Optimum design of the fin for CPU to cool

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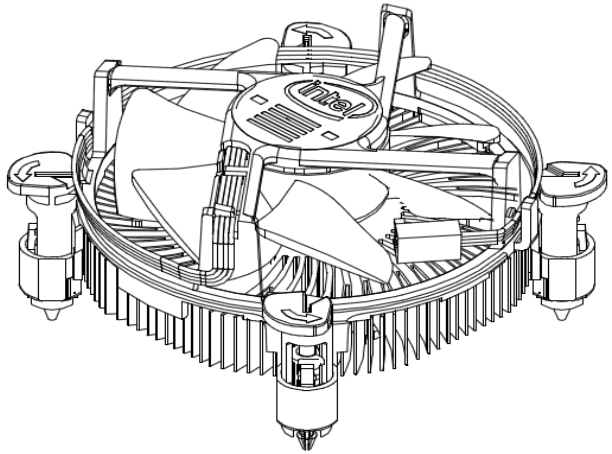
Introduction

To prevent from being broken CPU

Cooling



Heat

Problem statement

- **Purpose : To maintaining the temperature of CPU below 40℃.**

- **Considerations and assumpsions to be optimized**

① Producing a number of coolers with each CPU

- Cost must be minimized

② Cooler(Fan + Fin)

- The number of fins ∝ Total mass

③ Steady operation

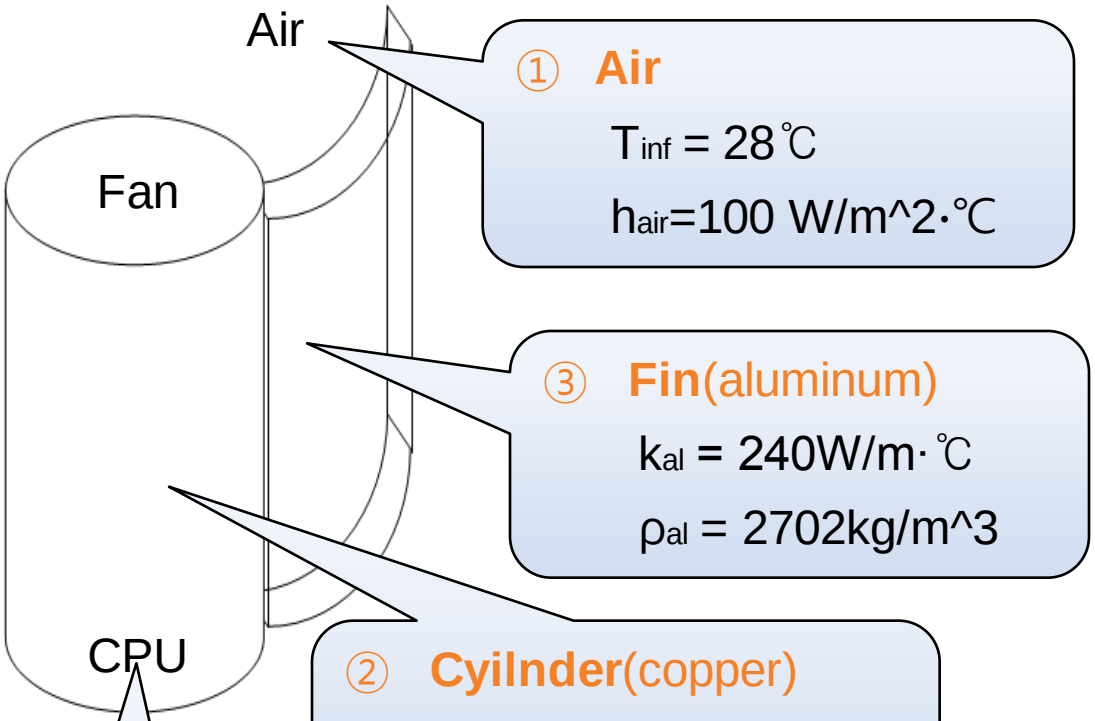
④ No heat generation in the fin

⑤ Thermal conductivity and heat transfer coefficient are constant.

