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Influence of strouhal number on the temperature fields in the locked space with the working source of the radiant heating

Alime Dudak[1], *Vyacheslav* Maksimov[1,*], and *Tatiana* A. Nagornova[1]

[1]National Research Tomsk Polytechnic University, 634050 Tomsk, Russia

Abstract. Is carried out a numerical study of the heat transfer process in the closed domain with the source of radiant heating. Is solved the system of differential equations in the dimensionless setting, which describes free convection in the airspace and thermal conductivities in the enclosing constructions. Examined the influence of the dimensionless parameter, which characterizes the unsteady motion of liquids or gases (Strouhal number), on the formation of temperature fields both near the heater and in the entire region. Is carried out the estimation of the average temperature, depending on the Sh.

1 Introduction

Recently increasingly more attention is given to the prognostication of thermal comfort in residential and industrial areas [1-4]. Used as commercial software packages [3] and developed by the authors [1, 2] mathematical models. In this case are used or standard balance models [2] or systems of nonstationary differential equations [1] into the partial derivatives, which consider the influence of different parameters, entering the dimensionless criteria, such, for example, as numbers of Prandtl, Reynolds and others. The number of studies is dedicated to the study of the influence of the criterion of eddy formation (Strouhal number) on the structure of the flow of gas or liquid after passage by them the obstacle [5-9]. Strouhal number is correlated with this phenomenon as the instability of the flow of working medium. The influence of this dimensionless parameter on the thermal characteristics of the heated region is not thus far studied. By the purpose of the work is the study of the influence of Strouhal number on the structure of airflow with the numerical simulation of the process of heating the source of the radiant heating of closed domain.

2 Formulation of the problem

In formulating the problem of heat transfer in a room with a working source of radiant heat was considered a rectangular area shown in Fig. 1.

* Corresponding author: elf@tpu.ru

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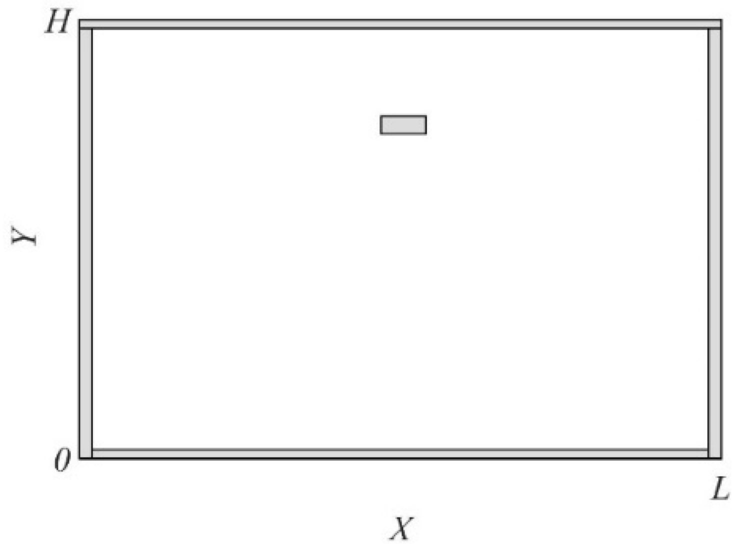

Fig. 1. Study region: *L*, *H* - the width and height of the region.

The heat sink to the enclosing heat-conducting walls was taken into account similarly to [1]. On the lower interface of media was assigned the value of heat flux q (coming from emitter), which varied depending on coordinate x. On the outer boundaries of the enclosing walls the nonlinear boundary conditions of heat exchange with the environment were assigned (caused by the convection and the emission). It was assumed that air of pure and it is possible to consider transparent for emission.

With the mathematical formulation of the problem of equation, that describe the process of free convection in the region with regime of conjugate heat transfer, were recorded by analogy [1] in the dimensionless variables. System of equations in the partial derivatives is solved by the finite-difference method with the use of an algorithm [1, 10], developed for the numerical solution of the conjugate natural convection in closed rectangular areas with local energy sources.

3 Results and discussion

In Fig. 2-4 are represented the fundamental characteristics of heat transfer in the locked space with the working source of radiant heating with different numerical values of Strouhal number.

Values Sh were selected in the range change, that corresponds to the conditions for the process from the quasi-stationary state of system in question “GIE – air – the enclosing constructions” to the substantially unsteady.

