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MATHEMATICAL MODELING OF HYDRODYNAMICS AND HEAT TRANSFER IN AIR COOLER POULTRY PREMISES

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The mathematical modeling of mass and heat transfer in a recuperative heat exchanger to cool the outside air entering the poultry houses. Completed engineering calculations heat exchanger and conducted numerical simulations of hydrodynamic and thermal processes using CAD software ANSYS Fluent 14.0. The distribution of velocity, pressure and temperature in the heat exchanger, heat exchanger.

Heat exchanger, heat exchanger, mathematical modeling of heat and mass transfer, engineering calculation.

Heat treatment of poultry houses is one of the decisive factors that determine the performance of the livestock industry. Keeping poultry in cold, wet areas are not satisfactory ventilation reduces the rate of loss of 20-30% reduction in egg production by 30-35% and increased incidence of 2-3 young and over-feed and exceedances of cultivation, livestock installed regulations. Thermal conditions set by poultry house heat transfer processes occurring in the middle of the room, and through its external enclosures. It is influenced by the heating and ventilation depending on the outside air meteorological parameters and thermal characteristics of building structures.

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Essence of work consists in the leadthrough of theoretical researches, heat-exchange processes related to adjusting, in poultry houses, which take place both into an apartment and through his external protections depending on the meteorological parameters of external air and heating engineering descriptions. Information of calculations is got enable to conduct the correct choice of build constructions for the systems of heating and ventilation of poultry houses.

The purpose of research - creating a mathematical model of the transport and engineering calculation and the calculation of local hydrodynamic and thermal characteristics of the regenerative type heat exchanger to cool the air in poultry houses using CAD software package ANSYS Fluent 14.0, the development of new design heat exchanger-regenerator.

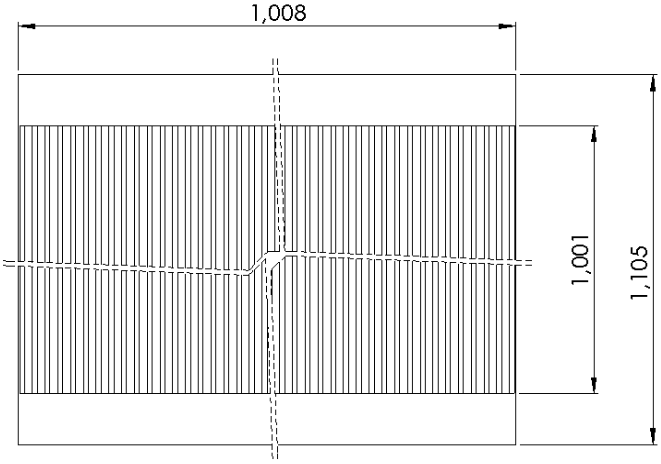
Materials and methods research. It is known that the minimum ventilation works in the winter and is calculated to remove pollutants (ammonia, carbon dioxide, dust and moisture) and provide the necessary supply of air saturated with oxygen.

Transitional ventilation is in spring and autumn. In place of air distribution throughout the poultry house which is used at the minimum ventilation is gradually activated air distribution along the length of chicken houses. The ventilation system for temperature changes, age, birds and limits the rate of air flow.

