Optimization of Heat-sink Fin Features using ANSYS

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Background:

Heat sinks are frequently used when heat exchange is required for electric circuits. In cases where the heat generation is evenly distributed, the height and spacing of fins are uniform. However, when heat generation is locally concentrated, uniform fin distribution is not the most efficient design.

Tasks of Virtual Prototyping:
Virtual prototyping is applied to the investigation of fin feature design in order to reduce the cost when re-tooling is required.

(1) To make sure that the new design will increase the heat transforming efficiency;
(2) To reduce the weight.

Procedures:
(1) Analyze original design as the baseline;
(2) Investigating heat generation sources;
(3) Simple method to see the possibility for weight cut;
(4) Optimize Fin Space, Height following the structure/installation requirement.
(5) Validation
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Heat Exchange: Improve ~10-15%
Material Reduction: ~10% of Heat Sink
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Step 1. Original Model (Baseline)

Ambient T=50°C, Max. 108.9°C

Ambient T=20°C, Max. 75.63°C
Total Heat Source: 88W  (1)
Center Wall:  
12W + 10W + 10W + 10W + 18W = 60W  (2)
Longer Side: 15W(R) + 7W = 22W  (3)
Shorter Side: 6W (R)

The investigation of heat generation:
Concentrate Distribution

Step 2. Heat Generating Source Investigation
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Step 3. Simple Method (Conduct/Film) for the Possibility of Weight Cut (A)

Test Model 1

Removing 3 Fins at the end of one side, Cut fin 0.05*3=0.15M

Test Model 2

Increasing the height of 3 Fins +0.025M. So total adding is 0.075M

Amb T=20C, Max. 77.8°C

Ambient T=20°C, Max. 75.8°C
The results suggest that changing the height of fin and density could reduce the weight by increasing heat transform efficient.

We know the possible method.

Now, we need to know how to determine their height and space (density) in detail. Optimization analysis by FEA is used.
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Step 4. Fin Density (Space) & Height Change, Model with Straight Fin Optimization Analyzing Base Model w/Straight Fin (Step 4-1, 4-2 & 4-3)

Max. 74.8°C under Bulk 20°C

Max. 107.5°C under Bulk 50°C

Straight Fin Baseline, Max. M=0.631kg
Step 4-1: Fin Density (Space) Change, Model with Straight Fin (A) (Optimization Analysis – Model with Parameters)

Eight (8) Parameters
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4-1 (B): Fin Density (Space) Change, Model with Straight Fin (Optimization -- Response Surface Result – Local Sensitivity)
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4-1 (C) : Fin Density (Space) Change, Model with Straight Fin (Optimization Analysis Result – Sensitivity Chart)

Hold b1, see how T changes (sensitivity) following b7/b6 (Left) and b5/b2 (right)?
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4-1 (D): Fin Density (Space) Change, Model with Straight Fin (Goal Driven Optimization Analysis Result Summary)

Best: 71.9 vs. 74.8°C (base), M=0.631

Tradeoff – Max. Temperature vs. Mass

Reduced Samples
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**Step 4-2**: Fin Height Change, Model with Straight Fin & Equal Space (A) (Optimization Analysis - Model)

Four Parameters in DesignModeler

APDL Command in Mechanical (add another parameter ARG1)
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4-2 (B): Fin Height Change, Model with Straight Fin (Optimization – Response Surface – Local Sensitivity)
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4-2 (C): Fin Height Change of Model with Straight Fin (Optimization Analysis –Sensitivity Chart)

- Max. T vs. h2 and l1
- Mass vs. h2 and l1
- Mass vs. h2 and h3
- Mass vs. h2 and h4
- Max. T vs. h2 and h4

Hold h2, see how T & Mass change (sensitivity) following l1 (best l1 for T, Left low), h4 (right) and h3 (center)?
4-2 (D): Fin Height Change of Model with Straight Fin (Goal Driven Optimization Analysis – Set & Result)

Tradeoff – Max. Temperature vs. Mass

Result of Optimized Model, Height Change only

Best: Mass 0.590 vs. 0.631 (base) T=74.78°C
Step 4-3. Combining Fin Height and Space Change (A) Optimization Model with Dimension Parameters

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8+4=12 Parameters
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4-3 (B). Combining Fin Height and Space Change

Optimized 12 Parameters, Mass=0.576kg, T=74.55°C (Base M:0.631Kg,T:74.8°C)

Inacceptable gap
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4-3(C). Combining Fin Height and Space Change
Re-adjusted 8 Parameters Toward to Market-Manufacture Acceptable Model - Optimization

Parameter Table

Detail of Design of Experiments

Note - h3: Shipping package; l1: optimized; b7: gap limit; w1: limited; TL: defined
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4-3 (D). Combining Fin Height and Space Change, Goal Driven Optimization Results

1. Selected as response point
2. Acceptable / Round for Manufacture
3. Pints Verification, Mass = 0.573Kg, Max. T = 74.7°C

Table of Schematic C3: Response Surface

<table>
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<th></th>
<th>A</th>
<th>B</th>
<th>C</th>
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Optimized Candidates

Sensitivity

Manuf. Acceptable - Verification
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**Step 4-3(E).** Combining Straight Fin Height and Space Change (Manufacture)

Results of **ALL** Accepted Parameters, Mass=0.579kg, T=74.7°C (Base Mass=0.631, T=74.8°C)

- Ambient T=20C, Max. T=74.7°C
- Ambient T=50C, Max. T=107.4°C
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**Step 5**: Final Model Validation (A)
Summary, Optimized vs. Original (Geometry & Results)

<table>
<thead>
<tr>
<th>Model</th>
<th>FEA Thermal Analysis</th>
<th>LC 4 (50C) Thermal Stress</th>
<th>LC 5 (50C) Thermal + F 11 lbf</th>
<th>Volume V (Fin L)</th>
<th>Reduction (Fin L)</th>
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<tbody>
<tr>
<td>#</td>
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<td>Report</td>
<td>Max. T</td>
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<td>108.9 C</td>
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<td>C, enforced</td>
<td>108.4 C</td>
<td>82.7 C</td>
<td>75.3 C</td>
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**Step 5 (B):** Final Model Validation -- Compared with Original in FEA Thermal

### Ambient T=52.5°C, Max. 108.4°C
- Max-Min=25.8°C

### Ambient T=50°C, Max. 108.9°C
- Max-Min=31.4°C

### Ambient T=21°C, Max. 75.3°C
- Max-Min=30°C

### Ambient T=20°C, Max. 75.6°C
- Max-Min=32.1°C
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**Step 5 (C).** Final Model Validation -- Thermal Structure Stress Check

- **Static Structure Analysis**

- **Thermal Structure Analysis**
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Step 5 (D). Final Model Validation -- Prototype Test

Test PASS/FAIL Criteria:
Test 2. Operating Temperature:
-20 °C to +60 °C. The power supply shall operate without any evidence of degradation throughout a “Normal Temperature” range of 0 °C to +40 °C. For thermal protection above +40 °C, its output will be reduced by 2.5% / °C until reaches 50% power at 60 °C, above which it will shutdown.

All prototypes passed test successfully.
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RESULTS & CONCLUSION

In summary, ANSYS, a virtual prototyping tool, is used for Heat Sink Redesign:
(1) The electric charge has been in mass production years and is very successful. The finding has been submitted to and is pending in US patent office.
(2) ANSYS is providing a powerful tool to help us to decide whether improvement is accessible;
(3) Optimization tool help us to determine the dimension rapidly and accurately ;
(4) Saved cost and valuable time.

ACKNOWLEDGEMENTS

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