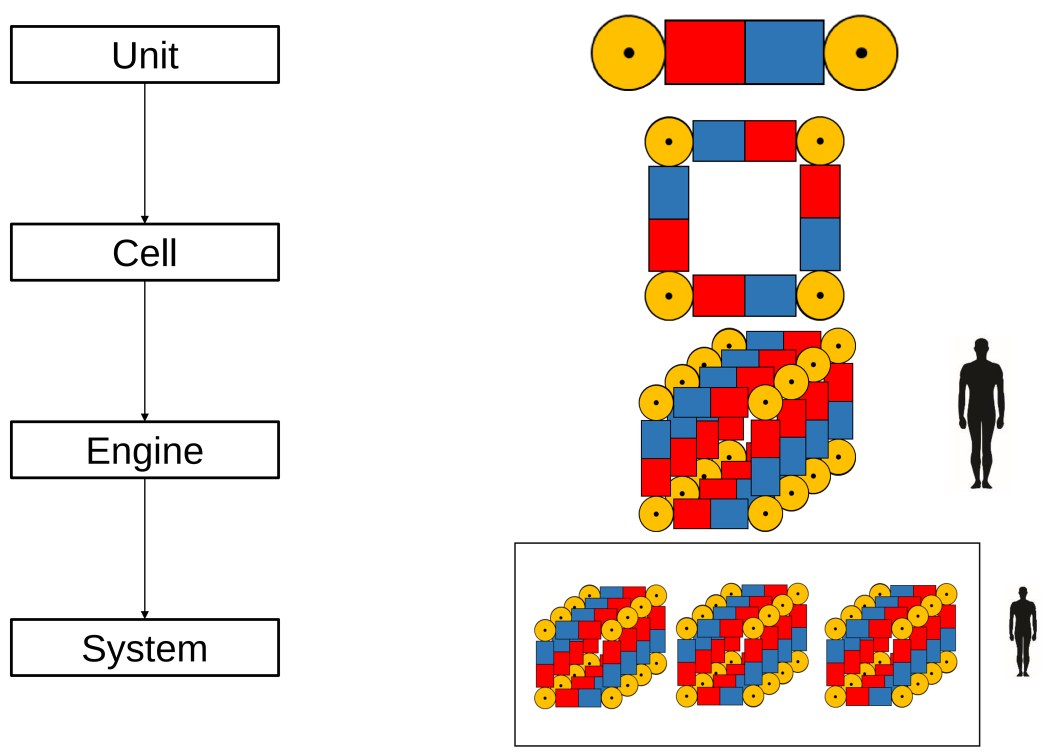
BACKGROUND

INCREASING SCALE

Low grade heat sources vary significantly in energy quantity, heat engines which utilize these resources must scale to match a given application. Mechanically coupled Stirling engines present a modular approach to solving this problem.

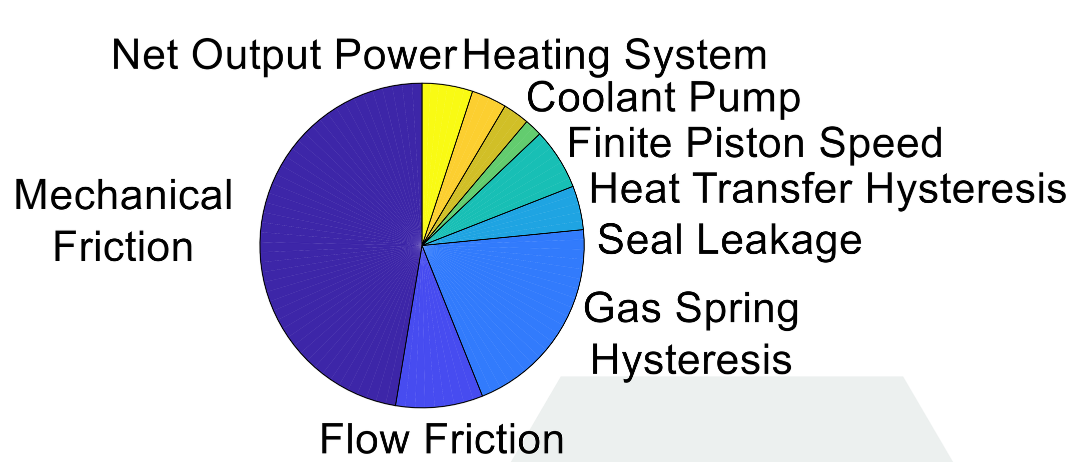


Unit to System Scaling Principle Diagram

SHORT-TERM OBJECTIVES

BENCH SCALE MODEL

Develop mathematical models for bench scale engines and compare them to experimental data.



