

NUMERICAL MODELING OF THE SYSTEM OF THERMAL REMOVAL OF A RESTS OF FUEL FROM THE FUEL TANK OF A ROCKET.

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The system of thermal removal of the rests of fuel from a fuel tank of a rocket operates as follows. The oxidizer is injected in a fuel tank in small amounts. There is its reaction with fuel. In result, the temperature and pressure raises in a tank. Fuel evaporates, reacts and expires from a tank through a drainage aperture. There are restrictions on heating a structure of a tank and pressure inside a tank. A mode of submission of an oxidizer and configuration of system should be correctly chosen to observe these restrictions and as ecological requirements.

It was originally supposed, that all amount of an injected oxidizer immediately reacts with fuel in some ratio. The mass-averaged thermal model has been made. In this model all internal space of a tank had the averaged temperature, and capacity of thermal emissions was proportional to amount of an injected oxidizer.

However, the criterion, which is taking into account parameters of chemical reactions, specified that in a fuel tank occurs the diffusion burning. The diffusion burning is characterized by the big non-uniformity of distribution of temperature and concentration of reacting components on volume in which there is a reaction. To take into account this non-uniformity, and its influence on a temperature mode of a structure of a tank and passage of chemical reactions, was accepted decision to use mathematical model on the basis of 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

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

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

$$\rho = \frac{P_0}{RT},$$

where, \mathbf{V} – a vector of speed;
h – enthalpy;

ρ - density;
P - pressure;
 \mathbf{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;
P₀ - static pressure, characteristic for the given problem.

In a structure of a tank the safety valve regulating pressure is stipulated. Therefore calculation is spent in the assumption of the virtual compressibility of environment. Pressure inside a tank is counted equal as much as possible allowable, and density is recalculated on each step on time on value of average temperature of environment.

Chemical transformations inside a tank are modeled by three reactions: oxidation of fuel; thermal decomposition of fuel; oxidation of products of thermal decomposition.

Results of numerical modeling have shown that processes in a fuel tank occur not how it was supposed in mass-averaged models. The limiting factor is not the amount of a submitted oxidizer, and distribution of liquid fuel inside a tank and speed of its evaporation. The injected oxidizer gradually fills in the most part of volume of a tank. Reaction of oxidation occurs above surfaces of evaporation of fuel. According to this the temperature (fig. 1-5) is allocated.

One of research problems was to not allow emission from a tank of not reacted fuel. For the decision of this task it was necessary to choose a correct relative positioning of an atomizer of injection of an oxidizer, the rests of a fuel and drainage aperture. Numerical researches are carried out and the optimum position (fig. 6-10) is determined.

Application of mathematical model on the basis of system of the partial differential equations has shown that initial assumptions of modeling of process were incorrect. And, those theoretical researches of similar systems are possible only within the framework of such model.

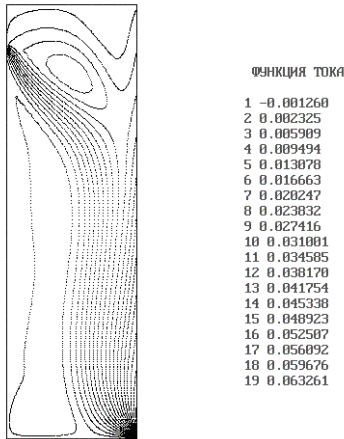


Fig. 1. The top arrangement of atomizers, the stream function.

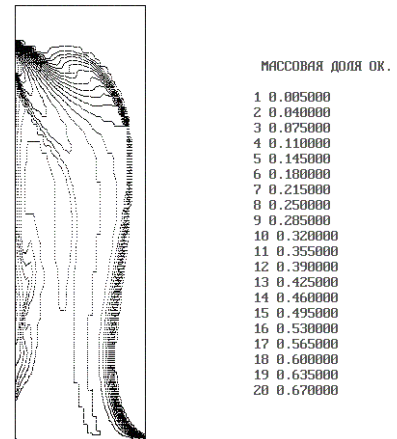


Fig. 4. The top arrangement of atomizers, a mass fraction of oxidizer.

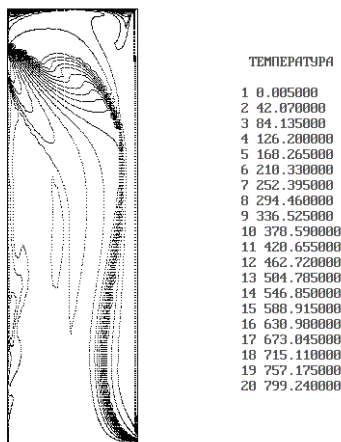


Fig. 2. The top arrangement of atomizers, a temperature.

