NUMERICAL MODELING OF PROTECTIVE PROPERTIES OF CONTAINERS, BEING UNDER INFLUENCE OF HEATING.

Frequently, for protection of some loads against a various kind of external influences uses special containers. Use them, also, and for thermal protection, for example from influence of a fire.

The problem of an estimation of protective properties of the container, being under influence of heating, represents a problem of the complex heat transfer, in which it is necessary to consider heat conductivity in a solid body, the convective heat transfer in fluid and heat transfer by radiation.

There are various methods of the solution of the given problem. Theoretical methods can be divided into two groups - using the mass-averaged model and using the differential model.

In the first case the container conditionally divide on n bodies and for each of them write down the equation of a kind.

$$C_i M_i \frac{dT_i}{dt} = Q_i \quad , \ i = 1..n$$

Where, C_i, M_i, T_i, Q_i – thermal capacity, weight, an averaged temperature and total thermal stream i bodies.

As a result of the solution of this system of the equations define dependence of temperature of each of n bodies from time.

In the second case the process of heat transfer is modeled by system of the partial differential equations, including equations Navier-Stokes

$$\nabla \mathbf{V} = 0$$

$$\frac{\partial \mathbf{V}}{\partial t} + \nabla(\mathbf{V} \otimes \mathbf{V}) = \frac{1}{\rho}\nabla(\mu \nabla \mathbf{V}) - \frac{\nabla P}{\rho} + \mathbf{G} ,$$

the equation of energy

$$\frac{\partial h}{\partial t} + \nabla(\mathbf{V} h) = \frac{1}{\rho}\nabla\left(\frac{\lambda}{C_p}\nabla h\right) + S \quad ,$$

the equations of concentration of reacting substances

$$\frac{\partial C_i}{\partial t} + \nabla(\mathbf{V} C_i) = \nabla(D_i \nabla C_i) + M_i ,$$

and also the thermal equation of a condition

$$\rho = P_0 / RT ,$$

where, $\mathbf{V}$ – a vector of speed;
h – enthalpy;
ρ - density;
P - pressure;
G – gravities;
S – sources of thermal emissions;
μ – dynamic viscosity;
Cp – a specific thermal capacity;
λ – coefficient of heat conductivity;
C_i – a mass fraction of quantity i;
D_i – diffusion coefficient for quantity i;
M_i – sources of mass emissions of quantity i;
P_o - static pressure, characteristic for the given problem.

For definition of intensity of radiant heat exchange the following model of radiation has been accepted. Internal and external surfaces of the device are radiating surfaces. Their temperature is supposed a constant by the current moment time, equal an averaged temperature. Absorption of radiation in associates of surface environments does not occur.

For the system consisting from n of surfaces of radiation, the density of a stream of resulting radiation is defined by dependence

$$q_{rezi} = \sum_{k=1}^{n} \left(E_{effi} - E_{effk}\right) \cdot \varphi_{ik} \qquad (*)$$

Where, φ_{ik} - angular coefficient of radiation i surface on k surface.

The density of a stream of effective radiation develops of own radiation of a surface and the reflected radiation of other surfaces

$$E_{effi} = E_i + (1 - \varepsilon_i)\sum_{k=1}^{n} E_{effk}\varphi_{ik} \qquad (**)$$

Where, $E_i = 5{,}67 \cdot \varepsilon_i \left(\frac{T_i}{100}\right)^4$ - own radiation i surface;

ε_i - a degree of blackness i surface.

Having written down the equation (**) for all surfaces we shall receive system from n the algebraic equations for definition n effective streams of radiation. On their values on the equation (*) find density of a stream of resulting radiation for all surfaces.

The problem is solved by numerical methods in the flow domain, which include areas, occupied with a solid bodies and a fluid.

The second approach, though is connected to carrying out of great volume of calculations, is preferable. The numerical model on the basis of the solution system of the differential equations yields more exact results of calculations, in comparison with mass-averaged model due to an opportunity of definition convective currents, and also the detailed account of internal structure of the container and its influence on various kinds of heat transfer.

