Heat Transfer: Conduction

Introduction to the topic of fins

Prof. Dr.-Ing. Reinhold Kneer

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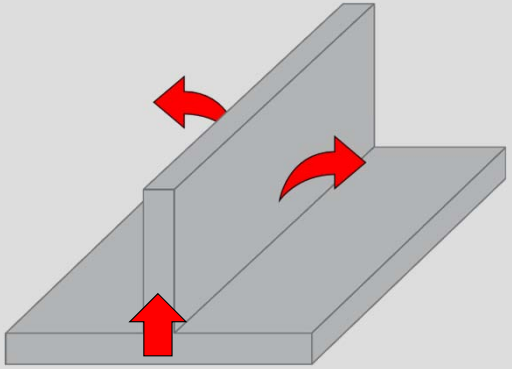
Video overview

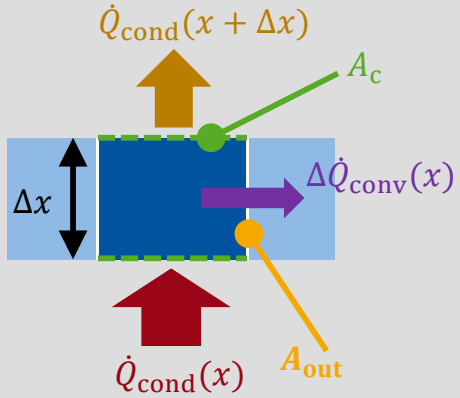
Fundamentals about fins

- What are fins?
- Which heat transfer processes are of relevance?
- How does the temperature profile in a fin look like?



Balance set-up und derivation of the differential equation for fins

- Establish the energy balance for fins
- Derivation of the differential equation for fins



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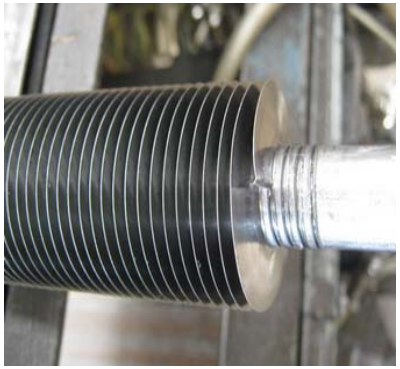
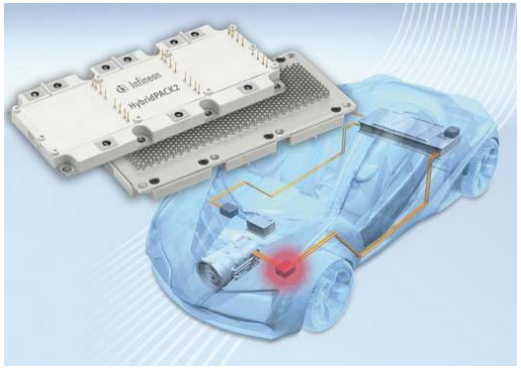
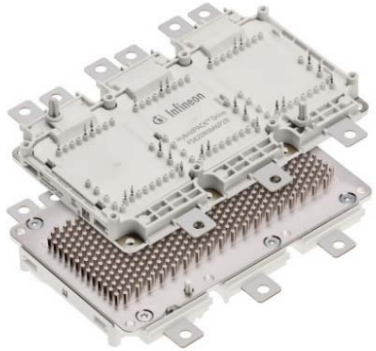
Fins application

Examples:



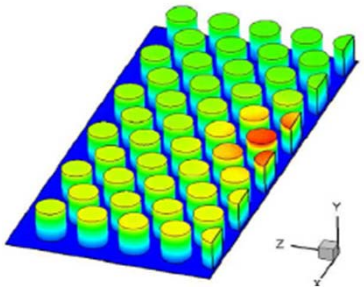
Finned tubes



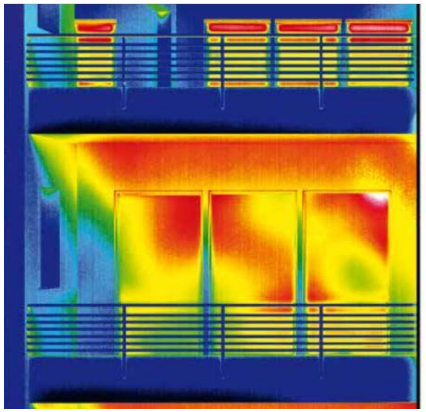


Infineon's **Hybrid PACK 2 power module**

Radiator



Pin fins



Thermal bridges

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Image sources: www.tibometals.com, www.infiniion.com, www.immowert-maier.de