Pie charts demonstrating various losses in Stirling engine

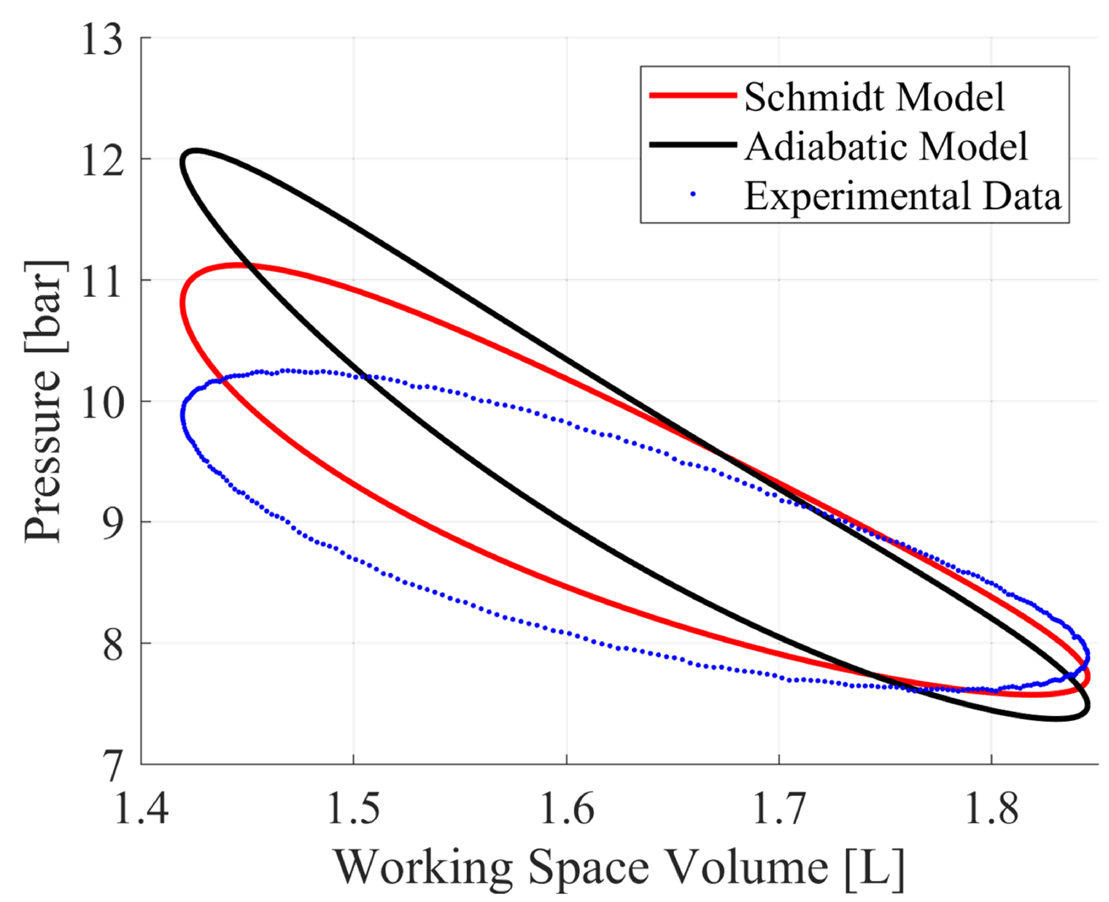
EXTERNAL PARTNERS

TERRAPIN GEOTHERMICS is a privately owned, Edmonton based geothermal energy company. Terrapin is developing and commercializing an engine capable of extracting usable energy from waste heat and geothermal brines.

PROJECT OVERVIEW

THERMODYNAMIC MODELING

Thermodynamic models quantify the performance potential of proposed engine designs. Most models in literature are written and validated for high temperature differential Stirling engines. Their applicability to large scale low temperature difference designs is unclear.



