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Mathematical Modeling of Work Processes on a Dry Mixing Drum and Creation of Computer Models

Azizbek Sarmonov

Tashkent Institute of Design, Construction & Maintenance of Automotive Roads, Department "Repair and maintenance of road-building machinery and equipment", 20, aveA.Timur, 100060, Tashkent, Uzbekistan

ABSTRACT:This article discusses ways to model an asphalt concrete drying and mixing drum using a variety of methods. The Gain, Constant, Integrator, Sum and Scope blocks and temperature calculation methods in the Matlab® / Simulink® software complex were used to obtain the Euler method and numerical solutions. Boundary conditions are obtained from graphs formed when the thermal conductivity of the drying drum varies

KEY WORDS: asphalt, thermal conductivity, drying drum, temperature, boundary condition, heat flux, polynomial, numerical solution.

I.INTRODUCTION

The main part of the roads in use in the country are asphalt roads. The production of hot asphalt mix consumes a large amount of energy resources. The demand for energy resources around the world is growing day by day. The main reasons for the increase in demand are population growth, development of technology and automation of production processes.

II. RELATED WORK

Modeling begins with the description of initial data and ideas to express the conditions of a vital, mathematical, or physical problem, and they are described in the language of strictly defined mathematical or physical, etc. concepts. Then the purpose of solving the problem, i.e. the need to determine exactly what or what is the result of solving the problem, is indicated. The study of a problem begins with the construction of its mathematical model, i.e., its distinctive basic features are distinguished and a mathematical relationship is established between them. In other words, first the essence of the physical phenomenon under study, its signs, the indicators used are expressed in detail in words, and then the necessary mathematical equations are derived on the basis of the laws of physics.

III. LITERATURE SURVEY

These equations are called mathematical models of the physical process or event being studied [2]. The degree of conformity of the mathematical model to the real object is checked by experience in practice. Typically, a mathematical model does not fully capture the properties of the object under consideration. It is approximate because it is based on various assumptions and constraints, and of course the results based on it are approximate. Therefore, it is possible to evaluate the created model by experiment and to define it if necessary [1].

IV. METHODOLOGY

One of the main issues of modeling is the accuracy of the mathematical model, its correctness, the assessment of the reliability and stability of the results obtained.

- Model: may be a feature of the case studied separately; for example: map, modern model, toys, models,
- A mathematical model is a representation of a technological process or a physical phenomenon by mathematical formulas.
- Why mathematics: mathematics helps students, engineers, researchers to understand, write, analyze, find optimal solutions to technological processes, the function of physical phenomena and their management. Through mathematical modeling, engineers can evaluate the properties of a system.

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We first consider the analysis of the mathematical expression for the heat flux in the drying drum.

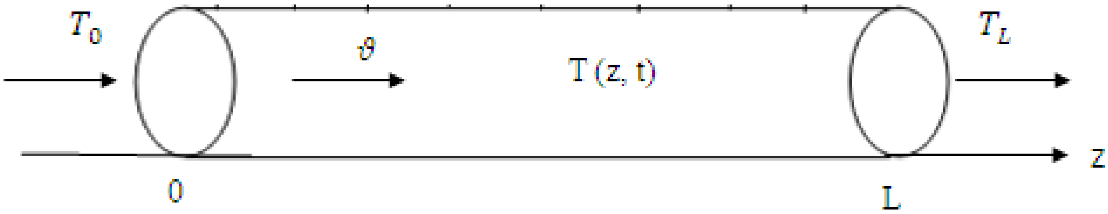

Figure 1.Schematic view of the heat flow in the drying drum.

In this case, a liquid (hot air or gas) flows from the drum with radius R at a constant velocity ((Fig. 1). The outside temperature does not change, much lower than the temperature inside the drum. It is known that this serves to cool the temperature of the liquid. Where T (z, t) is the change in temperature per unit time.