⑥ Fins are long straight fin because the thickness of fin is small value.

⑦ Curvature of fin is considered to expand area of fins.

Data and Information



① **Air**

T_{inf} = 28℃

h_{air}=100 W/m^2·℃

③ **Fin**(aluminum)

k_{al} = 240W/m·℃

ρ_{al} = 2702kg/m^3

② **CyiInder**(copper)

k_{cu} = 400W/m·℃

$T_{cyilnder}$ = 40℃ = const

④ **Heat**

Q_{elect} = 65W

① **Air**

T_{inf} = 28℃

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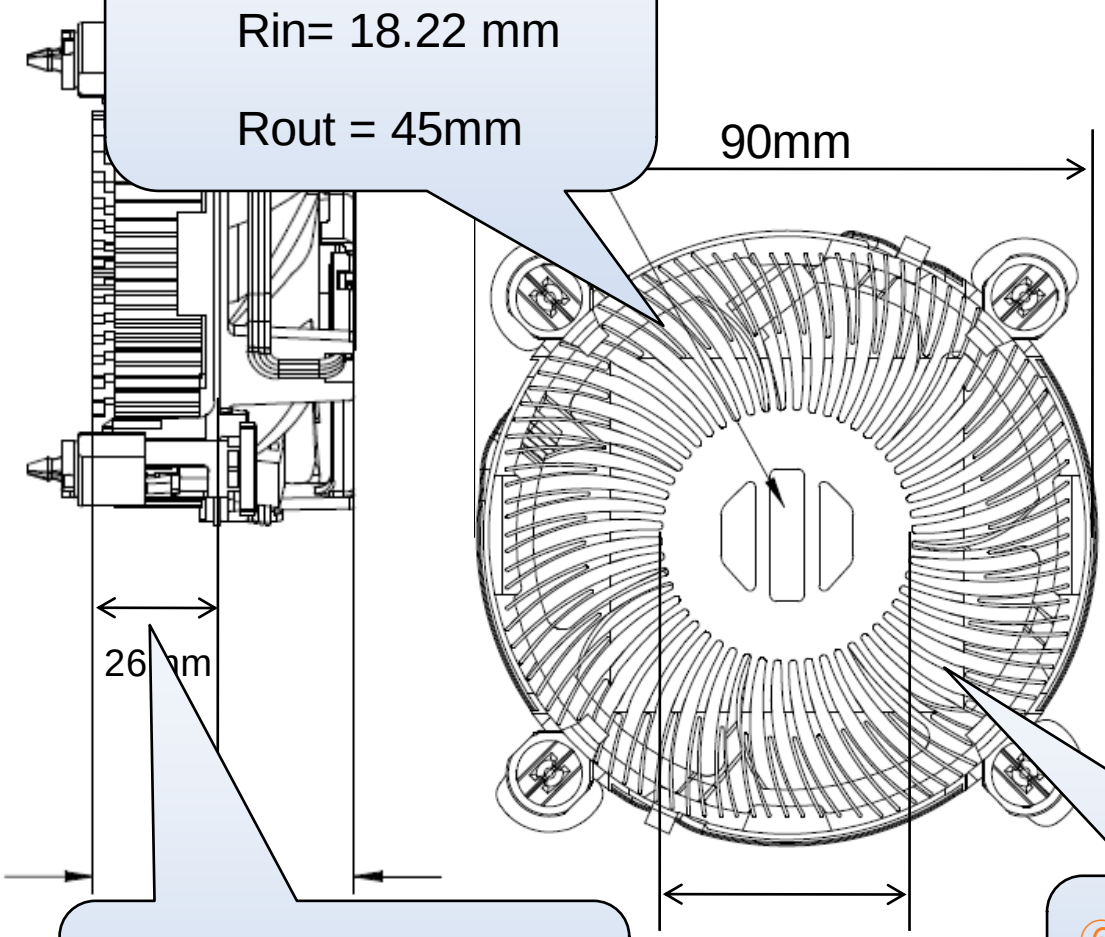
Data and Information