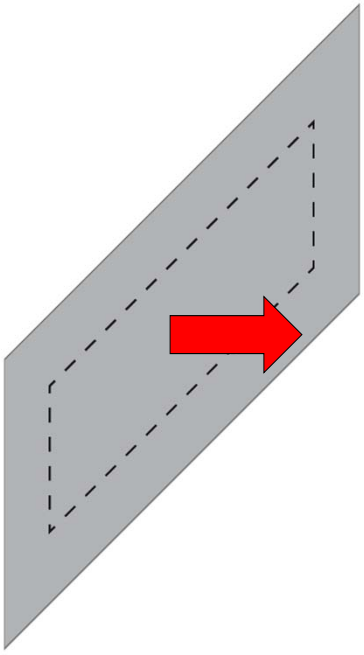
Fins: advantages and disadvantages

Advantages:

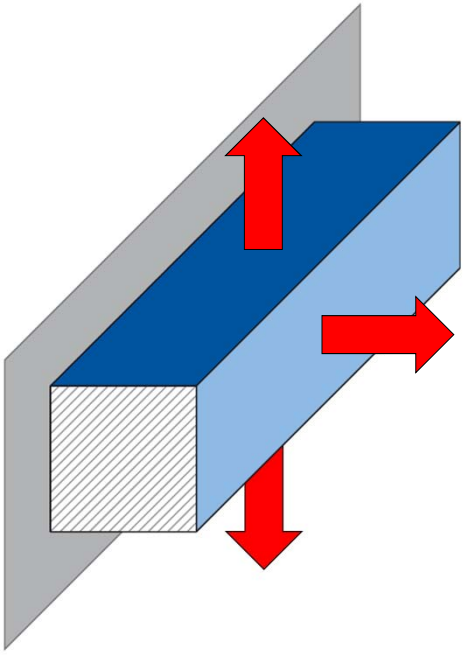
- Additional surface
- Due to increased surface area, heat is better transferred from the well-conducting solid to poorly conducting fluid

Disadvantages:

- Higher material consumption
- Additional weight and volume
- Increased pressure loss



