Problem Chosen	2025 MCM/ICM Summary Sheet	Team Control Number
A		0000000

Enjoy a Cozy and Green Bath

Summary

Abstract part

Keywords: Keyword1, Keyword2, Keyword3, Keyword4

Contents

1 Introduction

1.1 Background

Background Part

1.2 Literature Review

1.3 Restatement of the Problem

Restatement Part

In order to solve those problems, we will proceed as follows:

- **Stating assumptions**. By stating our assumptions, we will narrow the focus of our approach towards the problems and provide some insight into bathtub water temperature issues.
- **Making notations**. We will give some notations which are important for us to clarify our models.
- **Presenting our model**. In order to investigate the problem deeper, we divide our model into two sub-models. One is a steady convection heat transfer sub-model in which hot water is added constantly. The other one is an unsteady convection heat transfer sub-model where hot water is added discontinuously.
- **Defining evaluation criteria and conparing sub-models**.We define two main critia to
  1) ...
  2) ...
  3) ...
  4) ...

2 Assumptions and Justification

To simplify the problem and make it convenient for us to simulate real-life conditions, we make the following basic assumptions, each of which is properly justified.

- **The bath water is incompressible Non-Newtonian fluid**. The incompressible Non-Newtonian fluid is the basis of Navier–Stokes equations which are introduced to simulate the flow of bath water.
- **We ignore radiative thermal exchange**. According to Stefan-Boltzmann's law, the radiative thermal exchange can be ignored when the temperature is low. Refer to industrial standard, the temperature in bathroom is lower than 100 °C, so it is reasonable for us to make this assumption.
- **The temperature of the adding hot water from the faucet is stable**. This hypothesis can be easily achieved in reality and will simplify our process of solving the problem.

3 Notations

Symbols	description	Unit
h	Convection heat transfer coefficient	W/(m$^2\cdot$ K)
k	Thermal conductivity	W/(m $\cdot$ K)
c_p	Specific heat	J/(kg $\cdot$ K)
Θ	Density	kg/m^2
δ	Thickness	m
t	Temperature	°C, K
τ	Time	s, min, h
q_m	Mass flow	kg/s
Φ	Heat transfer power	W
T	A period of time	s, min, h
V	Volume	m^3, L
M, m	Mass	kg
A	Aera	m^2
a, b, c	The size of a bathtub	m^3

where we define the main parameters while specific value of those parameters will be given later.

4 Model Overview

After deriving the value of parameters, we deduce formulas to derive results and simulate the change of temperature field via CFD, as described by Anderson et al. (2006).

5 Sub-model I : Adding Water Continuously

Sub-model I

5.1 Model Establishment

Model Establishment

5.1.1 Control Equations and Boundary Conditions

We assume the hot water in the bathtub as a cube. Then we put it into a rectangular coordinate system. The length, width, and height of it is $a,\ b$ and c.

In the basis of this, we introduce the following equations:

- **Continuity equation:**

Figure 1: GoogleNet

$$\frac{\partial u}{\partial x}+\frac{\partial v}{\partial y}+\frac{\partial w}{\partial z}=0 \tag{1}$$

where the first component is the change of fluid mass along the X-ray. The second component is the change of fluid mass along the Y-ray. And the third component is the change of fluid mass along the Z-ray. The sum of the change in mass along those three directions is zero.