⑤ **Radius**

Rin= 18.22 mm

Rout = 45mm



⑦ **Height of fin**

h = 26mm

⑥ **Length of fin**

l = 5.1927mm

⑤ **Radius**

Rin= 18.22 mm

Rout = 45mm

⑥ **Length of fin**

l = 5.1927mm

⑦ **Height of fin**

h = 26mm

Optimum Design

Data and Information

Table 2–2. Heatsink Inlet Temperature of Intel Boxed Processor Thermal Solutions

Topic	Boxed Processor for Intel® Core™2 Duo Processor E8000, E7000 Series, Intel® Pentium® Dual-Core Processor E6000, E5000 Series, and Intel® Celeron® Processor E3x00 Series
Heatsink Inlet Temperature	40° C

NOTE:

1. Boxed Processor thermal solutions for ATX as… e use of the thermally advantaged chassis (refer to *Thermally Advantaged Chas… Design Guide* for TAC thermal and mechanical requirements). The TAC 2.0 … defines a new processor cooling solution inlet temperature target of 4… ting TAC 1.1 chassis can be compatible with TAC 2.0 guidelines.

⑧ **Temperature of CPU**

T_{base} = 40℃

Table 1. Fin parameters

Fin height	3…
Base thickness	3 – 16 mm
Fin thickness	0.15 – 0.8 mm
Fin pitch	dep… ds on fin thickness and …
Fan characteristics	axial … lable in
Flow length	

⑨ **Range of fin thickness**

w ≥ 0.15mm

⑧ **Temperature of CPU**

T_{base} = 40℃

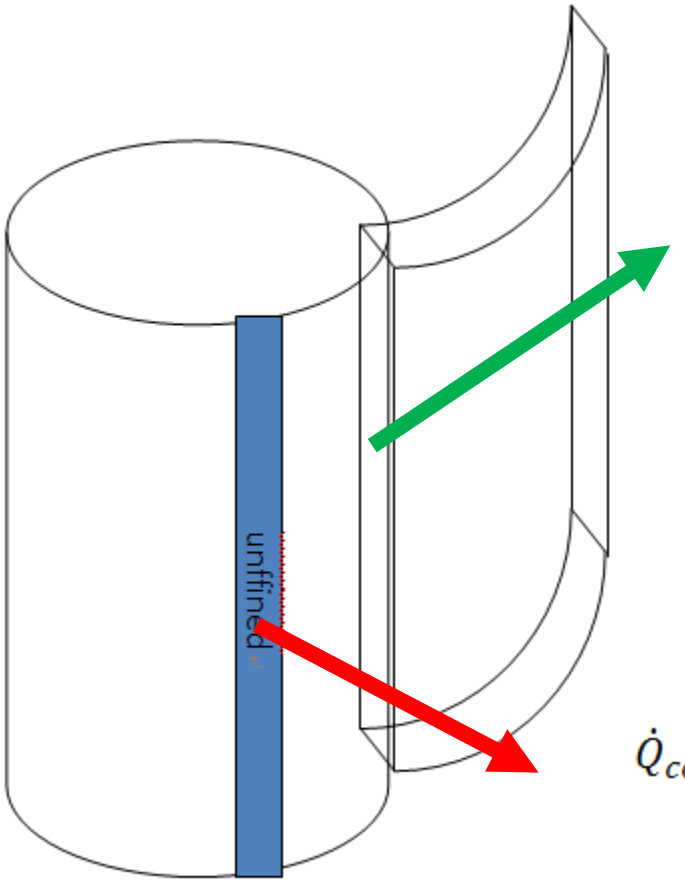
⑨ **Range of fin thickness**

w ≥ 0.15mm

⑩ **etc**

$A_{finned} \leq A_{side,cylinder}$

Problem Analysis



$$\dot{Q}_{fin} = n \times \sqrt{hPkA_c}(T_b - T_\infty)$$
$$= n \times \sqrt{2hk(w+b)wb}(T_b - T_\infty)$$

$$\dot{Q}_{conv} = hA_{unfinned}(T_b - T_\infty)$$
$$= h(2\pi r_{core}^2 b - nwb)(T_b - T_\infty)$$

