A Water Saving Bathtub Based on Time and Space

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Abstract. Ascribe to global energy crisis and civil conscious of energy conservation as well as strengthened environment protection, as one of the largest way of using water in life, bathing is getting more and more attention. We establish a two dimensional model to consider both the time and space. And considering the impact of body temperature. We build a model Based on some assumptions, applying the fluent software to the conclusion that the temperature of the water in the bathtub changes with time, space and body temperature.

1. Introduction

With the development of science and technology, people's requirement for the comfort has proposed, while the products' feature of energy-efficient has appeared in public view. Raphael firstly put forward the heat balance equation with hydrodynamic basis, which has influenced widely later. [3] However it was calculated by hands and the generality was poor. Stefan brought up a model by the method of energy. [4] The water research centre of the university in Western Australia proposed a more perfect model with hierarchical format DYRESM (Dynamic Reservoir Simulation Model) in 1978. [5] And Edinger exploited the earliest three-dimensional 2-d water temperature model in 1975. We have never stopped on exploring the water temperature mathematical model, and the results have also gradually from ideal to actual.

2. The Effect of Time and Space on temperature

We assume that,I) The hot water are spread out evenly on the water in the tub after feeding out,II) Ignore the heat loss around the bathtub and simplify the problem to one dimensional temperature field,III) The volume of the tub is determined.

We define a function describes the effect of time and space on temperature as T (Z,t)According to the original formula.

$$\lambda \frac{\partial^2 T}{\partial Z^2} = \frac{\partial T}{\partial t} \rho C_p$$ [6]

The boundary conditions are:
$$\begin{cases} T(Z,0) = T(1) \\ \dfrac{\partial T(Z,t)}{\partial Z}\Big|_{z=0} = Q(2) \\ \lambda \dfrac{\partial T(Z,T)}{\partial Z}\Big|_{Z=H} = h(T_s - T)(3) \end{cases}$$

(1)The initial temperature in the model we discussed is T.
(2)Heat transferred through the bottom surface.
(3)Heat transferred through the surface.
After solving the formula, and some of calculating, we get the final result.

$$\begin{cases} T_i^0 = T_{i+1}^0 \\ T_1^{k+1} = T_2^{k+1} \\ T_N^{k+1} = \dfrac{1}{\dfrac{h\Delta Z}{\lambda}+1}(T_{N-1}^{k+1} + \dfrac{h\Delta Z}{Z} T_s) \\ T_i^{k+1} = \dfrac{\left(a+bT_i^k\right)\Delta t}{\rho C_p \left(\Delta Z\right)^2}\left(T_{i-1}^k - 2T_i^k + T_{i+1}^k\right) + T_i^k + \dfrac{b\Delta t}{4\rho C_p \left(\Delta Z\right)^2}\left(T_{i+1}^k - T_{i-1}^k\right)^2 \end{cases}$$

3. The effect of the person on temperature

When it comes to the people, there are two positions.

1) The person doesn't move.
2) The person moves.

In this article, we only consider about the first position.

Extra assumptions

1) The bathtub is a cuboid.
2) The person's temperature has never changed. [7]
3) The whole points on the bathtub bottom have the same temperature.
4) Water injection point in the center of the bathtub.
5) Assume the person as two cuboids.

We establish a spatial coordinate system to describe the situation that a person in the bathtub. According to the relationship between temperature and distance, we can get a formula. Because the points on the same floor and the points on the different floor make different effects on somewhere, we determine (k_1, k_2, k_3) to describe the influence of (X, Y, Z) (Figure 1 and Table 1).

$$T(x,y,z)=\frac{\sum_{n}^{i=1}\frac{T_i}{k_1(x-x_i)^2+k_2(y-y_i)^2+k_3(z-z_i)^2}}{\sum_{n}^{i=1}\frac{1}{k_1(x-x_i)^2+k_2(y-y_i)^2+k_3(z-z_i)^2}}$$

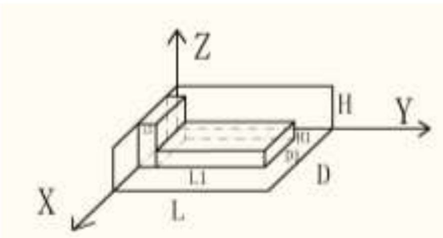

Figure 1. Space rectangular coordinate system when the person doesn't move.

Table 1. Parameter estimates

m	$0 \le m \le 1$	k_2	**0.23**
T_d	37 $°C$	T_m	38 $°C$
V	0.39 m^3	C_p	4200 $J/(k_g \cdot °C)$
L	1.3m	f_w	1337 $J/(m^2 \cdot °C)$
D	0.5m	T_s	40 $°C$
H	0.6m	T_c	35 $°C$
ρ	1000 k_g/m^3	q_t	$1.04\times10^{-3}\ m^3/s$
k_1	**0.23**	k_3	**0.4**

From the method, we are supposed to consider the energy equation. We define the highest temperature of the bathtub bottom as T_d, the temperature of the bathtub wall as T_b, and the temperature of the bathtub bottom as T'. Then,

$$\rho C_p V(\frac{T_s+T_d}{2}-T_c)=\rho q_v C_p(T_s-T_b)$$

That is

$$q_v = V\frac{(\frac{T_s+T_d}{2}-T_c)}{T_s-T_b}$$

In this part, we take $\frac{T_s+T'}{2}$ as the average temperature of the water in the tub, and we have $\frac{T_d+T_c}{2}$ take place of T'.