- **Moment differential equation (N-S equations):**

$$\begin{cases}\rho\Big(u\dfrac{\partial u}{\partial x}+v\dfrac{\partial u}{\partial y}+w\dfrac{\partial u}{\partial z}\Big)=-\dfrac{\partial p}{\partial x}+\eta\Big(\dfrac{\partial^2 u}{\partial x^2}+\dfrac{\partial^2 u}{\partial y^2}+\dfrac{\partial^2 u}{\partial z^2}\Big)\\ \rho\Big(u\dfrac{\partial v}{\partial x}+v\dfrac{\partial v}{\partial y}+w\dfrac{\partial v}{\partial z}\Big)=-\dfrac{\partial p}{\partial y}+\eta\Big(\dfrac{\partial^2 v}{\partial x^2}+\dfrac{\partial^2 v}{\partial y^2}+\dfrac{\partial^2 v}{\partial z^2}\Big)\\ \rho\Big(u\dfrac{\partial w}{\partial x}+v\dfrac{\partial w}{\partial y}+w\dfrac{\partial w}{\partial z}\Big)=-g-\dfrac{\partial p}{\partial z}+\eta\Big(\dfrac{\partial^2 w}{\partial x^2}+\dfrac{\partial^2 w}{\partial y^2}+\dfrac{\partial^2 w}{\partial z^2}\Big)\end{cases} \tag{2}$$

- **Energy differential equation:**

$$\rho c_p\Big(u\frac{\partial t}{\partial x}+v\frac{\partial t}{\partial y}+w\frac{\partial t}{\partial z}\Big)=\lambda\Big(\frac{\partial^2 t}{\partial x^2}+\frac{\partial^2 t}{\partial y^2}+\frac{\partial^2 t}{\partial z^2}\Big) \tag{3}$$

where the left three components are convection terms while the right three components are conduction terms.

By Equation (3), we have ......

......

On the right surface in Fig. **??**, the water also transfers heat firstly with bathtub inner surfaces and then the heat comes into air. The boundary condition here is ......

5.1.2 Definition of the Mean Temperature

......

5.1.3 Determination of Heat Transfer Capacity

......

6 Sub-model II: Adding Water Discontinuously

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6.1 Heating Model

6.1.1 Control Equations and Boundary Conditions

6.1.2 Determination of Inflow Time and Amount

6.2 Standby Model

6.3 Results

We first give the value of parameters based on others' studies. Then we get the calculation results and simulating results via those data.

6.3.1 Determination of Parameters

.....

6.3.2 Calculating Results

Putting the above value of parameters into the equations we derived before, we can get the some data as follows:

Table 1: The calculating results

Variables	Values	Unit
A_1	1.05	m^2
A_2	2.24	m^2
Φ_1	189.00	W
Φ_2	43.47	W
Φ	232.47	W
q_m	0.014	g/s

From Table 1, ...

......

7 Correction and Contrast of Sub-Models

......

7.1 Correction with Evaporation Heat Transfer

......

7.2 Contrast of Two Sub-Models

......

8 Model Analysis and Sensitivity Analysis

the shape and volume of the tub, the shape/volume/temperature/motions of the person, and the bubbles made from bubble bath additives, as discussed in (Smith, 2018; Brown, 2015).

8.1 The Influence of Different Bathtubs

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8.1.1 Different Volumes of Bathtubs

...

We assume the initial volume to be 280 L and change it by $\pm 5\%$, $\pm 8\%$, $\pm 12\%$ and $\pm 15\%$. With the aid of sub-models we established before, the variation of some parameters turns out to be as follows

Table 2: Variation of some parameters

V	A_1	A_2	T_2	q_{m1}	q_{m2}	Φ_q
-15.00%	-5.06%	-9.31%	-12.67%	-2.67%	-14.14%	-5.80%
-12.00%	-4.04%	-7.43%	-10.09%	-2.13%	-11.31%	-4.63%
-8.00%	-2.68%	-4.94%	-6.68%	-1.41%	-7.54%	-3.07%
-8.00%	-2.68%	-4.94%	-6.68%	-1.41%	-7.54%	-3.07%
-8.00%	-2.68%	-4.94%	-6.68%	-1.41%	-7.54%	-3.07%
-8.00%	-2.68%	-4.94%	-6.68%	-1.41%	-7.54%	-3.07%
-8.00%	-2.68%	-4.94%	-6.68%	-1.41%	-7.54%	-3.07%
-8.00%	-2.68%	-4.94%	-6.68%	-1.41%	-7.54%	-3.07%
-8.00%	-2.68%	-4.94%	-6.68%	-1.41%	-7.54%	-3.07%
-8.00%	-2.68%	-4.94%	-6.68%	-1.41%	-7.54%	-3.07%
-8.00%	-2.68%	-4.94%	-6.68%	-1.41%	-7.54%	-3.07%

9 Strength and Weakness

9.1 Strength

- ...

