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ІНФОРМАЦІЙНА ТЕХНОЛОГІЯ АНАЛІЗУ ТЕПЛОМАСООБМІНУ В ПРИМІЩЕННІ БУДІВЛІ

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Пропонується інформаційна технологія аналізу конвективного теплообміну в приміщенні будівлі в рамках нестаціонарного тривимірного турбулентного потоку двохкомпонентної пароповітряної суміші при наявності внутрішніх джерел і стоків енергії при наявності внутрішніх джерел і стоків енергії.

Ключові слова: *інформаційна технологія, модель, нестаціонарній тривимірний турбулентний рух, пароповітряна суміш.*

INFORMATION TECHNOLOGY OF HEAT AND MASS EXCHANGE ANALYSIS INDOORS

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We examine a non-stationary three-dimensional turbulent motion of the solid medium of two-component steam-air mixture in the presence of internal sources and drains of energy that allows to determine integral characteristics of thermal conditions in the lodging more exactly.

Keywords: *model, non-stationary three-dimensional turbulent motion, steam-air mixture.*

Introduction. Today, to satisfy customer requirements, for different application areas information and automated (application program packages) systems are created. This approach can significantly extend the functionality of the system and reduce costs both for the development of the system and for the accomplishment, and if necessary, for its subsequent upgrades.

The package language and system and content functionality are the constituent elements of application program packages. Functional content includes models and methods of effect analysis, processes and objects of subject area to which the package is oriented.

Nowadays there is an urgent need for development of the application program package to optimize heat loss in non-productive buildings.

This work is devoted to model building and methods of analysis and to optimization of heat loss in buildings as part of the functional content of the specialized application program package.

Analysis of studies and publications. The work deals with application of mathematical methods of system analysis to study the thermal efficiency of buildings [1]. It shows the scientific bases and methodological principles of designing energy efficient buildings, the features of the development of mathematical models for the thermal management regime in intelligent buildings. This work is the methodological basis of these studies.

The purpose of the study, problem statement. To develop an effective model of non-stationary three-dimensional turbulent motion analysis of continuum of two-component steam-air mixture in the presence of internal energy sources and drains.

Research materials. Non-stationary turbulent three-dimensional motion of two-component steam-air mixture is described by such a system of equations [2]:

$$\frac{\partial \rho}{\partial t} + \nabla(\rho \overline{U}) = 0 ,$$
$$\frac{\partial \rho \overline{U}}{\partial t} + \nabla(\rho \overline{U}\,\overline{U}) = -\nabla P^{*} + \nabla \sigma + g(\rho - \rho_h) ,$$
$$c_p \left[\frac{\partial \rho T}{\partial t} + \nabla(\rho \overline{U} T) \right] = \frac{\partial P_a}{\partial t} - \nabla \overline{q} - (c_{pg}\overline{m}_g + c_{pV}\overline{m}_V)\nabla T ,$$
$$\frac{\partial \rho y_V}{\partial t} + \nabla(\rho \overline{U} y_V) = \nabla \overline{m}_V ,$$
$$y_g + y_V = 1. \qquad (1)$$

Here ρ, P, $\overline{U} = \left(U_x, U_y, U_z\right)$ and T are density, pressure, velocity vector and temperature of the mixture; P^* - modified pressure; P_a - average pressure of the mixture; c_p - specific heat capacity of the mixture; $y_i = \frac{\rho_i}{\rho}$ - mass concentrations of multipliers (ρ_i - partial density, $i=V$, g). Subscripts $(...)_V$ and $(...)_g$ mark appropriate values for non-condensed steam and air.

The total diffusion transfer is given in the system (1) with a stress tensor σ and density vectors of heat $\overline{q}$ and mass $\overline{m}_i$ flux, which use gradient approximations in the form of Newton, Fourier and Fick's laws [2].