Flat surface



Surface with fins

Example: Cooling fins for graphics cards cooling

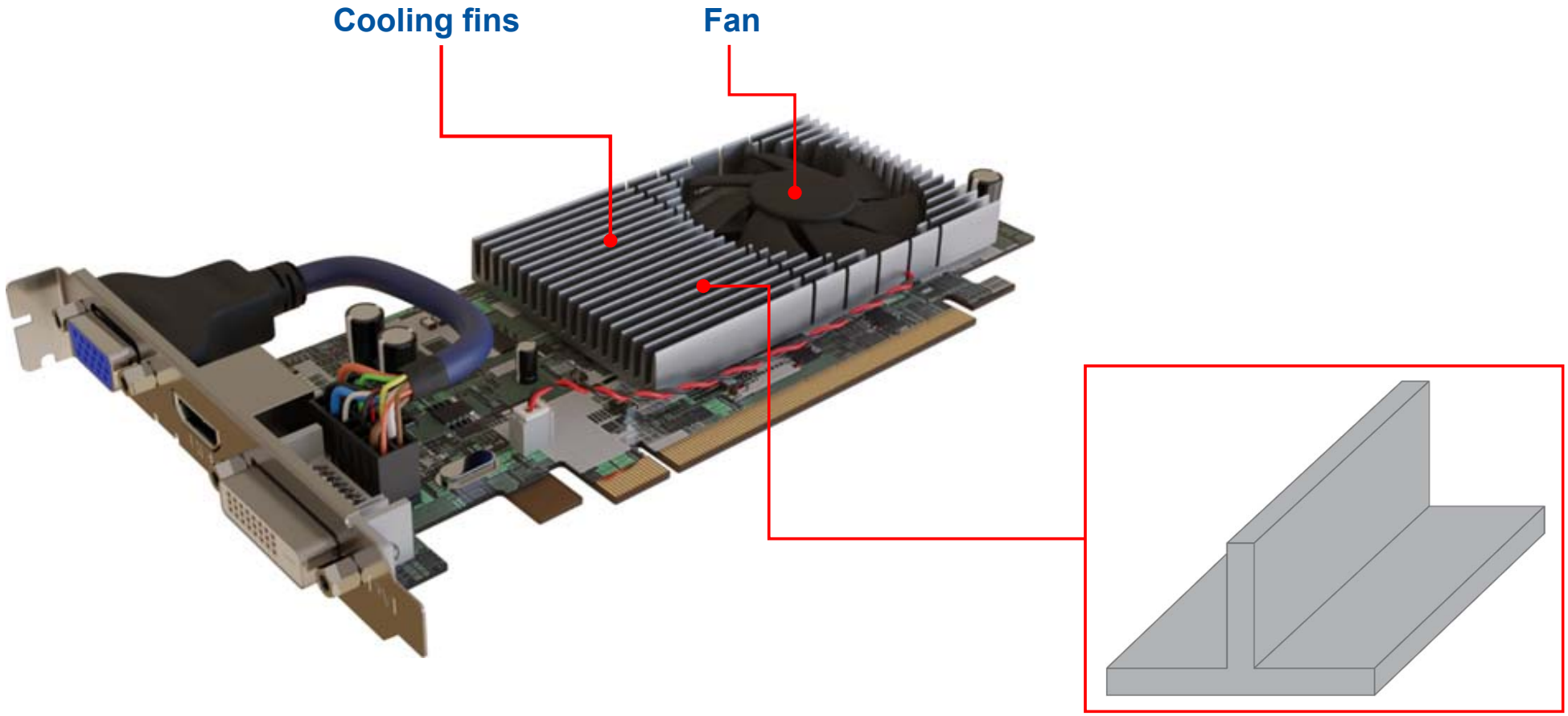
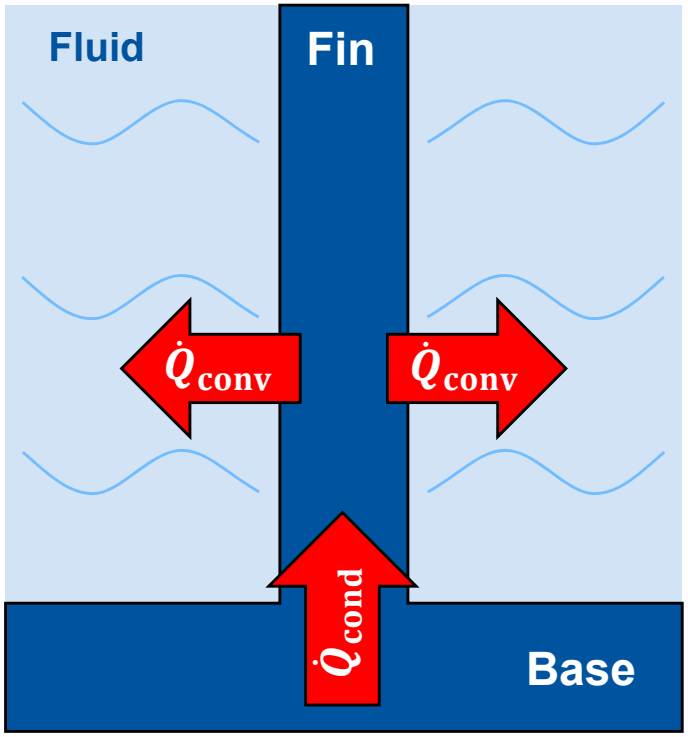


