With a Finned-Hat to Lower Head's Surface Temperature
Let the Cool Head Prevail

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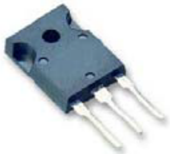
Could one design a finned-hat to let cool head prevail?

Introduction

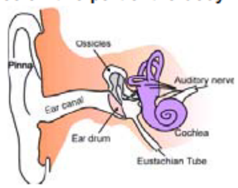
- There is some reason to believe that the dinosaur stegosaurus (shown below) had bony plates on their backs that were presumed to cool down the blood like a car radiator.

- The brain could be looked at as an electrical circuit. Electrical circuits have a failure rate dependent upon temperature. If there is a 10ºC reduction, the failure rate is halved.



- Ear size has also been speculated to be related to the intelligence quotient (IQ) of an individual. The ear is the greatest supplier of sensor energy which is turn is the greatest changer of one's electrical activity of the brain.

- Studies were done on preschool children's tympanic membrane (eardrum) in which affected the child's behavior or emotion with different temperatures on this part of the body.



Method

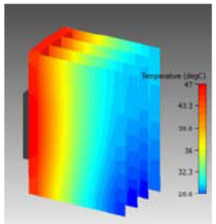
- Newton's law of cooling yields the rate of heat transfer equation from finned surfaces:

$$\dot{Q}_{conv} = hA_s(T_s - T_\infty)$$

h = convection heat transfer coefficient
A_s = surface area
T_s = temperature of the surface
T_∞ = temperature to the surrounding area

- There are two ways to increase the rate of heat transfer: (1) increase the convection heat transfer coefficient and (2) increase the surface area. Fins enhance heat transfer by exposing a larger surface area to convection and radiation or an alternative (3) attach extended surfaces (fins) to the surface using high conductive materials such as aluminum.

- A fin of constant cross sectional area that is attached to a surface can transfer heat from the surface of the fin by conduction and the surrounding medium by convection. This creates a gradual decrease in temperature from the fin base to the fin tip.



- This temperature change along the fin is taken into account by fin efficiency.

$$\eta_{fin} = \frac{\dot{Q}_{fin}}{\dot{Q}_{fin,max}} = \frac{\text{actual heat transfer from the fin}}{\text{ideal heat transfer from the fin}}$$

•Also, there is a factor of fin effectiveness which is the relation between the fin and the no fin case:

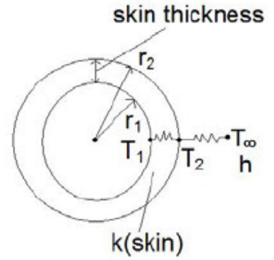
$$\varepsilon_{fin} = \frac{\dot{Q}_{fin}}{\dot{Q}_{no\,fin}} = \frac{A_{fin}}{A_b}\eta_{fin}$$

Results

- Design of a finned hat

Assumptions:
(1)Fin efficiency (η_{fin}) = 100%
(2)Skin thickness = 0.1 cm

Approximations:
(1)Fin effectiveness = 1 (no fin) or 3 (with fin)
(2)Radius of head = 9 cm



Values for experiment:
(1)k(skin) = 0.37 W/m*K
(2)T_1 = 37ºC
(3)h = 6 W/m²*K * ε_{fin}
(4) T_2 = ? (temperature of forehead)
Thermal resistance:

$$R_{sphere} = \frac{r_1 - r_2}{4\pi r_1 r_2 k} \qquad R_{conv} = \frac{1}{hA}$$

$$\dot{Q} = \frac{T_1 - T_\infty}{R_{total}} = \frac{T_1 - T_\infty}{R_{sphere} + R_{conv}} = \frac{T_2 - T_\infty}{R_{conv}}$$

First example:
T_∞ = 21ºC, ε_{fin} = 1 (no fin) and 3 (with fin)

$$\dot{Q} = 9.62\,W\,(\varepsilon_{fin} = 1) \qquad \dot{Q} = 27.93\,W\,(\varepsilon_{fin} = 3)$$

$$T_2 = 36.7℃ \qquad T_2 = 36.25℃$$

$$\Delta T_2 = 0.45\ ℃$$

Second example:
T_∞ = 27ºC, ε_{fin} = 1 (no fin) and 3 (with fin)

$$\dot{Q} = 6.01\,W\,(\varepsilon_{fin} = 1) \qquad \dot{Q} = 17.456\,W\,(\varepsilon_{fin} = 3)$$

$$T_2 = 36.84℃ \qquad T_2 = 36.53℃$$

$$\Delta T_2 = 0.31\ ℃$$

Discussion

- The value of T_2 is decreased by 0.3 0.5 ºC when the fin is used. This is due to the fact that since :

$$\dot{Q} = \varepsilon_{fin} hA_s \Delta T$$

So, with the increase of the fin effectiveness, the rate of heat transfer is tripled which affected the T_2 temperature to decrease. Such decrease could be physiologically significant.

Next Steps

1. Build a prototype of a finned hat using aluminum material instead of paper model

2. Measure the skin temperature reduction with hat and without the hat and then compare to calculations.
3. Using a brain scan (fn MRI) to establish a correlation with the effect of the skin temperature reduction to blood flow and brain function.

References

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