The density of the mixture is determined by the equation of state (M_i - molecular weight of the components):

$$\rho = \frac{1}{\dfrac{y_g}{M_g} + \dfrac{y_V}{M_V}} \frac{P_a}{RT} .$$

Specific heat capacity of the mixture consists of specific heats of its multipliers on account of their mass particles:

$$c_p = c_{pg} M_g + c_{pV} M_V.$$

Dynamic viscosity coefficient is determined similarly:

$$\mu = \mu_g M_g + \mu_V M_V.$$

Turbulence modelling is based on a Menter's SST-model [3]. Menter's model (SST-model) on the set of its properties is one of the best (perhaps the best) among existing RANS turbulence models (in the averaged equations by Reynolds). The SST-model is a combination of known k-ε and k-ω models, providing a combination of the best qualities of these models. In the terms of k (turbulence kinetic energy) and ω (specific rate of its dissipation), this model looks like [3]:

$$\frac{D(\rho k)}{Dt} = \nabla\left[\left(\mu + \sigma_k \mu_T\right)\nabla k\right] + P_k - \beta^{*}\rho\omega k , \qquad (2).$$

$$\frac{D(\rho\omega)}{Dt} = \nabla\left[\left(\mu + \sigma_\omega \mu_T\right)\nabla \omega\right] + \gamma \frac{\rho}{\mu_T} P_k - \beta\rho\omega^2 + \left(1 - F_1\right) D_{k\omega}. \quad (3)$$

When solving convective heat exchange indoors it is used several types of boundary conditions, including permeable boundary conditions within the calculated area (input and output), the boundary conditions on a solid impermeable wall, boundary conditions of symmetry, periodic boundary conditions.

Heat and mass exchange equation (1) is written in integral form:

$$\int_V \frac{\partial \rho}{\partial t} dV + \oint_S \rho \bar{U} d\bar{S} = 0,$$

$$\int_V \frac{\partial \left(\rho \bar{U}\right)_x}{\partial t} dV + \oint_S \rho U_x \bar{U} d\bar{S} = -\oint_S \frac{P^*}{\rho} dS_x + \int_V g(\rho - \rho_h) dV + \oint_S \sigma_{xj} dS_j$$

$$\int_V \frac{\partial \left(\rho \bar{U}\right)_y}{\partial t} dV + \oint_S \rho U_y \bar{U} d\bar{S} = -\oint_S \frac{P^*}{\rho} dS_y + \int_V g(\rho - \rho_h) dV + \oint_S \sigma_{yj} dS_j ,$$

$$\int_V \frac{\partial \left(\rho \bar{U}\right)_z}{\partial t} dV + \oint_S \rho U_z \bar{U} d\bar{S} = -\oint_S \frac{P^*}{\rho} dS_z + \int_V g(\rho - \rho_h) dV + \oint_S \sigma_{zj} dS_j ,$$

$$\int_V c_p \frac{\partial \rho T}{\partial t} dV + \oint_S c_p \rho \bar{U} T d\bar{S} = \int_V \frac{\partial P_a}{\partial t} dV - \oint_S \bar{q} d\bar{S} - \oint_S \left(c_{pg} \bar{m}_g + c_{pV} \bar{m}_V\right) T d\bar{S}$$

$$\int_V \frac{\partial \rho y_V}{\partial t} dV + \oint_S \rho \bar{U} y_V d\bar{S} = \oint_S \bar{m}_V d\bar{S} . \qquad (4)$$

Turbulence Menter's model, recorded in terms of k (turbulence kinetic energy) and ω (specific velocity of dissipation), has such an integral form:

$$\int_V \frac{\partial \rho k}{\partial t} dV + \oint_S \left[U_n(\rho k) - (\mu + \sigma_k \mu_t) \frac{\partial k}{\partial n} \right] dS = \int_V \rho (P_k - \beta^* k \omega) dV ,$$

$$\int_V \frac{\partial \rho \omega}{\partial t} dV + \oint_S \left[U_n(\rho \omega) - (\mu + \sigma_\omega \mu_t) \frac{\partial \omega}{\partial n} \right] dS =$$