The function of the change in the amount of heat in the drum is expressed as: q (z, t), [j / m^2s]. The heat energy consumed outside is as follows:

$Q_S = k\Delta TS$, [j]; (1)

Here, k - is the thermal conductivity of the drum wall, [j / Km^2s], $\Delta T = T - T_{машки}$, the difference between internal and external temperature, [K]; S is the full surface area of the drum, [m^2]; Km^2s

Also, the equilibrium equation for the amount of heat is:

$$\frac{d}{dt}\int_{z}^{z+dz} T(z,t)\rho c\pi R^2\delta z = q(z,t)\pi R^2 - q(z+\delta z,t)\pi R^2 - k(T - T_{машки})2\pi R\delta z \quad (2)$$

If $\delta z \to 0$ tends to, then equation (2) is:

$$\rho c\frac{dT}{dt} = -\frac{dq}{dz} - \frac{2k}{R}(T - T_{машки}) \; ; \quad (3)$$

If we can express the amount of heat (q) mathematically by the temperature-dependent equation (T), that is, the heat dissipation is formed by convection and diffusion:

$$q = \upsilon\rho cT - \alpha\frac{dT}{dt} \; ; \quad (4)$$

Here, if we put expression (4) into expression (3), we obtain a special derivative differential equation of the change of heat flux along the z axis:

$$\rho c\frac{dT}{dt} + \upsilon\rho c\frac{dT}{dz} = \alpha\frac{d^2T}{dz^2} + \frac{2k}{R}(T - T_{машки}) \; ; (5)$$

where, R is the radius of the drum, [m]; - density of liquid inside the drum, [kg / m^3]; c is the heat capacity of the substance, [J / Kkg]; - fluid velocity, [m / s^2]; a - diffusion coefficient, [J / Kkg];

If Equation (5) is simplified so that diffusion does not occur in the air distribution in the drum, then it is in the form of the following equation:

$$\rho c\frac{dT}{dt} + \upsilon\rho c\frac{dT}{dz} + \frac{2k}{R}(T - T_{машки}) = 0 \quad (6)$$

In this work, we model a drying drum as an example of a differential equation with a specific product of the following parabolic type:

Under initial conditions, the liquid temperature in the drying drum and the outside ambient temperature will be the same. However, in a short time, the temperature inside the drum reaches its maximum value

$$\frac{\partial T}{\partial z} + \frac{1}{v}\frac{\partial T}{\partial t} + k(T - T_{cool}) = 0 \; , \quad 0 \le z \le L \; (7)$$

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Here equal to $k=\frac{2K}{\rho vcR}$

Using the differential equation (7) above, using the Euler method, we obtain the following expression (8):

$$\frac{\partial T_i}{\partial t}=-(\frac{v}{h}+k)T_i+\frac{vT_{i-1}}{h}+vkT_{cool} \qquad (8)$$

(8) We express the mathematical expression using the method of finite difference in the form divided into N parts, namely:

$$\left.\begin{aligned}
&i=1\quad \frac{\partial T_1}{\partial t}=-(\frac{v}{h}+k)T_1+\frac{vT_0}{h}+kT_{cool}\\
&i=2\quad \frac{\partial T_2}{\partial t}=-(\frac{v}{h}+k)T_2+\frac{vT_1}{h}+kT_{cool}\\
&i=3\quad \frac{\partial T_3}{\partial t}=-(\frac{v}{h}+k)T_3+\frac{vT_2}{h}+kT_{cool}\\
&\cdots\\
&\cdots\\
&i=N\quad \frac{\partial T_N}{\partial t}=-(\frac{v}{h}+k)T_N+\frac{vT_{N-1}}{h}+kT_{cool}
\end{aligned}\right\} \quad (9)$$

Expressing the system of equations (9) in the form of a matrix, we express it by the following notation, namely:

$$\frac{dT}{dt}=AT+b \qquad (10)$$

Here T is the matrix formed from the equation of temperature change per unit time,

$$A=\begin{bmatrix} X & 0 & 0 & \dots & 0 & 0\\ Y & X & & & & 0\\ & Y & X & & & 0\\ \dots & \dots & \dots & \dots & \dots & \dots\\ 0 & 0 & 0 & \dots & X & 0\\ 0 & 0 & 0 & \dots & Y & X\end{bmatrix},\quad b=\begin{bmatrix}\frac{v}{h}+vk\\ kT_{col}\\ kT_{col}\\ \dots\\ \dots\\ kT_{col}\end{bmatrix},\quad T(0)=kT_{col}\begin{bmatrix}1\\1\\1\\ ..\\ ..\\ 1\end{bmatrix}$$

ва $X=-(v/h+k)$,

$$Y=v/h \qquad (11)$$

To obtain numerical solutions of equation (10), we create a model of it using the blocks Gain, Constant, Integrator, Sum and Scope in the software complex Matlab® / Simulink® [5].