The solution.

Calculations of protective properties of containers, being under influence of heating were carried out under the scheme submitted on (fig. 1).

The scheme of zones and surfaces of radiant heat transfer (fig. 2).

We count; that gas inside the container is air, walls of the container is steel.

The external surface of the container is external border of computational area. On it we set the thermal stream modeling influence of a fire.

Process proceeds as follows. There is a heating walls of the container from which air, which is taking place inside, is heated up, whirlwinds are formed in the top and bottom of the container and between walls in the central part.

Heat transfer between an internal surface of walls of the container and a load occurs basically thanking convection and to radiation. Through the thermal bridge which is made with the central walls, passes smaller amount of heat. Allocation of temperature inside a cargo testifies to it (fig. 3). The cargo has the greatest temperature in the bottom and top part, in the central part the temperature is lower. On depth 30мм from a surface the load reaches dangerous temperature in 416 seconds after the beginning of heating in the top angular part.

Thus, the carried out calculations shows the correctness of the suggested approach for modeling dynamics of heating of the objects, having complex structure.

Development of the given approach will give an opportunity of expansion of computational area and inclusion in it together with the container of the center of a fire, an opportunity of the account of infringement of integrity of the container and a filtration in it of external gases, an opportunity of modeling of burning inside the container.

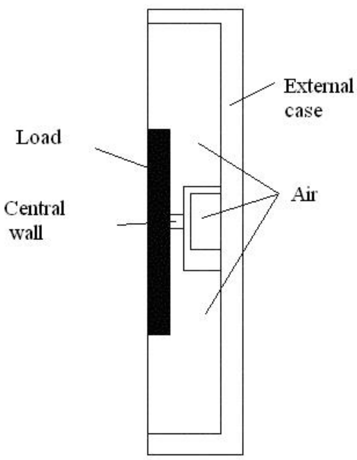


Fig. 1. Flow domain.

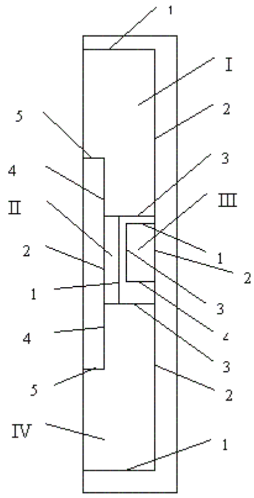
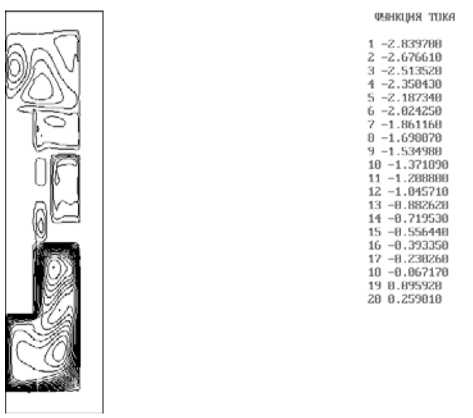


Fig. 2. The scheme of zones and surfaces of radiant heat transfer.

a)



б)

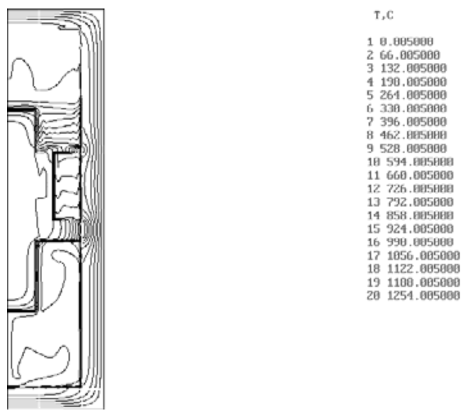


Fig.3. Heating of the container (416 s. After the beginning)
а- the stream function, б- a temperature.