Optimal Operating Temperature of a Solar Thermal Stirling Engine

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Introduction

**Goal:** Explore the relationship between the operating temperature and energy production of a simple heat engine powered by the sun.

**Stirling engines**
- Simple external combustion heat engine
- Alpha-type Stirling engines (Fig. 1) – used in experiment
  - Two cylinders attached to (e) flywheels with (d) 90 degrees phase difference and connected by a (c) tube which allows air to flow between the (a) cold cylinder and (b) hot cylinder.

![Figure 1. Alpha-type Stirling engine.](image1)

![Figure 2. Ivanpah Solar Power Facility, CA.](image2)

**Solar thermal electricity**
- Temperature differential created by solar thermal energy
- Current power plants:
  - Small scale: Parabolic mirrors heat a liquid salt solution which flows to a boiler, produces steam, runs a turbine, and generates energy.
  - Large scale: Ivanpah Solar Power Facility in California (Fig. 2) uses arrays of thousands of mirrors to focus sunlight to a single tower which houses the pipes where the liquid solution flows to produce energy.

**Significance:**
It is essential that alternatives for electricity production are researched and tested in order to improve efficiencies, reduce the cost of renewable energy, and be more environmentally friendly.

![Figure 3. Stirling engine and data collection setup with labels as described above. Fresnel lens not shown.](image3)

![Figure 4. Circuit diagram of electronics involved with collecting data.](image4)

Materials

a) Alpha-type Stirling engine (made by Sunnytech)
b) Fresnel lens – solar collector (not pictured)
c) Arduino UNO microcontroller board
d) K-type thermocouple & Arduino MAX6675 module
e) Brushless DC motor
f) Adafruit ADA254 MicroSD card breakout board
g) Arduino ICM1602C 16x2 LCD screen
h) IC74HC595N 8-bit shift register

Results

- **Graph 1** – First data set
  - Spike in engine output can be seen around 175°C
  - Output decreases exponentially to a rough plateau
  - T > 475°C: data lacks real output due to disconnecting motor from flywheel
- **Graph 2** – Second data set
  - Odd zero-output data

![Graph 1. Initial data with linear best-fit line with slope = 0.0059 V/°C.](image5)

![Graph 2. Second data set with linear best-fit line with slope = 0.0032 V/°C.](image6)

Discussion

- **Uneven alternator output**
  - Varying rotational speed or Belt slippage
- **Graph 1: Sharp rise in output**
  - Greater thermal energy gives exponentially more output
    - Disregarding zero-output data for now
    - Lower minimum operating temperature to run engine
    - Groupings of data points
- **Graph 2: Fairly linear output increase**

![Graph 3. Graph 2: Fairly linear output increase.](image7)

Future Work

- Wire DC motor in series with capacitor to avoid large drops in output
- Measure angular velocity of the flywheel without a load (i.e., the alternator assembly)

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Contact

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References

3. pv-thermal.com (website).

Legends

- **Graph 1:** Initial data with linear best-fit line with slope = 0.0059 V/°C.
- **Graph 2:** Second data set with linear best-fit line with slope = 0.0032 V/°C.