MEMS Rankine Engine

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Outline

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Objective

- Design a closed system Rankine engine in micro scale.
- Create system that can be used as a bottoming cycle for other devices or as a stand alone power device.
- Engine need to produce enough power to replace batteries used in portable devices.
Motivation

- The power usage of portable devices is increasing rapidly with increase in speed, power, and functionality.

- Battery capacity is not increasing fast enough to keep up with this large demand.

- To compensate for insufficient power density batteries increase in size and weight.

- Batteries are also made of toxic materials which is not easily disposed of.

- An alternative means of powering portable electric device needs to be created.

- Energy Desities
  - Typical Battery 170 Whr/kr
  - Butane 13000 Whr/kg
Analysis

- Circulating fluid chosen is Water
- High side input Temperature 750K
- Temperature drop across hot side due to Thermal Resistances 27K
- Flow Rate of 30mg/s
- Low side temperature is 300K
- Highest Pressure in system .59bar
- Lowest Pressure in system .09bar
- Thermal Analysis of system performed using Cycle-Tempo available from the Delft University of Technology
Modeling Analysis
Design

- Approximate outside diameter of AA battery 10mm.
- Three Section Design
  - Condenser
  - Evaporator
  - Turbine/Pump Assembly
- Condenser and Evaporator
  - Major Consideration Good Heat Transfer Rate and bearing surfaces.
  - Aluminum Heat Transfer Surface
- Turbine/Pump Assembly
  - Strength Because of Rotational Forces
  - Heat Resistance
  - Silicone or Silicone Carbide Rotor Assembly
  - Silicone working limit 900K
  - Silicone at micro scale has very few defects and in turn high strength.
Design

Power Take-Off Shaft

Cold Side

Pump

Condenser

Turbine Blades

Evaporator

Hot Side
Modeling
Prototyping

- Modeling done using Solidworks.
- Prototyping done using Dimension Rapid Prototype.
- ABS plastic part that is constructed in layers.
- Support structure has to be broken away from model.
- For testing purposes a large scale model can be machine out of aluminum and fiberglass and subjected to similar conditions to analyze actual feasibility.
Fabrication

- Because of design complexities the engine will be broken down into separate parts and then bonded together to easy fabrication.
- MUMPS process cannot be used for fabrication.
- **Turbine/Pump Assembly**
  - Blade construction can be done with the use of DRIE.
  - Due to complex axial pump geometry the blades would have to be constructed in layers to obtain spiraling geometry.
  - Layers of hard surfacing will also have to be added to the turbine in locations where bearings will be placed.
- **Condenser and Evaporator**
  - Complexities due to multiply surface materials and large vacant spaces.
- **Considerations**
  - Item Placement
  - Layering or additive techniques to simplify fabrication.
MEMS Rankine engine has been designed as a bottoming cycle which can be used with other combustion Power MEMS devices

- 10W of power is produced by engine in designed condition.
- Typical 9V Battery produces 5W of power.
- Multiply fabrication techniques have to be used to produce engine.
Future Work

- Optimize pump configuration.
- Optimize turbine configuration.
- Design method of converting mechanical power into electrical power.
- Optimization of working fluid depending on input temperatures.
Questions