- ...
- ...
- ...

9.2 Weakness

- ...
- ...
- ...

10 Further Discussion

In addition, we make improvements for applying our model in real life, as suggested by the patent Wilson (2023).

- Different Distribution of Inflow Faucets

  In our before discussion, we assume there being just one entrance of inflow.

  From the simulating outcome, we find the temperature of bath water is hardly even. So we come up with the idea of adding more entrances.

  The simulation turns out to be as follows

  In conclusion, if we design more entrances, it will be easier to realize the goal to keep temperature even throughout the bathtub.

- Model Application

  Our before discussion is based on ideal assumptions. In reality, we have to make some corrections and improvement.

  1) Adding hot water continually with the mass flow of 0.16 kg/s. This way can ensure even mean temperature throughout the bathtub and waste less water.
  2) The manufacturers can design an intelligent control system to monitor the temperature so that users can get more enjoyable bath experience.
  3) We recommend users to add bubble additives to slow down the water being cooler and help cleanse. The additives with lower thermal conductivity are optimal.
  4) The study method of our establishing model can be applied in other area relative to convection heat transfer, such as air conditioners.

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Wilson, G. (2023). *Smart bath water temperature control system* (US Patent No. 1234567).

Enjoy Your Bath Time!

......

- Adding hot water consistently
- Using smaller bathtub if possible
- Decreasing motions during bath
- Using bubble bath additives
- Arranging more faucets of inflow

Sincerely yours,

Your friends

Appendices

Appendix A First appendix

appendix1 Here is simulation programme we used in our model as follow (Liu et al., 2002).

Input matlab source:

```
function [t,seat,aisle]=OI6Sim(n,target,seated)
pab=rand(1,n);
for i=1:n
    if pab(i)<0.4
       aisleTime(i)=0;
    else
        aisleTime(i)=trirnd(3.2,7.1,38.7);
    end
end
```

Appendix B Second appendix

some more text **Input C++ source:**

```
//===========================================================================
// Name        : Sudoku.cpp
// Author      : wzlf11
// Version     : a.0
// Copyright   : Your copyright notice
// Description : Sudoku in C++.
//===========================================================================

#include <iostream>
#include <cstdlib>
#include <ctime>

using namespace std;

int table[9][9];

int main() {

    for(int i = 0; i < 9; i++){
        table[0][i] = i + 1;
    }

    srand((unsigned int)time(NULL));

    shuffle((int *)&table[0], 9);

    while(!put_line(1))
    {
        shuffle((int *)&table[0], 9);
```

```
    }

    for(int x = 0; x < 9; x++){
        for(int y = 0; y < 9; y++){
            cout << table[x][y] << " ";
        }

        cout << endl;
    }

    return 0;
}
```

Report on Use of AI

1. OpenAI ChatGPT (Nov 5, 2023 version, ChatGPT-4,)

   Query1: <insert the exact wording you input into the AI tool>

   Output: <insert the complete output from the AI tool>

2. OpenAI Ernie (Nov 5, 2023 version, Ernie 4.0)

   Query1: <insert the exact wording of any subsequent input into the AI tool>

   Output: <insert the complete output from the second query>

3. Github CoPilot (Feb 3, 2024 version)

   Query1: <insert the exact wording you input into the AI tool>

   Output: <insert the complete output from the AI tool>

4. Google Bard (Feb 2, 2024 version)

   Query1: <insert the exact wording of your query>

   Output: <insert the complete output from the AI tool>

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