With the small numbers Sh in the upper part of the region (Fig. being investigated. 2 *a*, *b*) it is formed 2 small of vortex. It is noticeable (Fig. 2), that with an increase in Strouhal number the turbulence above the source of radiant heating decreases, their speeds are reduced (Fig. 2 *d*) and then disappear completely (Fig. 2 *f*). For example, with Sh = 10 are observed only main flows, distributed along the entire upper interface of media (Fig. 2 *e*, *f*).

A change in the structure of the movement of air near the source of heating leads to a significant change in temperatures in this region (to 20 % (Fig. 3)), (to their value practically they coincide near $Y = H/2$) the lower interface of media.

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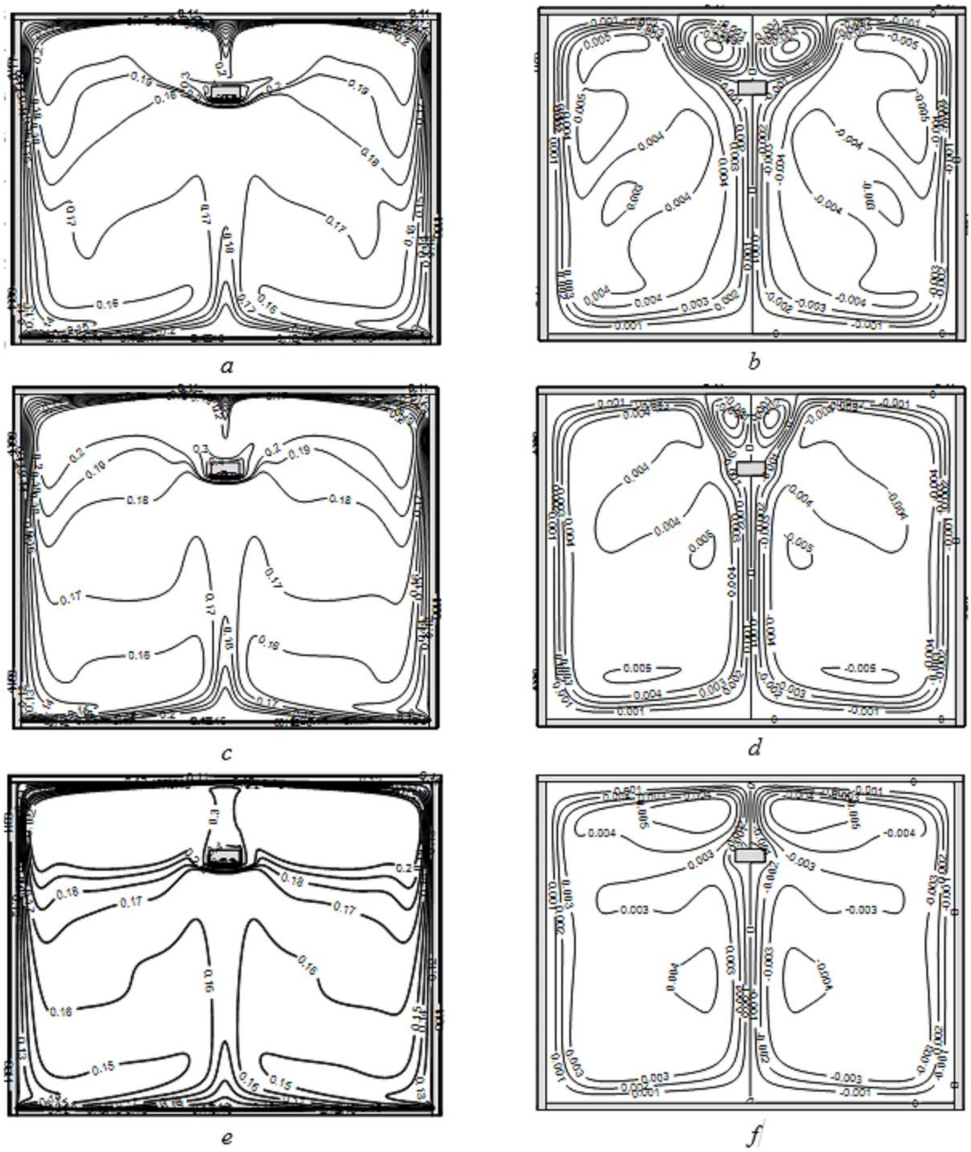

Fig. 2. Area of solving the problem: *L*, *H* - the height and length of solutions area respectively. The temperature field (*a*, *c*, *e*) and the isolines of the current function (*b*, *d*, f) at the instant $\tau = 24 \cdot 10^4$ for different values of the Strouhal number: Sh = 0.1 (a, b); Sh = 1 (c, d); Sh = 10 (d, e).