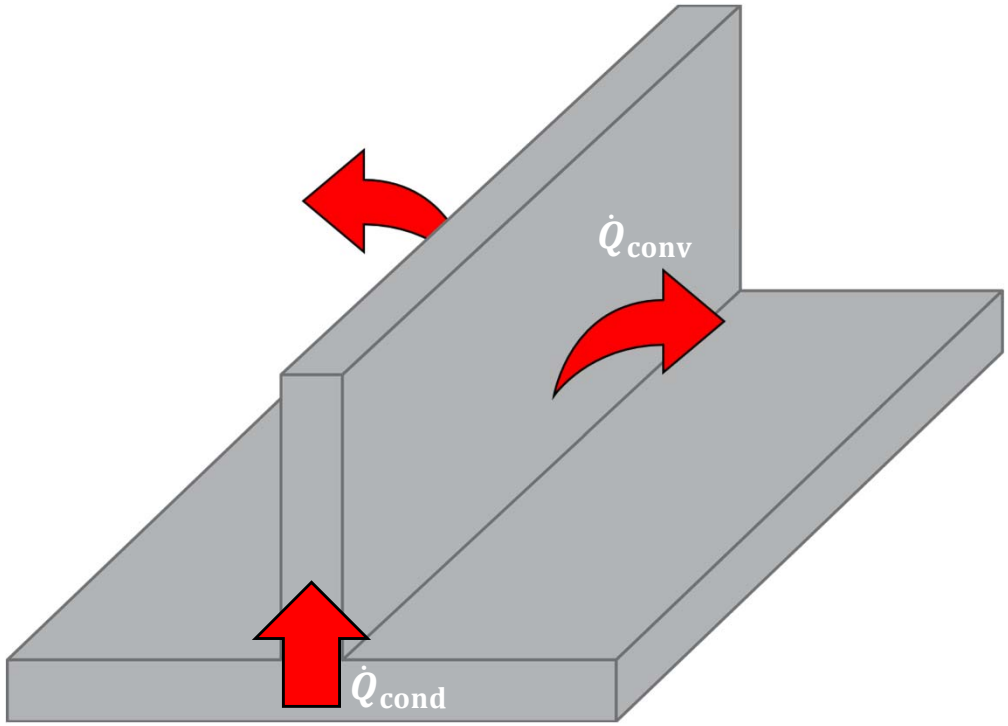
Image source: www.tec-science.com

Heat dissipation through fins

Principle of operation:

- Heat conduction from the base into the fins
- Convective heat dissipation via the side surfaces of the fin to the surrounding fluid





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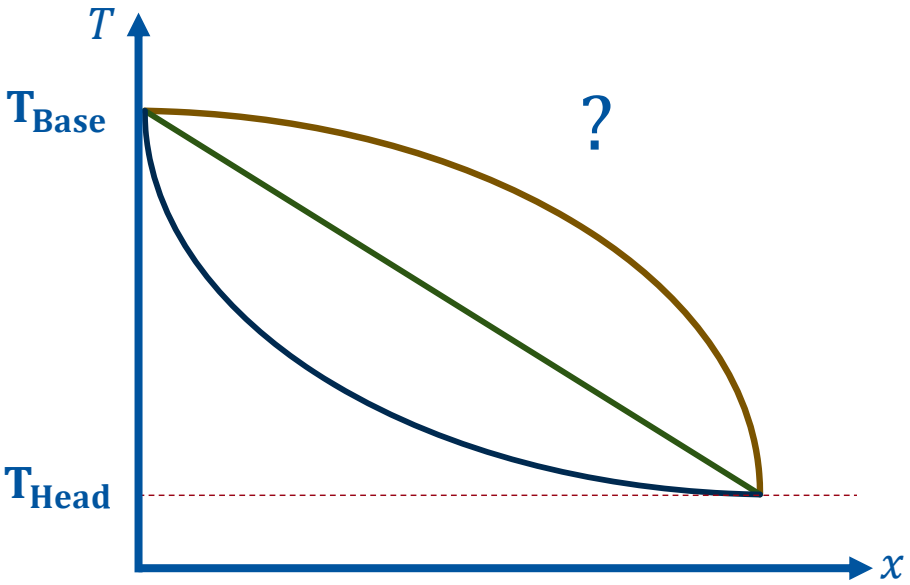
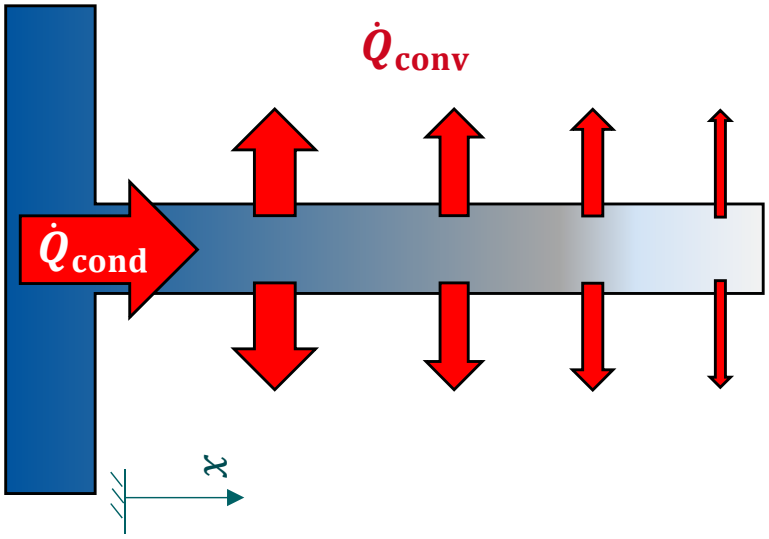
Derivation of fins differential equation by energy balance

Which temperature profile is correct?:

Due to the increased temperature difference to the environment, more heat is dissipated at the beginning.

