The Best Injection Method to Save Water and Heat

Xi Yanping[1]

[1]School of Electrical and Electric Engineering, North China Electric Power University, Beijing, 102206, China

Keywords: Bubble Bath, Periodical Change, Ratio of Injection Time and Non-Injection Time

Abstract. Nowadays, saving water and saving energy saving has become a trend of lifestyle. Therefore, it is quite necessary and practical to find an optimal injection method to save heat and water, which can be widely used in many various situations, such 0000as having a bubble bath, keeping tropical fish and so on.

Here, we take the bubble bath as the example to study. And then, the approach is extended to other situations.

In our study,periodical change of discontinuous water supply is revealed visually in water supplement model. To begin with, it is prerequisite to consult the highest water temperature that the bather can bear.On account of discontinuous water supply, we study the periodical change of the average water temperature. As the proportion of injection period in every cycle increases, discontinuous water supply is transformed into continuous water supply. To maintain the temperature in the set range,we change the flux of inlet water and study the correlation of flux and the injection time. We get the maximum water-saving effect when the ratio of injection time and non-injection time is 2. Also, in this situation, the temperature of bathtub is stabilized in a relative range.

Similarly, in other cases, you can use the same method to get the best way of supplying water, which means our method is realistic and practical.

Introduction

In now shortage of resources days,the study to find an optimal injection method to save heat and water is an instant and reality task.

In this paper, we study the optimal water supply method of bubble bath。To minimize the amount of water supply while keeping the temperature steady, we consider the law of conservation of energy and conclude that less water used requires higher temperature. But it's also noticeable that we should avoid scald when generating the strategy. It's necessary to analyze the influence of the portion of the injection time on the total water usage amount.

Finding the Best Way of Supplying Water

In this part, we discuss which one is more water-efficient under the same circumstance, between continuous water supply and discontinuous water supply. In addition, at the limit situation, discontinuous water supply can be transferred into continuous water supply. Now, we'll start from discontinuous water supply and get the best water supply strategy.

© 2016. The authors - Published by Atlantis Press

Obtaining the Highest Temperature. The heat of water supply is proportional to thesupplywater temperature and flow rate. In order to save water as much as possible, it is necessary to improve the water supply temperature as possible as one could. But the contradiction is, the water temperature getting too high can lead to the local temperature being too high, which may cause burns. Therefore, it is necessary to analyze the highest water temperature that the bather can bear.

The hot wateraround the faucet can be treated as internal heat source. According to heat transfer theory, the temperature of the internal heat source is distributed along the quadratic curve.Thus we have

$$t = -ax^2 + c \quad (2.1)$$

Of which a and c are constants and are associated with the water temperature of section A and B.

According to the aboveequation (2.1), the highest water temperature t_{in} can be obtained. That is to say the temperature of the inlet water can provide is below t_{in}.

Analysis on Time Variation Law of Water Temperature. During discontinuous water supply, the water temperature can rise to the highest temperature $t_{\max}$ ($t_{\max} < t_{\text{in}}$). When the temperature gradually decreased to the lowest temperature $t_{\min}$ after water supply stops, thus a periodic cycleis formed. Based the discussion of Model One, we can know that most of the heat loss lies in convective heat transfer, so the temperature drop rate is proportional to the temperature difference between water and air.

$$\frac{dt}{d\tau} = -k_1(t - t_\infty) \quad (2.2)$$

Where k_1 is constant,and it is in connection with water-airinterface heat transfer coefficient and the heat loss caused by heat conduction.

Similarly, if adding water to the bathtub continuously, the temperature rise rate is proportional to the temperature differences between bath water and the added hot water, as well as the water added per unit time q_m:

Similarly, if adding water to the bathtub continuously, the temperature rise rate is proportional to the temperature differences between bath water and the added hot water, as well as the water added per unit time q_m:

$$\frac{dt}{d\tau} = k_2 q_m (t_{in} - t) \quad (2.3)$$

Where k_2 is constant and is related to the heat exchange efficiency of water.

Assume the water temperature of the bathtub begins at the highest temperature t_1 . After a period of time the temperature drops to t_2 , from equation(2.1) we can calculate thechange oftemperature over time, which is

$$t = t_\infty + (t_1 - t_\infty)e^{-k_1\tau} \quad (2.4)$$

Similarly, assume the water temperature begins at t_2 , then it rises to t_1, when being heated. Thus we have

$$t = t_{in} + (t_2 - t_{in})e^{-k_2 q_m \tau} \quad (2.5)$$

From equation (2.4) and equation(2.5), we can calculate the time τ_1, τ_2 which required for each rise and fall within $[t_1, t_2]$ .Thus in the whole period, the ratio of the water supply time accounting for the total time is

$$\lambda = \frac{\tau_1}{\tau_1 + \tau_2} \quad (2.6)$$

Combined the temperature change law of Formula (2.4) with Formula (2.5), we obtain the following figure