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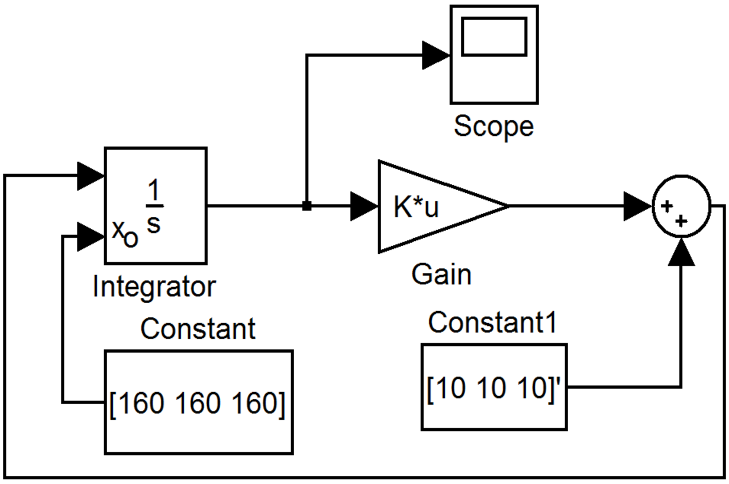

Figure 2. Model for calculating the temperature change of the drying drum in the software complex Matlab® / Simulink®.

Here K, A inside the Gain block represents the matrix and U represents the temperature.

Several cases can be studied using simulation models in determining the amount of energy consumption.

In this case, the initial and boundary conditions are given to the simulation model based on the real conditions and the result is obtained. The results obtained are analyzed. Another way to get calculation results is to use the MATLAB® software package [3, 4, 7].

We model a drying drum as an example of a special derivative differential equation of the existing parabolic type: where hot air (liquid or gas) flows at a constant th speed from a drum with radius R. The outside T_{out} temperature does not change, much lower than the temperature inside the drum. It is known that this serves to cool the hot air temperature.

V. EXPERIMENTAL RESULTS

The distribution equation for the two axes is given.

$$\rho C\frac{\partial T}{\partial t} - \nabla(k\nabla T) = Q + h(T_{\text{таш}} - T) \quad (12)$$

We use the pdetool section of the MATLAB® program to solve this type of equation.

Now we choose a section with a length of 10 m and a height of 2 m (parameters of the drying drum Asphalt plant brand Teltomat, common in Uzbekistan) and divide it into several elements using the method of finite elements, which is shown in Figure 3.

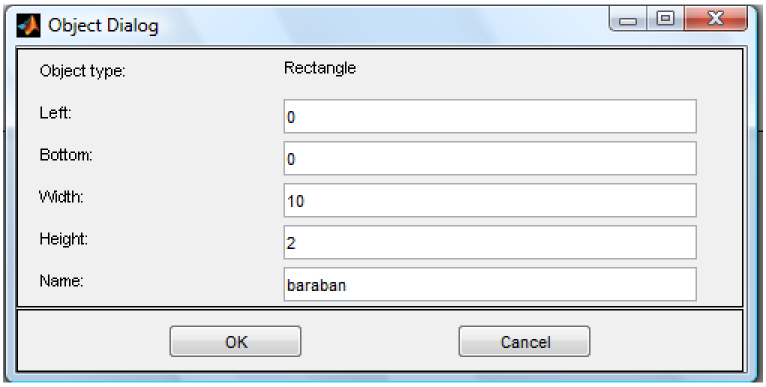

Figure 3. Dimensional view of the drying drum

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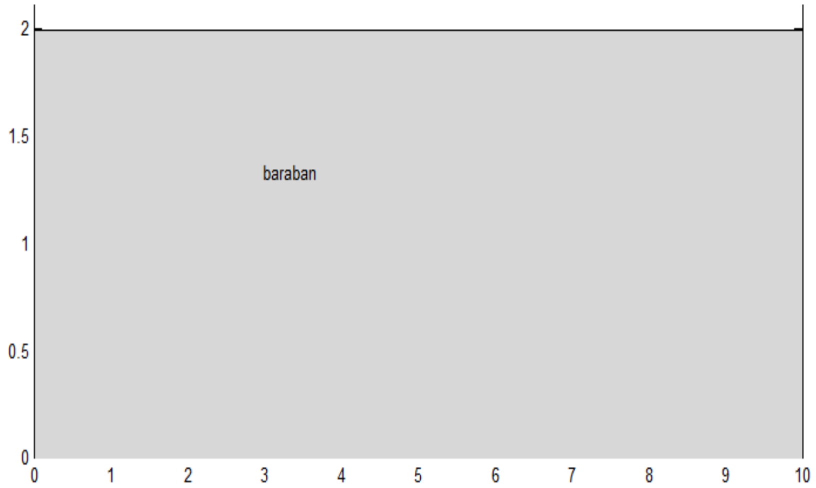