- At the foot: Large temperature difference compared to the environment
- At the head: Low temperature difference compared to the environment





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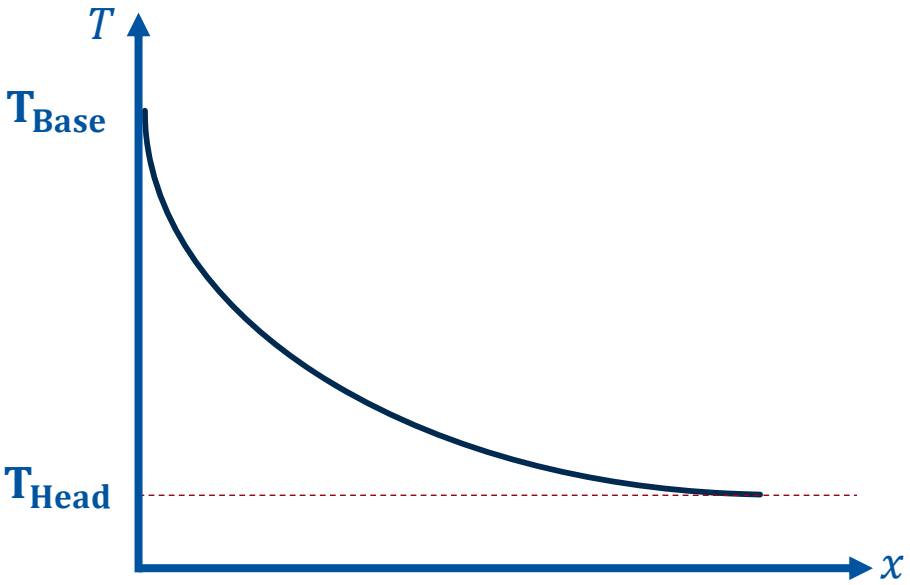
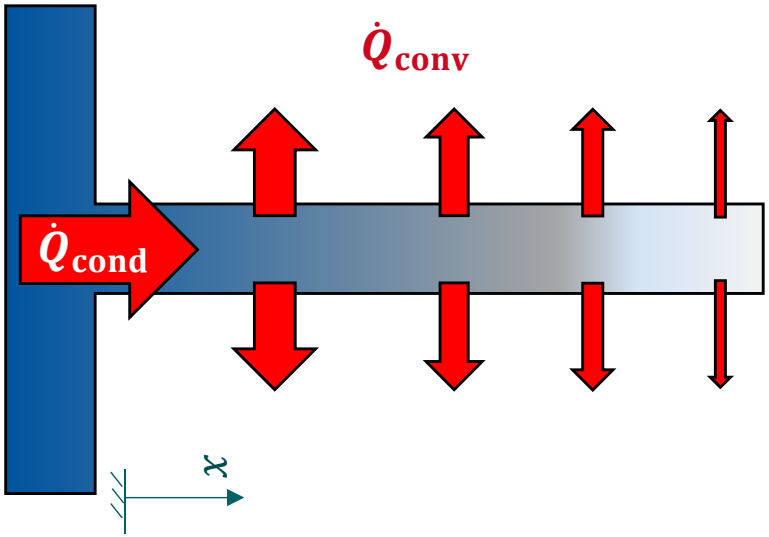
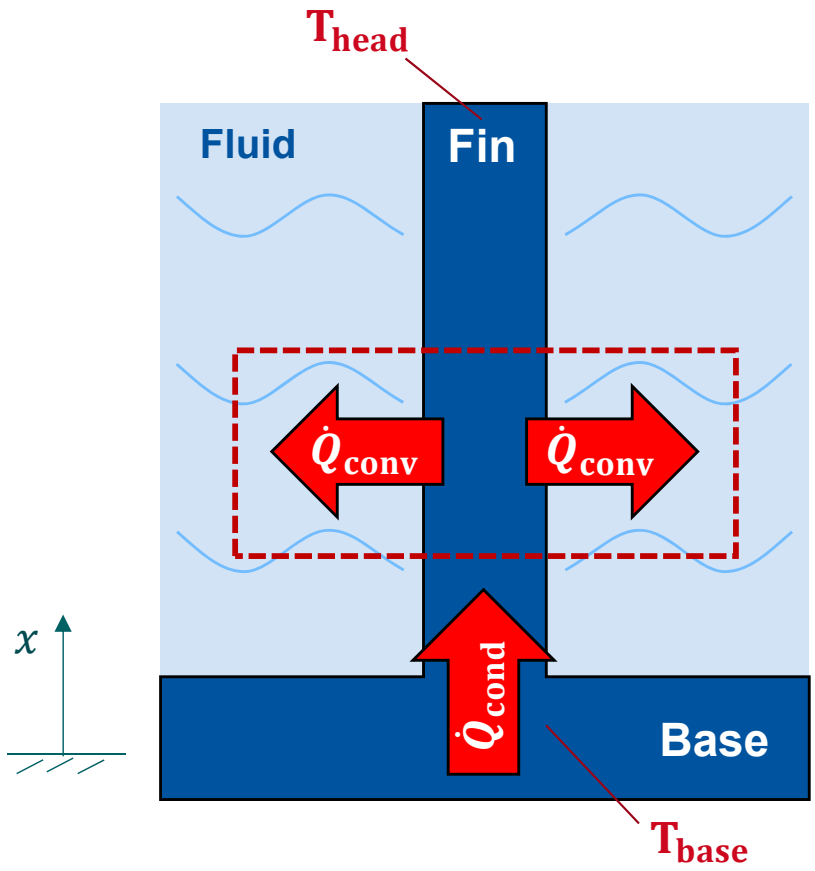