That's

$$q_v = \frac{3(T_s-T_d)-6T_c}{2T_s-T_d-T_c}V$$

4. Result and Conclusion

In order to study the distribution of temperature field more comprehensive, we can get the result as shown in Figure 2, Figure 3 and Figure 4.

When the temperature of the bathtub bottom is 35 degrees Celsius, we can get three temperature distribution maps in three different water layers.

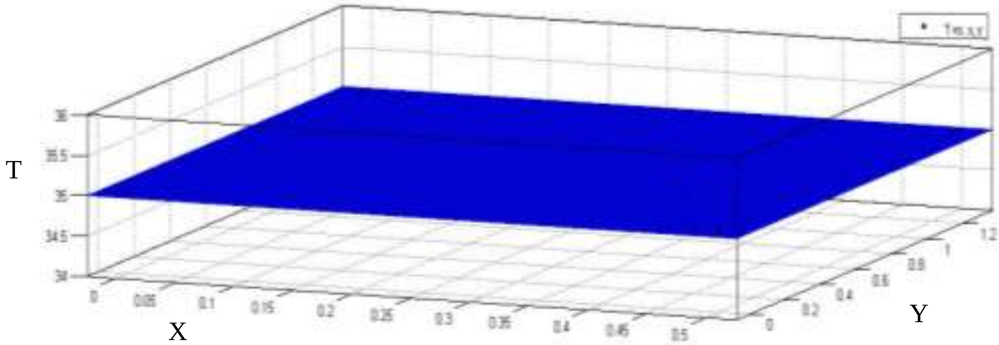

Figure 2. The temperature distribution layer when Z=0

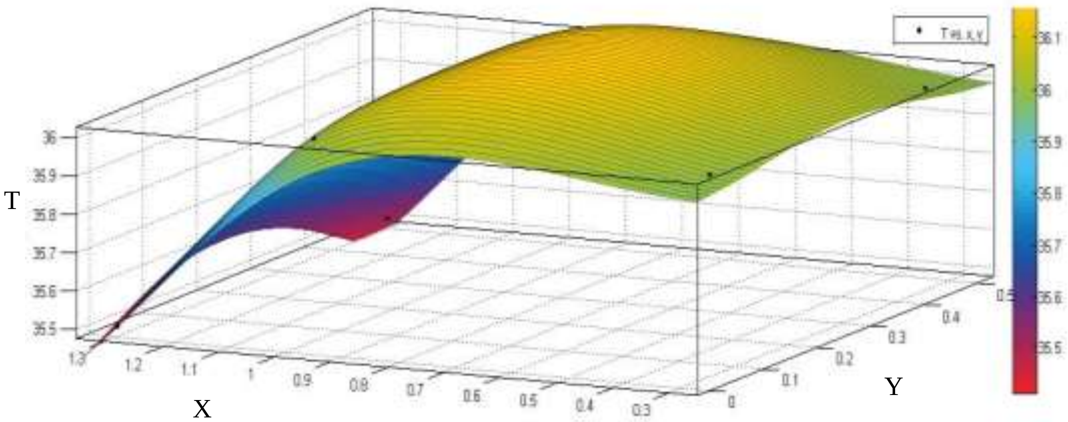

Figure 3. The temperature distribution layer when Z=0.2

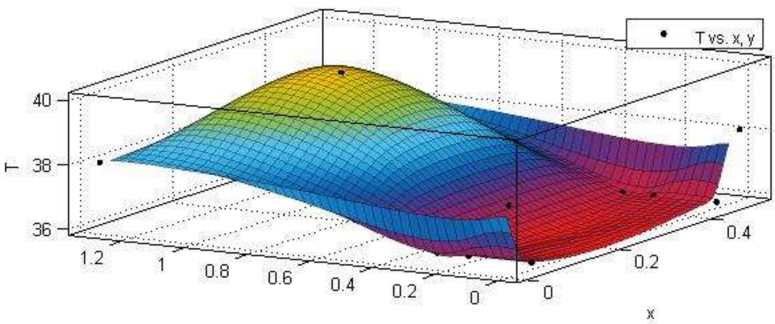

Figure 4. The temperature distribution map of water layer when Z=0.6m

References

[1] The first bathtub in the world, http://zhidao. baidu.com/question /584353840294877405. html? Fr = iks&word=%D4%A1%B8%D7%B5%C4%B7%A2%D5%B9%CA%B7&ie=gbk

[2] China sanitary ware network, The development of the bathtub is from scratch to popular, update December, 2013.

[3] Raphael J M. Prediction of Temperature in Rivers and Reservoirs[J], ASCE Journal of the Power Division, 1962, 88(2); 157-181.

[4] Stefan H G, Ford D E. Temperature dynamics lakes [J], Journal of the Hydraulics Division. 1975, 101(1): 97-114.

[5]Imberger J,Loh I,Hebbert B,et al.Dynamics of reservoir of medium size[J].Journal of theHydraul ics Division,1978,104(5):725-743.

[6] YANG Neng-biao, Non-steady State Numerical Solution about One-dimension Heat Transmitiom [J],Journal of Qinghai Normal University(Natural Science Edition),2006,04: 24-26.

[7] Yumingsun,Experimental study of human skin temperature under neutral conditions[D],Dalian University of Technology,2009.