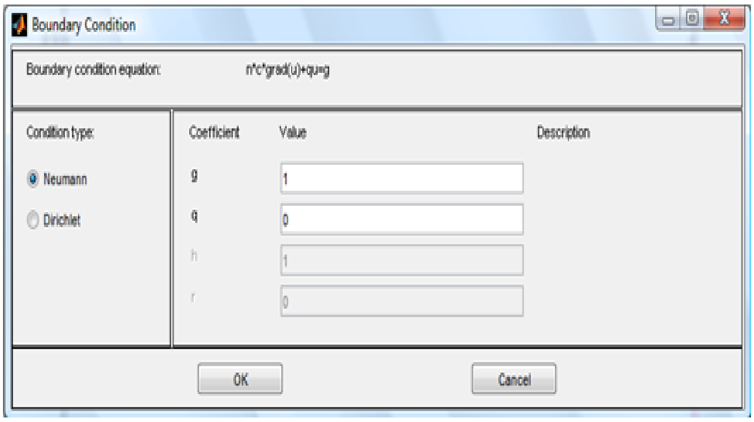

Figure 4. Two-dimensional view of the drying drum

Figure 5. Scheme of setting the boundary conditions for heat dissipation in the drying drum by the Neuman method
In this case, the step of boundary conditions according to the Neuman method is based on the following.

$x_i = \left(i - \frac{3}{2}\right)\Delta x$ (13)

Δx=1/(N-2) (14)

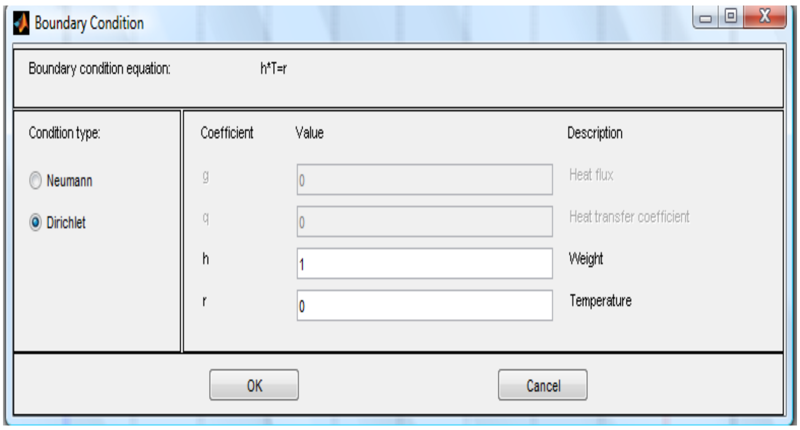

Figure 6. Scheme of setting the boundary conditions for heat dissipation in the drying drum by the Dirichlet method

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In this case, the step of boundary conditions according to the Dirichlet method is based on the following.

$x_i = i\Delta x$ (15)

Δx=1/(N-1) (16)

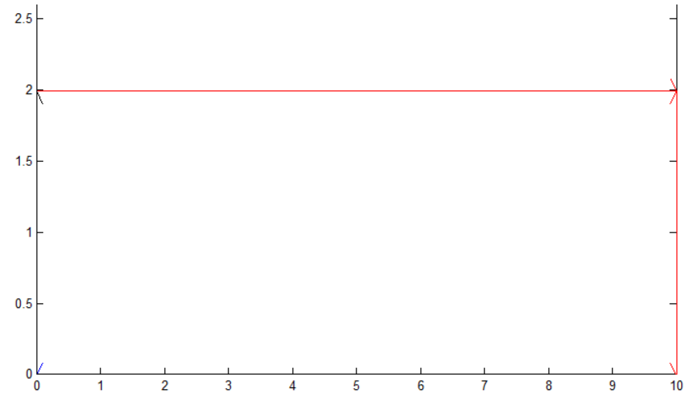

Figure 7. Scheme of setting the boundary conditions for heat dissipation in the drying drum by the Dirichlet method