Derivation of fins differential equation by energy balance

How is calculated the heat flow transferred to the environment?



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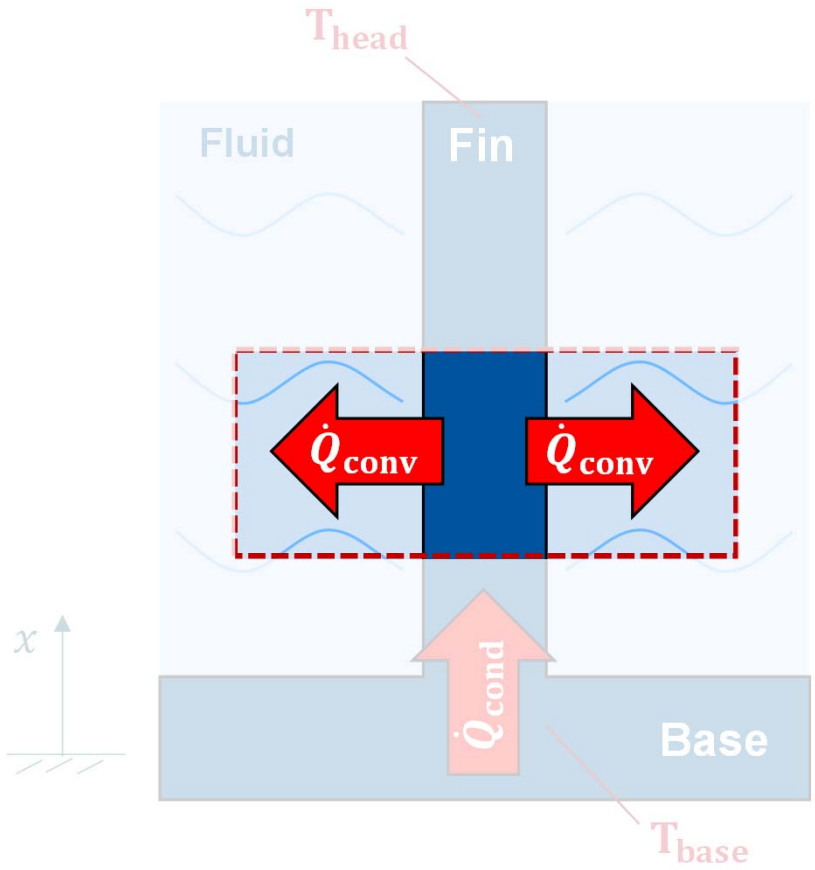

