Optimization of Various Thermal Management Techniques for High Thermal Loads

Space Engineering Institute
Carl Schwendeman
Rebecca Hay
Cable Kurwitz

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Introduction

• Carl Schwendeman
  – Mechanical Engineering student Texas A&M
• Rebecca Hay
  – Aerospace Engineering student Texas A&M
• Dr. Cable Kurwitz
  – Nuclear Engineering Dept.
  – Mentor
• Space Engineering Institute
  – Undergrad & graduate research at Texas A&M University
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Objective

• Find the optimal radiator for a given thermal load
  – Optimize and compare
    • Heat pipe radiator
    • Loop heat pipe radiator
    • Single phase pumped loop radiator
Heat Pipe & Loop Heat Pipe

(Saied)

(Thermacore)
Study Over View

• Theoretical studies in Matlab
• Compare optimized
  – Heat pipe
  – Loop heat pipe
  – Single phase pumped loop radiators
• Optimized parameters
  – Diameter, facesheet thickness & spacing, mass flow, number of heat pipes
Global Study Assumptions

• **Thermal Parameters**
  – Radiating from both sides
    • 0.8 emissivity
  – Hot Temperature = 323K (50°C)
  – Sink Temperature = 4K (-269°C)

• **Geometry & Materials**
  – 6061 Aluminum Pipes & Facesheets
  – Core material
    • Aluminum honeycomb
  – OSR on both sides
  – Adhesive around the pipes, attaching the face sheets and OSR
  – Working fluid: Ammonia
  – Adiabatic length: 1m
Heat Pipe Radiator

- Assumed: Isothermal 50°C, Radius of nucleation: 0.11 μm
- Optimized Parameters:
  - Pipe diameter & wall thickness
    - For: lightest heat pipe that meets the capillary limit
  - Wick thickness
    - For: lowest pressure loss in liquid and vapor
  - Heat pipe spacing & facesheet thickness
    - For: lightest radiator kg/kW
      - Via “Optimization of a Heat Pipe Radiator”, H. Chang
  - Number of heat pipes
    - For: lightest radiator configuration
    - Compared the mass trade off between a few large heat pipes or many smaller heat pipes
Loop Heat Pipe

• Assumed: Square radiator, facesheet thickness, fin efficiency 85%

• Optimized Parameters:
  – Pipe diameter, pipe length, run spacing, mass flow

• Used Matlab’s Fsolve
Single Phase Pumped Loop

- Used Matlab’s Fsolve and FEA analysis
- Assumed: Square radiator
- Optimized Parameters:
  - Pipe diameter, pipe length, run spacing, mass flow, facesheet thickness
Radiator Comparison

![Graph showing comparison of mass (kg) vs. power (kW) for different radiator types: HP, SPPL, and LHP. The graph illustrates the relationship between power and mass for each type, with HP having the highest mass at higher powers.]
Trends

• Heat Pipe Radiator
  – Linear
  – Use below 700W

• Loop Heat Pipe Radiator
  – Use above 700W
  – Deployable configuration

• Single Phase Pumped Loop
  – Use above 700W
  – Deployable configuration
  – Requires power
Loop Heat Pipe Mass Breakdown
Single Phase Pumped Loop
Mass Breakdown

Percent Mass

Power (kW)

0.1
1.5
6

Pipe
Fluid
Pump
Facesheet
OSR
Adhesive
Honeycomb

0
20
40
60
80
100
Summary

• Power levels< 700W
  – Heat Pipe radiator two sided

• Power levels> 700W
  – Loop Heat Pipe or Single Phase Pumped Loop
  – Deployable configuration

• Weight reduction
  – Alternate materials
    • Facesheet
Questions
Citations