-Left side according to the Neuman method
-Right side by Dirichlet method
-The right part is according to the Neuman method
-The upper part by the Dirichlet method

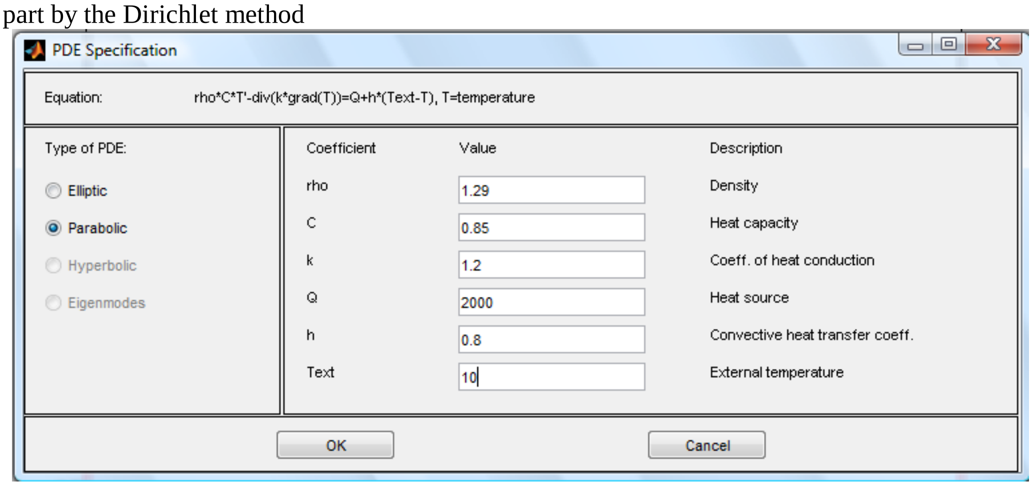

Figure 8. Scheme of input of factors affecting the drying drum.

Analysis of results from computer models.

We consider the heat flux in the drying mixing drum of the asphalt plant using the models created in the MATLAB® / Simulink® [5] complex when the thermal conductivity of the drum wall is 0.1, 0.15, 0.2.

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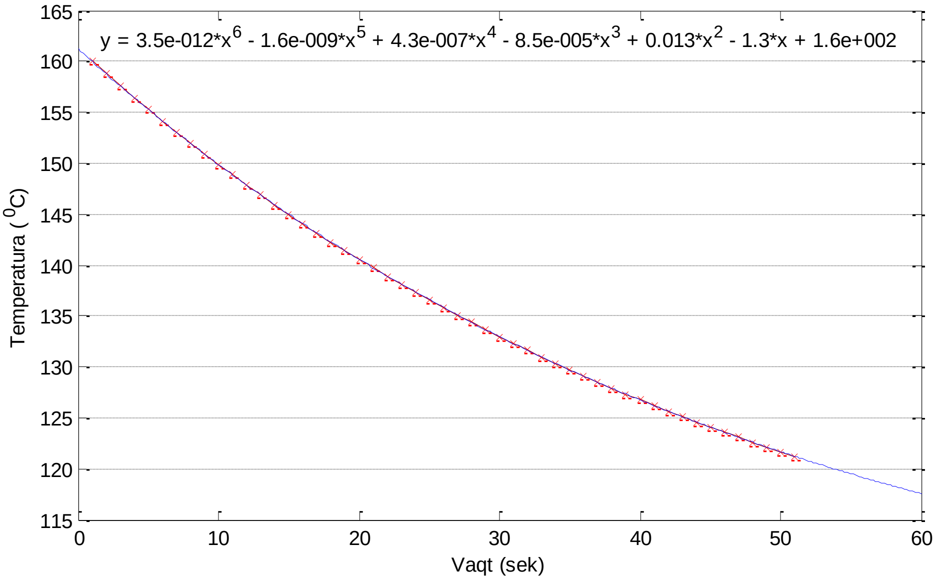