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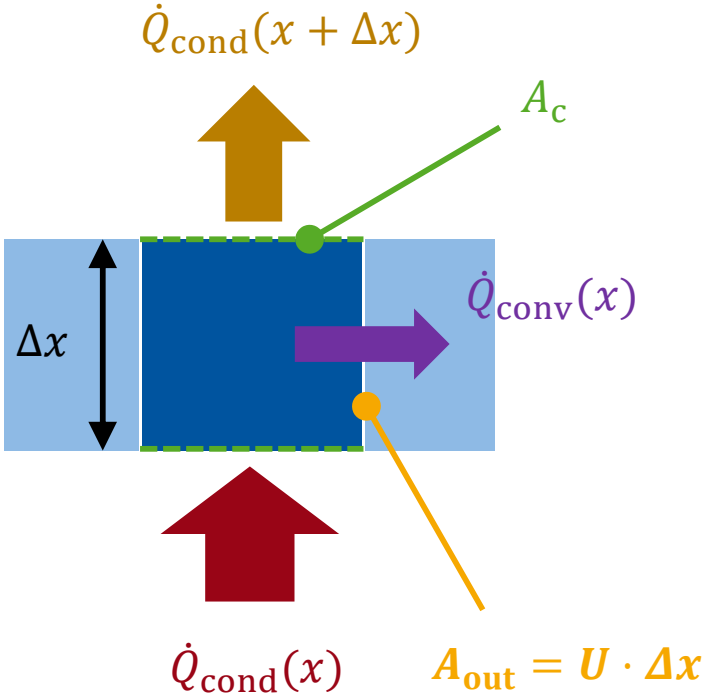

Explanation:

$\dot{Q}_{cond}$	Heat conduction in axial direction
$\dot{Q}_{conv}$	Convective heat transferred to fluid
Δx	Length of the finite element
A_c	Cross-sectional area of the fin
A_{out}	Outer surface area (shell area) of the finite element
U	Circumference (perimeter) of the fin
T_A	Ambient temperature

Derivation of fins differential equation by energy balance

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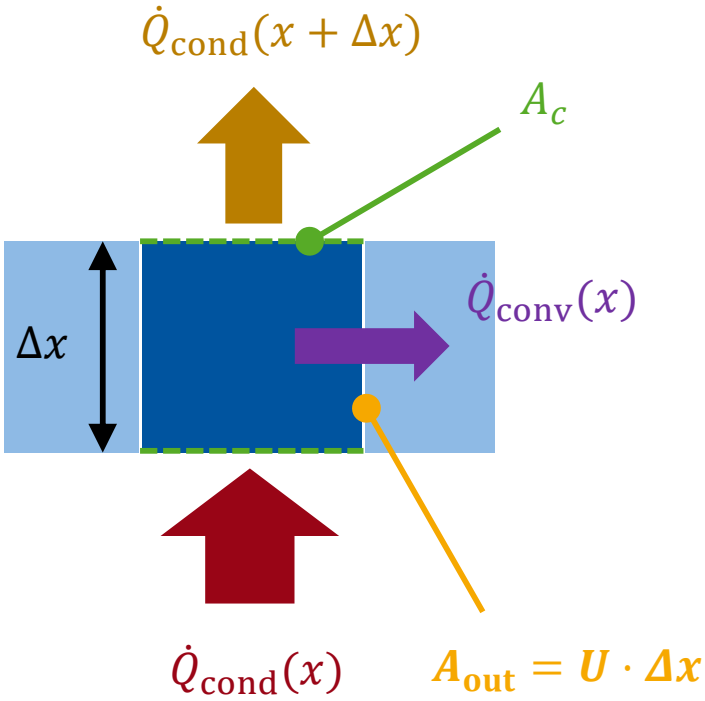

Infinitisimal energy balance:

$$\dot{Q}_{\mathrm{cond}}(x) - \dot{Q}_{\mathrm{cond}}(x+\Delta x) - \dot{Q}_{\mathrm{conv}}(x) = 0$$

$$\dot{Q}_{\mathrm{cond}}(x) = A_c \cdot \dot{q}''_{\mathrm{cond}}(x)$$

$$\dot{Q}_{\mathrm{cond}}(x+\Delta x) = \dot{Q}_{\mathrm{cond}}(x) + \frac{\partial\, \dot{Q}(x)}{\partial\, x} \cdot \Delta x$$

$$\dot{Q}_{\mathrm{conv}}(x) = A_{\mathrm{out}} \cdot \dot{q}''_{\mathrm{conv}}(x)$$