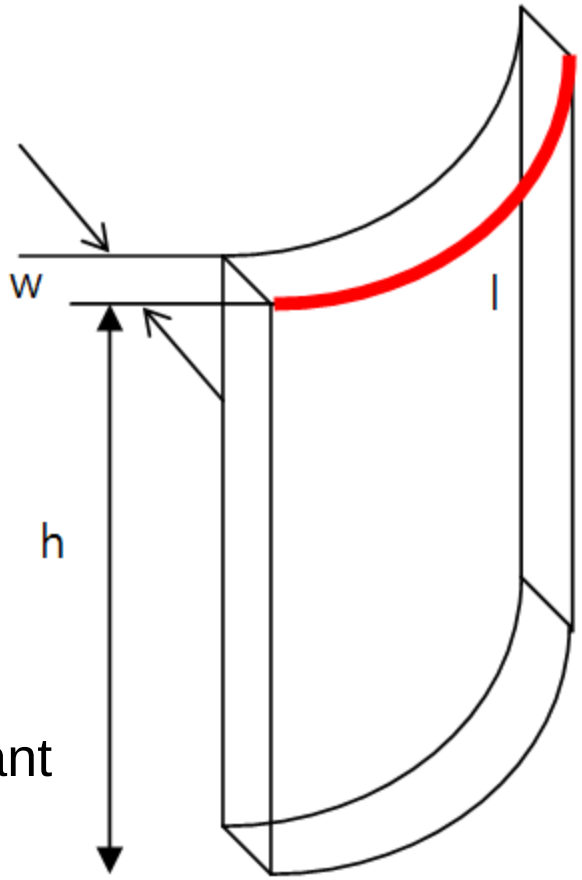
$$\dot{Q}_{total} = \dot{Q}_{elect} = \dot{Q}_{conv} + \dot{Q}_{fin}$$

Optimum Design

- **Design Variables**

  n : the number of fins

  w : thickness of a fin



- **Cost Function**

  Cost $\propto$ M_{total} = Mass(al) + Mass(cu)