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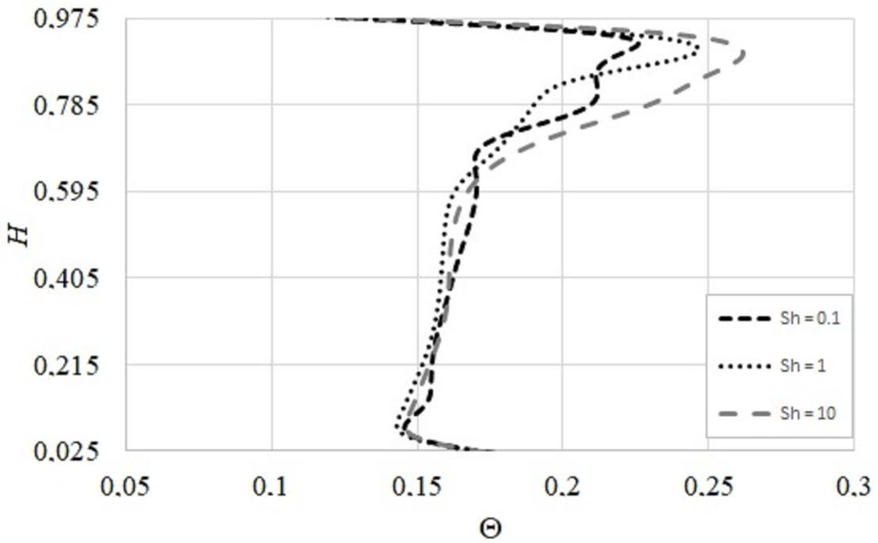

Fig. 3. Temperature distribution along the height of the investigated region in the cross section $X = L/4$ at time $\tau = 24{\cdot}10^4$.

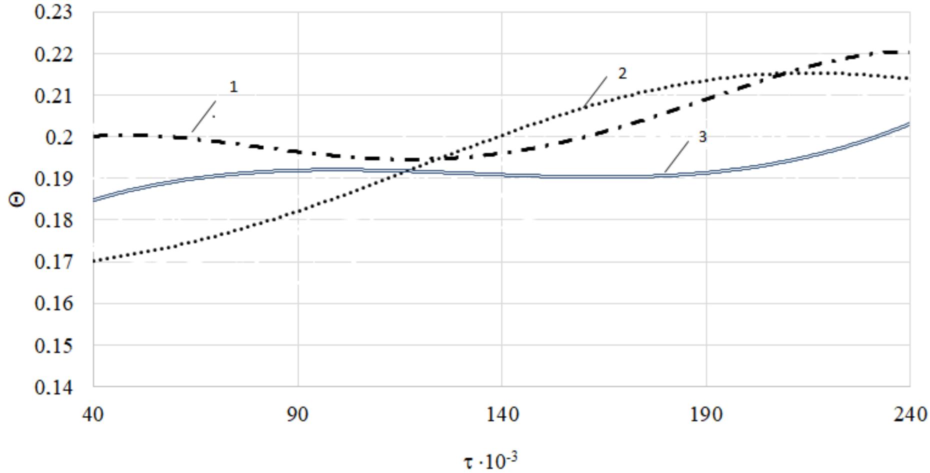

Fig. 4. Dependences of the average temperature of the air medium on time for different values of the Strouhal number: 1) Sh = 0.1; 2) Sh = 1; 3) Sh = 10.

Reduction in the speeds (Fig. 2 *b*, *d*, *f*) and the intensity of mixing respectively reduce average air temperatures (Fig. 4). With Sh = 10 temperature are minimum (Fig. 4), but with greater τ the difference in the values Θ becomes less 10 %. Interesting is the agreement of the values of average dimensionless temperature with $\tau = 12{\cdot}10^4$ (1 the hour of physical time), calculated with the different Sh.

4 Conclusion

Is carried out the numerical simulation of the process of heat transfer in the closed domain, heated by the source of radiant heating. The results of numerical studies illustrate a change in the structure of the flow of heated air with an increase in the number Sh only near the source of the radiant heating, which has high temperature. In the environment of the lower interface of media changes in temperatures are insignificant. It is established that an increase Sh from 0.1 to 10 leads to an unessential change in the structure of the flows of heated air and temperature fields in the closed domains (to 20 %) and practically it does not influence the temperature of the surface of the enclosing constructions.

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