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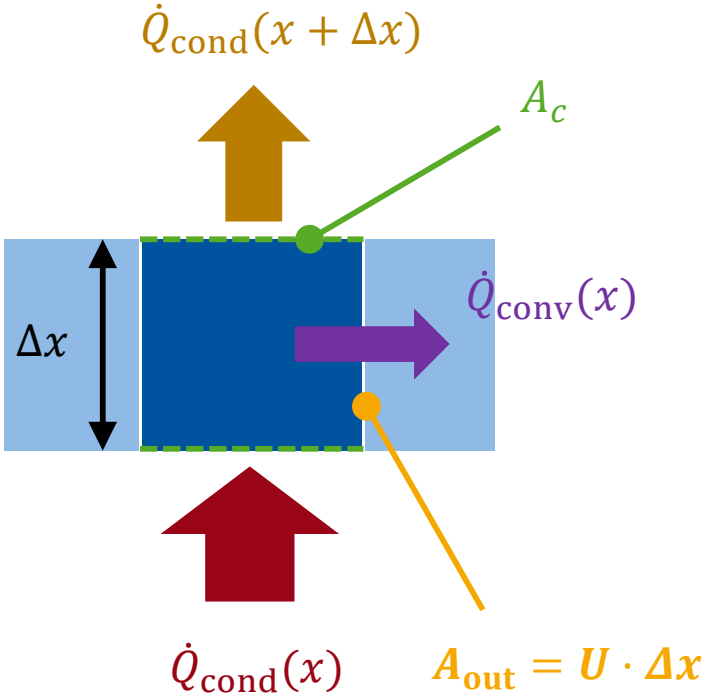

Infinitisimal energy balance:

$$0 = -\frac{\partial \dot{q}''_{cond}(x)}{\partial x} \cdot \Delta x \cdot A_c - A_{out} \cdot \dot{q}''_{conv}(x)$$

Fourier Law:

$$\dot{q}''_{cond}(x) = -\lambda \cdot \frac{\partial T}{\partial x}$$

Convective heat transfer:

$$\dot{q}''_{conv}(x) = \alpha \cdot (T(x) - T_A)$$

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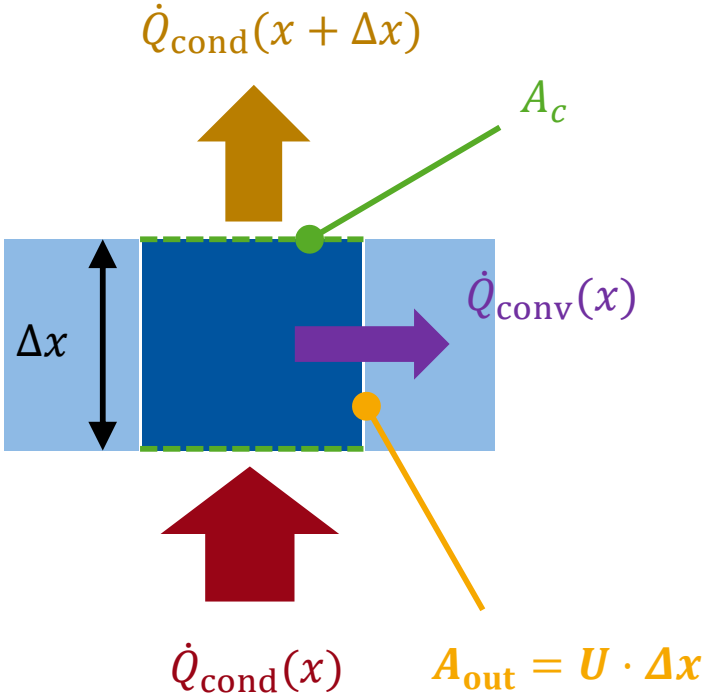

Insert $\dot{q}''_{\mathrm{cond}}(x)$ and $\dot{q}''_{\mathrm{conv}}$ in balance:

$$\lambda \cdot A_c \frac{\partial^2 T}{\partial x^2} = \alpha \cdot U \left(T(x) - T_A\right)$$

Inhomogeneous differential equation of 2nd order

Comprehension questions

What are fins and what are they used for?

Which heat flow are considered in the derivation of the fin differential equation?

What is the temperature profile in a fin (from physical consideration)?

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