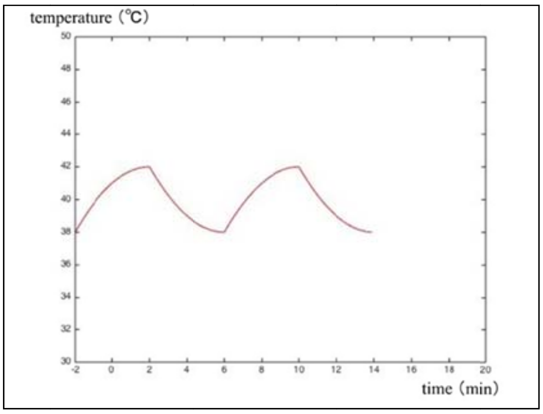

Figure 2.1

As can be seen from the picture above, in discontinuous water supply, the water temperature fluctuates periodically in the range we set.

The Establishment of the Best Water-Saving Strategy. Change the ratio of cycle λ, and observe the change of temperature curve and water quantity in the same parameters settings.

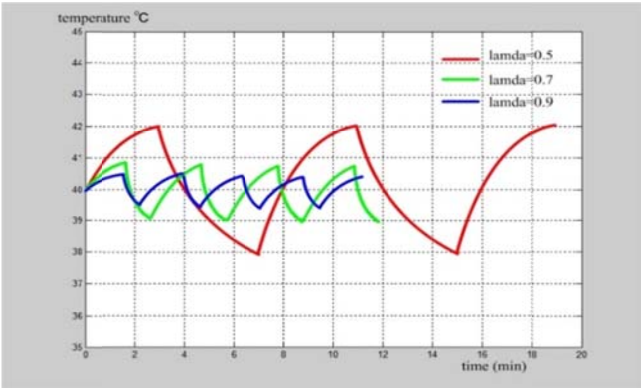

Figure 2.2

From the figure2.2we can discover the pattern: as λ increases, the water flux q_m decreases. When λ is in close to 1, discontinuous water supply is transformed into continuous water supply. At this time, the absorption and dissipation of heat in the bathtub is in a dynamic balance.

As for the best water saving strategy, we calculate the total amount of water supply:

$$q_{total} = q_m \cdot \lambda \quad (2.7)$$

When the total amount of water addition q_{total} is the smallest, we get the best water saving strategy.

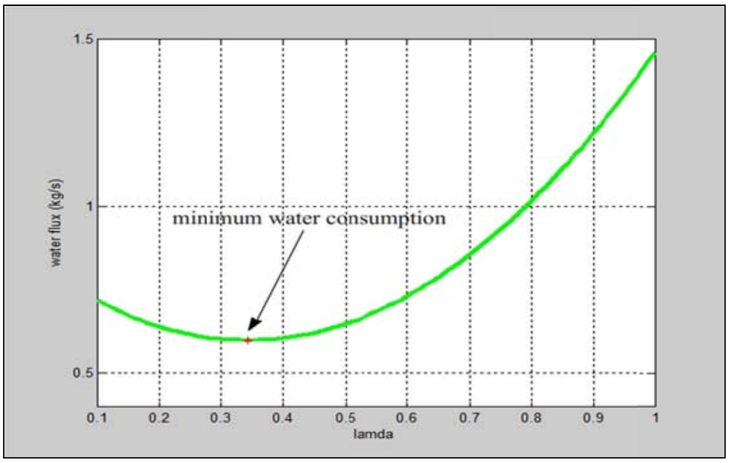

Figure 2.3

The Test of the water Supplement Model. Based on the study of Formula (2.1), andconsider the highest temperature acceptable at the same time,we can calculate the maximum inlet water temperature is $52.13°C$.

Through the optimizing function of MATLAB, we can calculate that the best water supply strategyis $\lambda = 0.3427$, namely the water injection rate taking up about 0.3427 of the total cycle of time,and the temperaturevaries from $38.74°C$ to $40.1°C$.

Conclusion

We obtain the optimal water saving effect under the following conditions: The ratio of water injection time and non-injection time is 1:2. Furthermore, we discover that the water temperature of discontinuous water supply changes periodically. In the limit case, discontinuous water supply can be converted to continuous water supply with small flow.

In other cases, we can apply the same method to obtain the best way of supplying water as long as changing different parameters and other conditions.We can see that our method is very practical.

Reference

[1] Shiming Yang, Wenquan Tao. Heat Transfer[M]. Fourth Edition, Beijing: Higher Education Press, 2006.

[2] Jialu Yan, Yongqing Wang. Engineering Thermodynamics[M]. Beijing: China Electric Power Press, 2007.

[3] Long Kong, Engineering Fluid Mechanics[M]. Fourth Edition, Beijing: China Electric Power Press, 2009.

[4] Shimin Mao. Discussion on the formula and application of heat dissipation of water.[J]. Journal of Hydraulic Engineering, 2004.

[5] Congzhi Zhou, Steven C.Chapra. Simulation of thermal structure and evaporation of Lake[J]. Chinese Journal of Environmental Science, 1994, 15:33~37.