Figure 9. Temperature change when K = 0.1

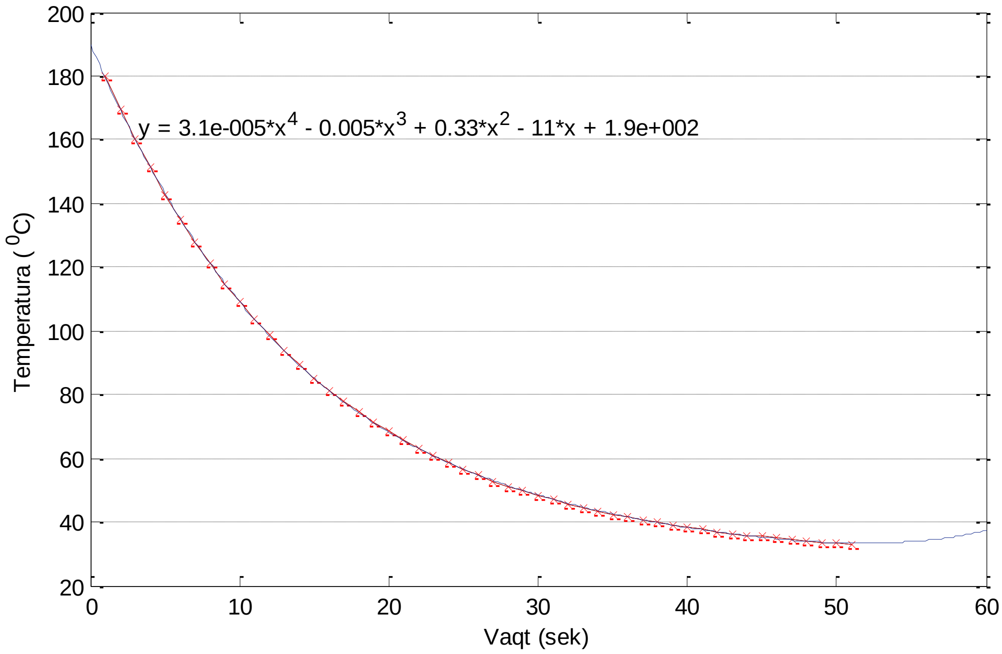

Figure 10. Temperature change when K = 0.15

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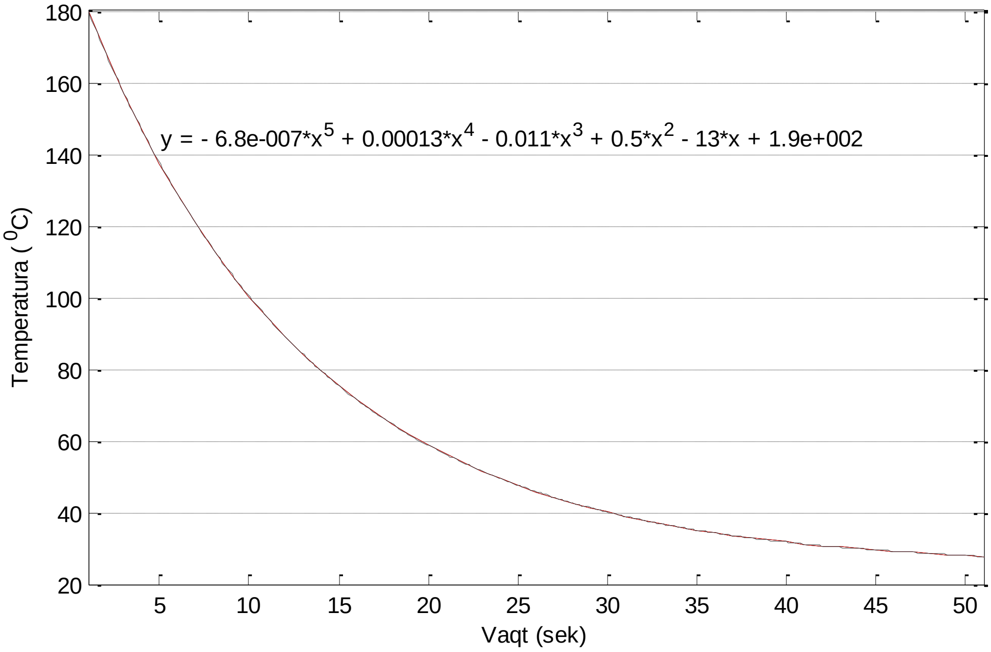
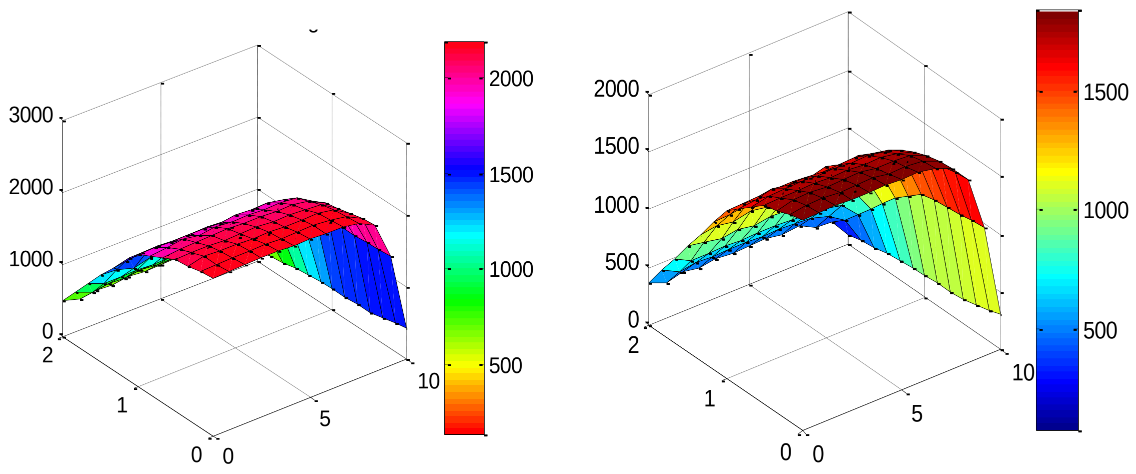