  ↳ constant

  $\therefore$ Minimize **$f=Mass(al)=\rho_{al} \cdot l \cdot h \cdot n \cdot w$**

Optimum Design

- **Constraints**

$$g_1 = \dot{Q}_{elect} - \dot{Q}_{total} \leq 0$$

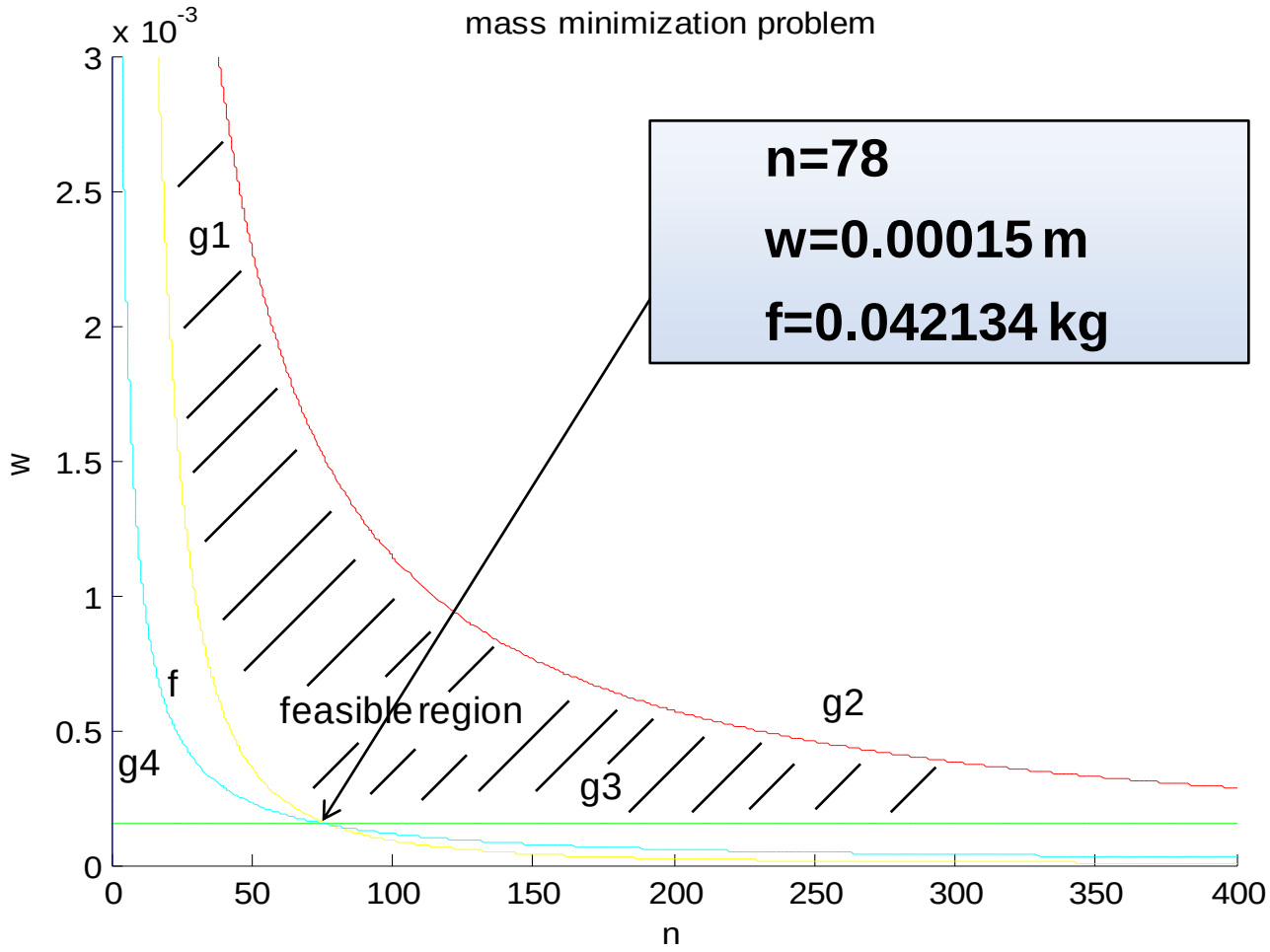
$$g_2 = nw - 2\pi r_{in} \leq 0$$

$$g_3 = 0.00015 - w \leq 0$$

$$g_4 = -n \leq 0 \text{ (integer)}$$

Optimum Design

- **Graphical Method**



Conclusion

- From the optimum design

  n=78, w=0.00015 m

  f=0.042134 kg

- w is the least value of the range of w.

- Governing feasible region to minimize f is determined by g1 and g3.

Comments

- The value of h can be a variable value by the fan.

  If h is 50, n increases to 110. So f is 0.059656 (< 0.042134).

  Therefore the role of fan is important to minimize the cost.

- If we don't assume the temperature of core is uniform,

  the problem is more complcated and the cost is going up.

- In this problem, the curvature is constant. but it can be a variable value. If we handle it, the number of design variables will be three.

  But its effect is small, so we use l_{max} when the curvature is largest .

Reference

- **www.intel.com**

  Intel® Core™2 Duo Processor E8000¹ and E7000¹ Series Datasheet

  Intel® Core™2 Duo Processor E8000¹ and E7000¹ Series and Intel® Pentium® Dual-Core Processor E5000¹ Series Thermal and Mechanical Design Guidelines

- **http://www.biberthermal.com/Reference_Links/Publications_List/isps99paper.pdf**

- **Heat transfer 2nd edition by Yunus A.Cengel / Mc Graw Hill**