$$= \int_V \rho \left(P_k - \beta \omega^2 + 2(1 - F_1) \sigma_\omega \frac{1}{\omega} \frac{\partial k}{\partial x_i} \frac{\partial \omega}{\partial x_i} \right) dV ;$$

$$\mu_t = \frac{\rho k}{\omega}, \tau_{ij} = 2\mu_t S_{ij} - 2\bar{I} \frac{\mu_t \nabla \cdot \bar{U} + \rho k}{3}, P_k = \tau_{ij} \frac{\partial u_i}{\partial x_j}, P_\omega = \frac{\gamma}{\mu_t} \tau_{ij} \frac{\partial u_i}{\partial x_j} . \qquad (5)$$

For numerical implementation of convective heat and mass exchange indoors we use the final volumes method [4], and the basic equations are written in the integral form (4) - (5).

In this paper, the integral over a closed circuit is shown as a sum of integrals along the circuit of each face of the control volume. Making a discrete analog of gas dynamics and heat and mass exchange equations, pay attention to how relatively examining face of the control volume the velocity vector is directed. This integral approximation is based on the assumption of constancy of *f* over the entire surface of examining face:

$$\int_{S_e} f dS = f_e \int_{S_e} dS = f_e S_e . \qquad (6)$$

This approximation has another order of accuracy.

Time in physics is considered as a kind of fourth coordinate with the only difference that the past and future vary clearly. What happened in the last moment, can affect future events only, but not to those that have already occurred (principle of causality).

Consequently, when numerical solving the task the process time can be divided into some steps, creating a time grid along with the spatial one.

Partial initials of time are presented as a final difference forward:

$$\frac{\theta_i^n - \theta_i^{n-1}}{dt}.$$

As a result we get a clear difference scheme which is stable under the condition of Courant

$$dt < \frac{\min(dx, dy, dz)}{\max(U_x, U_y, U_z)}.$$

Heating appliances realized in the model as distributed heat sources in space with geometry, location and other characteristics that meet the real heating appliances.

Numerical research, in particular, found that the density of the air in the room does not change, despite the fact that it was substantially increased the temperature of the heating device. Therefore, modeling the thermal regime can be considered that the density is constant. At the same time the system of equations describing convective heat exchange within the considered model becomes simpler.

Fig. 1 presents temperature distribution in height of the room in its center.

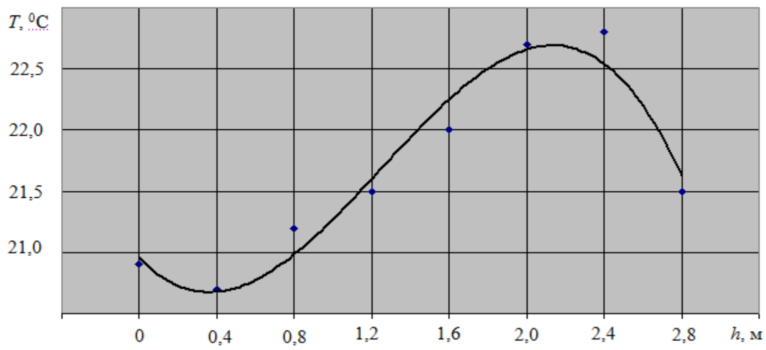

Fig. 1. The temperature distribution in height of the room.

On Fig. 3 the calculated temperature by proposed model is marked with a solid line, and experimental values taken in the work – with dots [5]. Room size: height – 3 m, length – 6 m and width – 3 m. Heating device dimensions – 80×60 cm, and the temperature is 85 C. Ambient temperature is -20 C.

Conclusion. Thus, in the course of this work within the framework of modern information technologies, where methods of mathematical modeling play key role, it is propounded the method of modeling of three-dimensional non-stationary turbulent convective heat and mass exchange in the room of non-production buildings.

The results of numerical experiment conform the results obtained experimentally quite well.

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