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Effects of Fat Thickness on Heat Transfer

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Abstract. In order to study the influence of fat layer and environment temperature on the amount of energy lost. We take the natural convection and thermal radiation into account. At this point, the heat transfer of skin surface natural convection and radiation is equal to the sum of internal heat conduction. First we assume the temperature of skin surface and we use REFORP to call physical parameters under different temperature. Calculating the human body skin surface heat transfer coefficient. Then calculate the difference of two kinds of heat transmission, if the difference is less than 0.1W, we think the temperature is the temperature of skin surface at that environment temperature. Thus we can calculate the heat transfer at that environment temperature.

Introduction

As is known to us all, the body heat of the skin is relevant to fat layer thickness and environment temperature [1, 2]. So, what are their specific relationship? We only know the summer is hotter than winter and the fat person is not afraid of the cold. In this text, we will explore the specific relationship between them. And we hope we can figure out the effects of fat thickness on heat transfer.

Design

In the text, we simplify the body into five cylinders. Respectively, on behalf of the human body trunk, two arms and two legs which is shown in Figure 1 [3]. At the same time, each cylinder is simplified to three levels. Respectively, for the internal tissue layer, fat layer and skin surface. In addition, because the human body head fat content less, so in the heat transfer process does not consider the head heat [4].

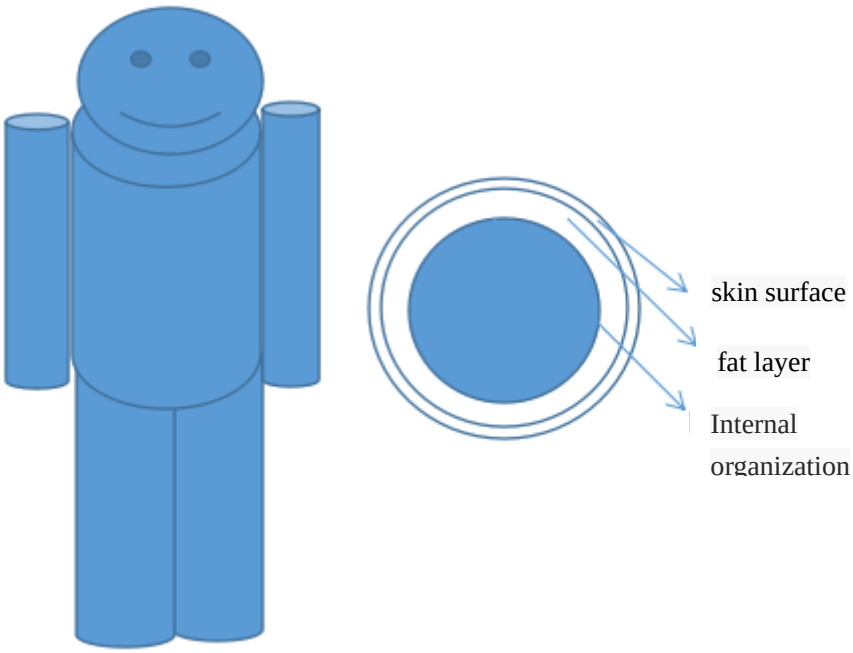

Fig.1. The body geometry simplified diagram

The temperature of the inner layer is r_1, the temperature is t_1, the radius of the fat layer is r_2, the

temperature is t_2, the skin surface radius is r_3, the temperature is t_3, the thickness of the fat layer is δ_2, and the ambient temperature is t_∞, which is shown in Figure 2.

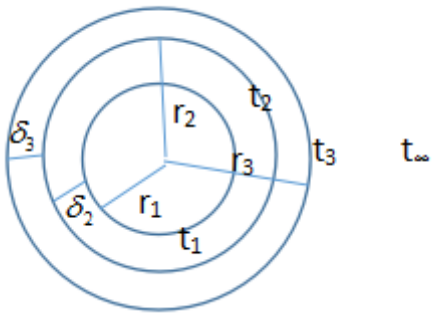

Fig.2. Some physical quantities

(1)The body is the steady state. (2)Don't consider the effect of human clothing for heat dissipation. (3)Each part of the fat layer thickness is the same. (3) The body temperature of constant temperature. (4)There is no inner heat source.

Specific Calculation

By the thermal conductivity equation, the human body skin internal thermal conductivity:

$$\varphi_1 = \frac{t_1 - t_3}{\frac{1}{2\pi\lambda_2 H}\ln\frac{r_2}{r_1} + \frac{1}{2\pi\lambda_3 H}\ln\frac{r_3}{r_2}}$$

Human body heat dissipation, including natural convection heat transfer and radiation heat transfer in two parts, by the Newton cooling formula:

$$\phi_2' = h_3 A_3 (t_3 - t_\infty)$$

So the body skin heat:

$$\phi_2 = \phi_2' + \phi_2'' = \xi_3 A_3 \sigma (T_3^4 - T_\infty^4) + h_3 A_3 (t_3 - t_\infty)$$

Therefore, the main calculation of this problem focused on the calculation of "*h*". We choose the characteristic relation of the Nusselt number:

$$Nu = C(Gr\,\mathrm{Pr})^n$$

After estimation, $1.43\times10^4 < Gr < 3\times10^9$, so C=0.59, n=0.25.