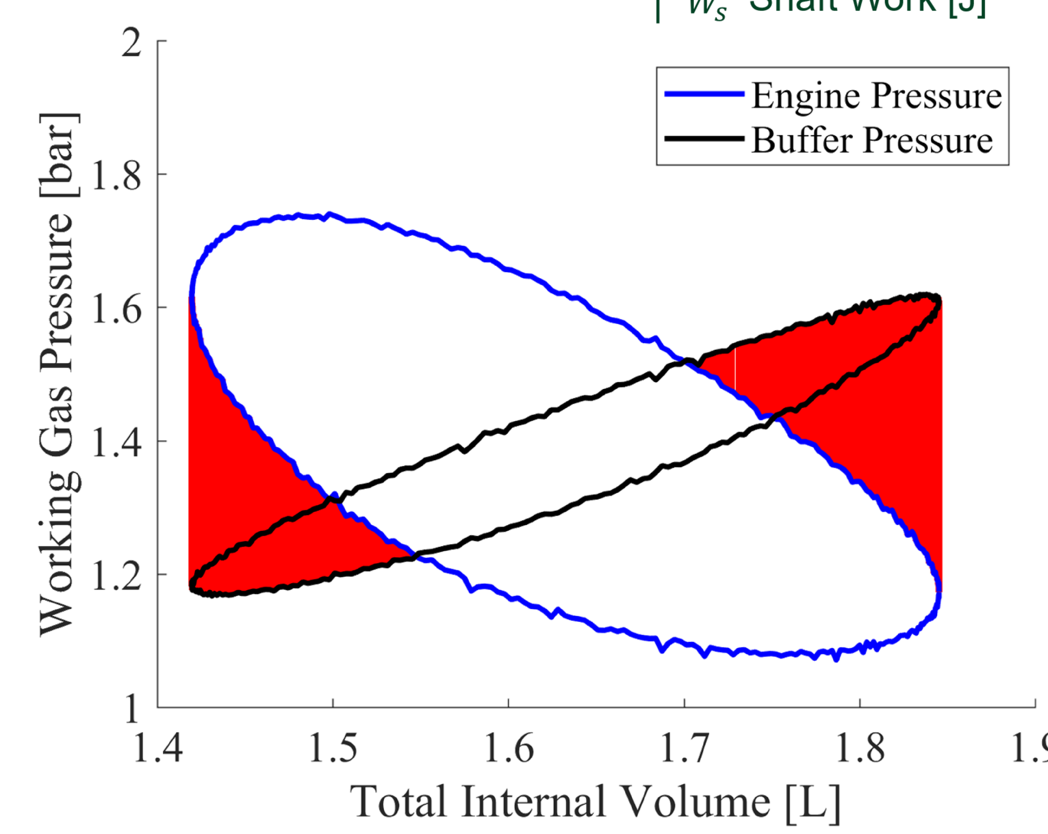
Optimal, Modelled, and Real Engine PV Diagram

FORCED WORK

Forced work relates the mechanical effectiveness to the mechanical efficiency of the engine, and its presence can inhibit and engine from running. Predicting and accounting for forced work in Stirling engine design is an unexplored topic.

$$W_s = EW_i - \left(\frac{1}{E} - E\right) W_f$$

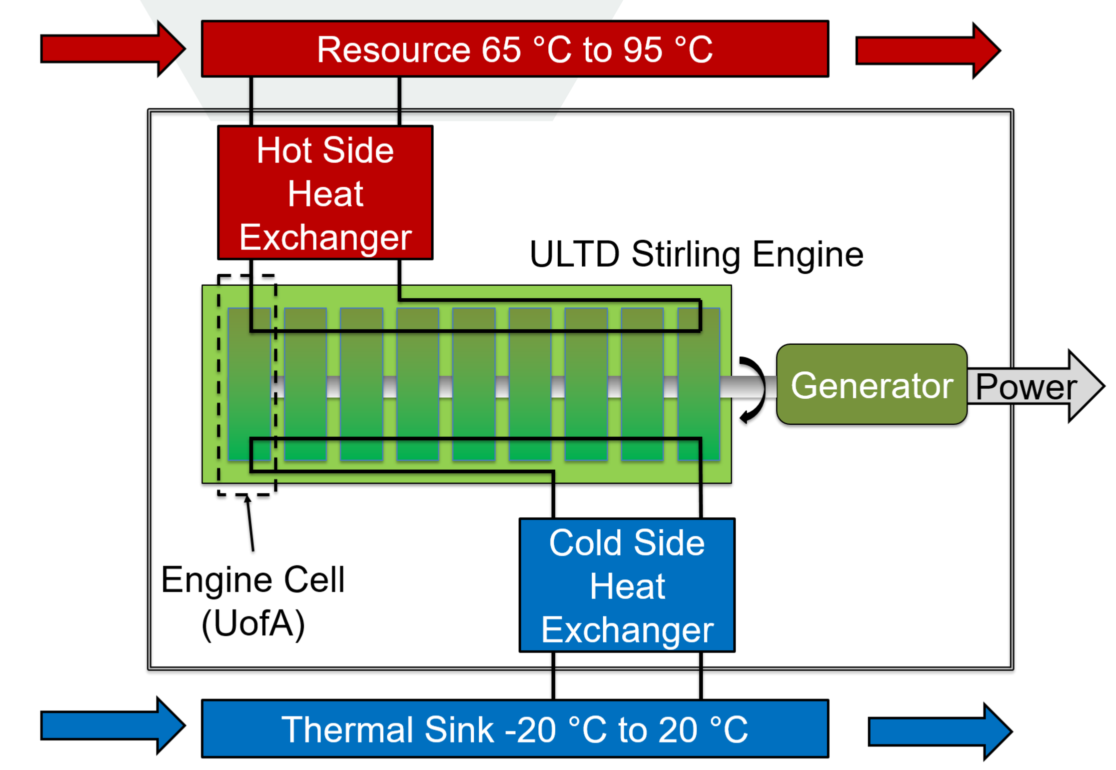
E Mechanism Effectiveness
W_f Forced Work [J]
W_i Indicated Work [J]
W_s Shaft Work [J]