Figure 11. Temperature change when K = 0.2

We consider the heat flux in the drying mixing drum of the asphalt concrete plant in cases where the thermal conductivity of the heat transfer process through the madeo created in the pdetool section of the MATLAB® complex is 0.4, 0.8, 1.2, 1.4.



A- Figure B- Figure

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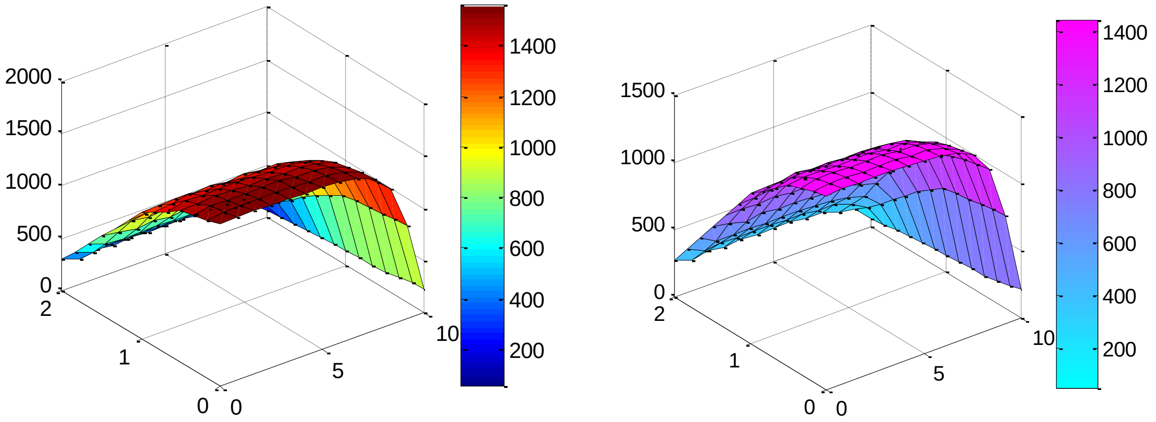

C- Figure D- Figure

Figure 12. Three-dimensional view of the heat flux distribution in the drum

Here:
In Figure A, K = 0.4, respectively.
In Figure B, K = 0.8, respectively.
In Figure S, K = 1.2, respectively.
In Figure D, K = 1.4, respectively.

VI.CONCLUSION AND FUTURE WORK

This article describes the sequence of the process of mathematical modeling of the heat flow in the drying mixing drum of an asphalt concrete plant. An example is the computer model of the method of using Gain, Constant, Integrator, Sum and Scope blocks in different models, where the mathematical expression of the heat flow in the drying drum is calculated in different software packages. Numerical solutions of the heat flow in the drying mixing drum of the asphalt concrete plant were obtained through models of a computer software complex. Through the graph of these numerical solutions, the errors of the temperature distribution process and the polynomial equations are derived.

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