The two characteristic numbers involved in the trial are the Grahovian number G_r, the Prandtl P_r, where:

$$Gr = \frac{g\alpha_v (t_3 - t_\infty) H^3}{v^3}$$

When you find *Nu*, it can be solved:

$$h_3 = \frac{\lambda_m}{H} Nu$$

Equation of the physical parameters involved in the use of REFORP query, and then use MATLAB programming to solve the different ambient temperature, the fat layer thickness from 0.5cm-8cm change, the different surface temperature.

Calculation Results

Take the body torso as an example. When the outside temperature is equal to -10 ℃, 0 ℃, 10 ℃, 20 ℃, 30 ℃, the thickness of the fat layer corresponding to the surface temperature as shown in the Table 1.

Table 1 Fat layer thickness corresponding to the surface temperature

Fat layer δ/m	0.005	0.01	0.015	0.02	0.025	0.03
Body surface /°C	27.5	22.4	18.6	15.5	13	11
Fat layer δ/m	0.035	0.04	0.045	0.05	0.055	0.06
Body surface/°C	9.2	7.7	6.4	5.3	4.3	3.4
Fat layer δ/m	0.065	0.07	0.075	0.08		
Body surface/°C	2.6	1.9	1.2	0.6		

Further calculation, you can get the body heat dissipation [5]. Similarly, we can calculate the five cylindrical heat dissipation, add, you can get the total body heat dissipation. Using excel to draw in different ambient temperature, the body heat with the thickness of the fat layer changes in the curve shown as Figure 3.

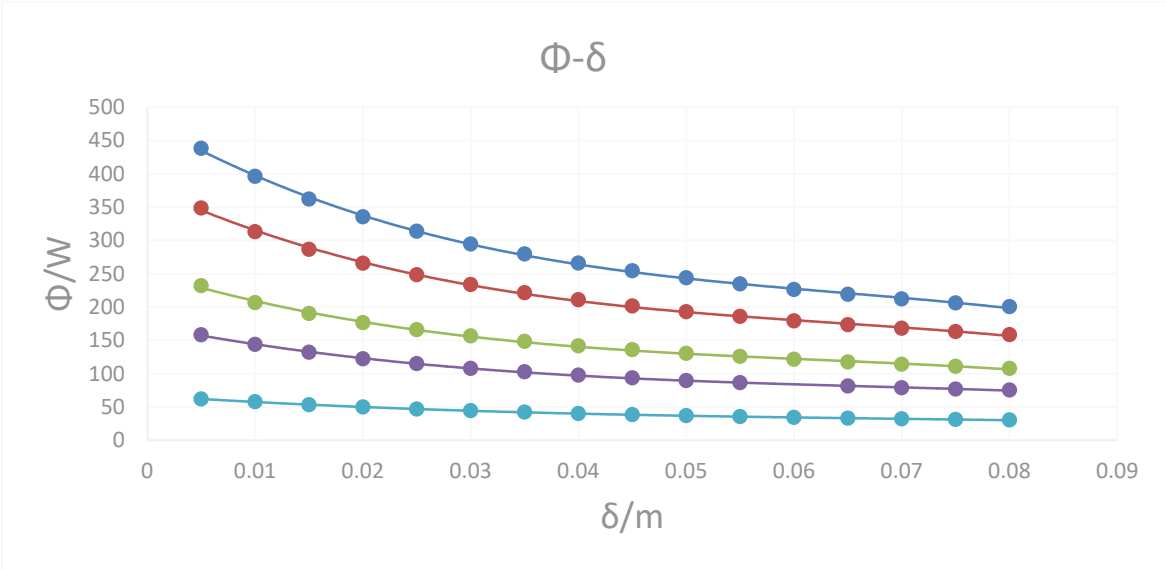

Fig.3. Consider the natural convection and heat radiation when the body heat with the thickness of the fat layer curve

It can be seen from the figure, the overall trend is still with the fat layer thickness increases, the body gradually reduce the amount of heat, and reduce the rate of heat dissipation gradually reduced. At the same time, in the same thickness of the fat layer conditions, the lower the ambient temperature, the body more heat [6].

Summary

For a particular external temperature, we found that the body heat dissipation decreases as the thickness of the fat layer increases, especially when the fat layer thickness changes between 0.005 and 0.04, the curve changes more rapidly, and when the fat layer thickness of 0.04 To 0.08 between the changes, the curve is relatively flat, since we can get the more fat body, because of its fat layer thickness was significantly larger than the body of the thinner, so its less heat in the same external temperature, This is also in line with our real life: winter fat to freeze a little, that fat layer can play a very good insulation effect.

For different external temperatures, we find that for the same fat layer thickness, the lower the ambient temperature, the greater the amount of heat, which is also very much in line with our real life: winter people are more likely to feel hungry, need to consume more energy To maintain its normal life activities, which is why people in the winter appetite is greater than the reasons for the summer.

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