PV Diagram Including Forced Work

SYSTEM LAYOUT

The full scale system consists of coupled Stirling engine cells, heat exchanges to interface with the geothermal resource and the thermal sink, and a generator to convert the shaft work into electrical energy.



Geothermal Stirling Engine System Diagram

HEAT TRANSFER

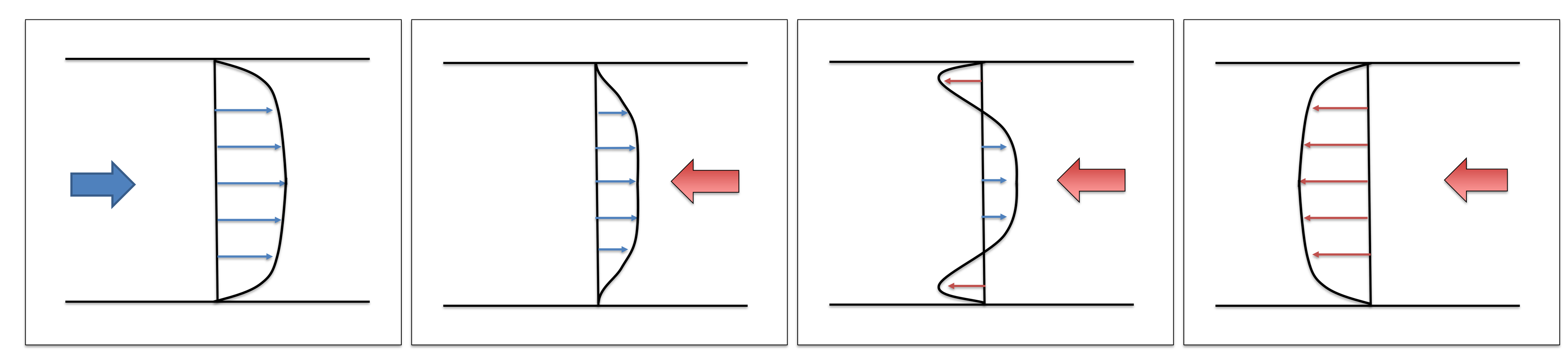
Maximizing the amount of heat that can be added and removed from the working fluid is crucial for maximizing performance. Methods to improve the amount of heat transferred will involve increasing the surface area and the convective heat transfer coefficient. The convective heat transfer equation is shown below.

$$\dot{Q} = hA(T_w - T_f)$$

A Heat Transfer Area [m²]
h Heat Transfer Coefficient [W/m² K]
$\dot{Q}$ Heat Transfer Rate [W]
T_f Fluid Temperature [K]
T_w Wall Temperature [K]

FLUID MECHANICS MODELING

Understanding heat transfer and fluid friction is crucial for effective Stirling engine design. The unique oscillating flow conditions of the Stirling engine make commonly used flow and heat transfer correlations invalid.



Oscillating Fluid Flow Velocity Profile

THEME OVERVIEW

GEOTHERMAL

Canada's geoscape possesses more potential geothermal energy than hydrocarbon energy, but numerous challenges must be overcome if this renewable resource is to be effectively harnessed. Reservoirs of geothermal energy must be located, characterized, and modeled. The nature of the interaction between rock at reservoir sites and geothermal fluids must be understood, and the potential costs of exploiting them in real-world scenarios must be understood. At the same, new engine technologies must be developed to enable generation of power from geothermal heat sources with non-ideal temperatures.

EXPECTED OUTCOMES

PERFORMANCE PREDICTION

Develop the ability to predict performance of candidate engine designs.

DESIGN OPTIMIZATION

Optimize engine geometries to maximize performance.

SCALING PROCESS

Apply knowledge developed at bench scale to industrial scale engine design.

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