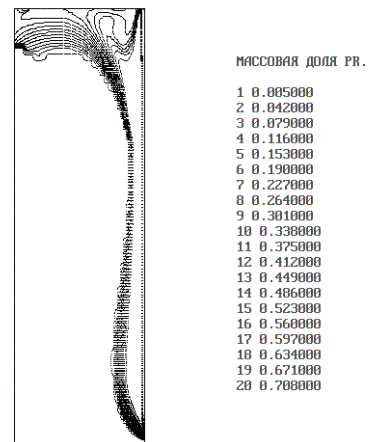


Fig. 5. The top arrangement of atomizers, a mass fraction of products of thermal decomposition of fuel.

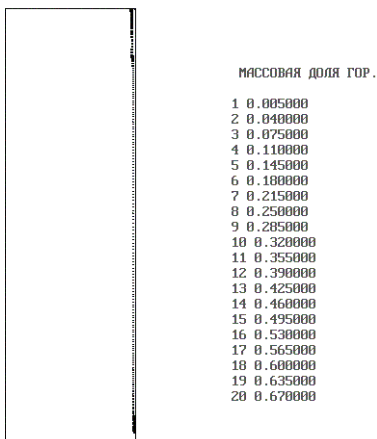


Fig. 3. The top arrangement of atomizers, a mass fraction of fuel.

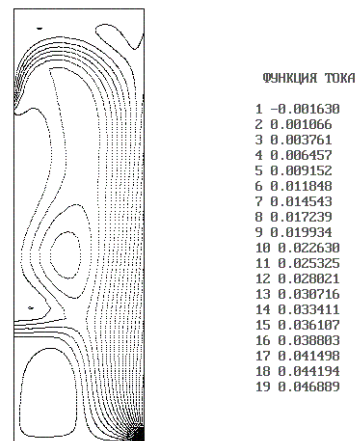


Fig. 6. Uniform arrangement of atomizers with an inclination, the stream function.

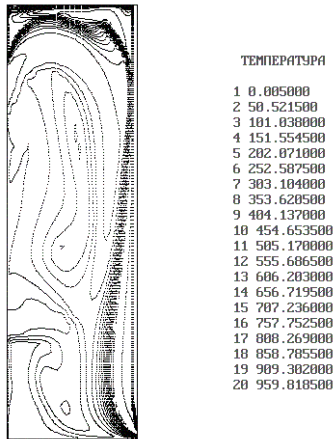


Fig. 7. Uniform arrangement of atomizers with an inclination, a temperature.

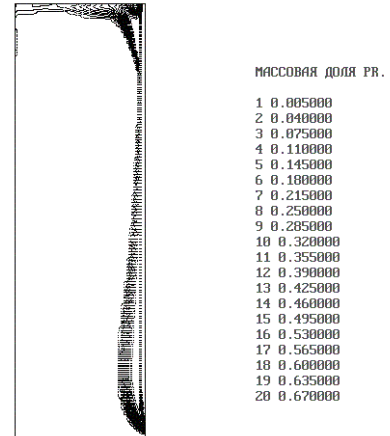


Fig. 10. Uniform arrangement of atomizers with an inclination, a mass fraction of products of thermal decomposition of fuel.

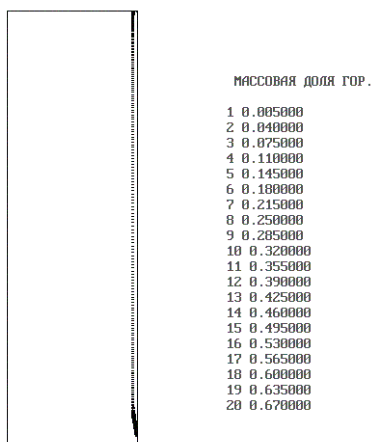


Fig. 8. Uniform arrangement of atomizers with an inclination, a mass fraction of fuel.

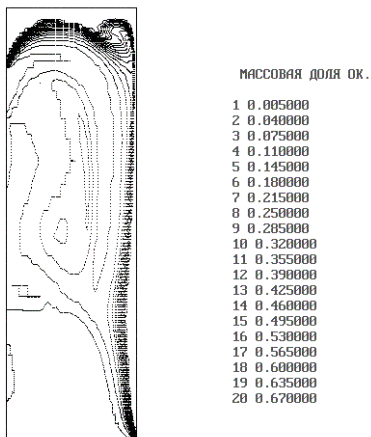


Fig. 9. Uniform arrangement of atomizers with an inclination, a mass fraction of oxidizer.