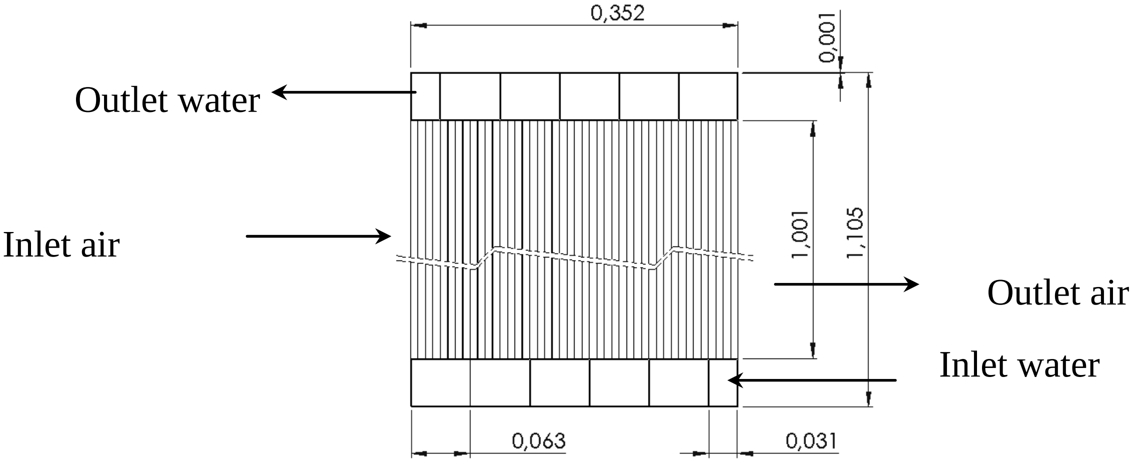
Tunnel ventilation is in the summer season (temperature over 26 ° C). At this stage it is important to ensure the removal of excess heat, which creates a bird.

Complete with tunnel ventilation commonly used cooling system. In this case, the cooling system will recuperative heat exchanger.

When choosing the direction of the coolant preferred counter flow and cross flow, for which the highest specific heat load [1]. In addition, the countercurrent cold coolant may be heated to a higher temperature than the straight-circuit apparatus. Heat exchanger circuit layout is shown in Fig. 1.



a



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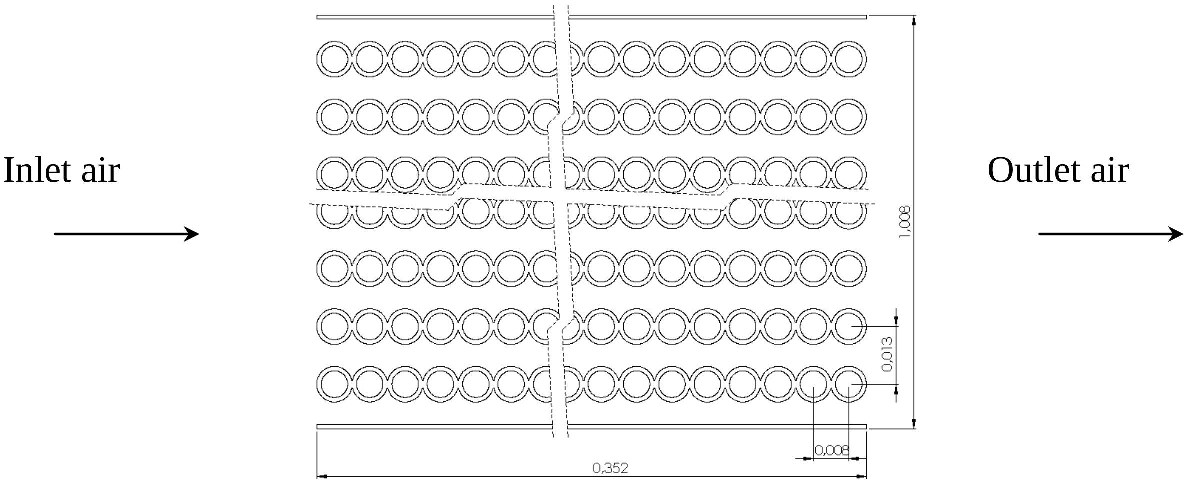

c

Figure. 1. General view tube heat exchanger;

a - front view, *b* - side view, *c* - view from the top.

The choice of material depends on the aggressiveness of the pipe coolant. For aggressive environments at low pressures and temperatures used seamless steel pipe steel grades 10, 20, for aggressive - use seamless tubes of alloy steel, copper, aluminum. Depends on the pipe diameter selected material and operating conditions. In the case of selected steel seamless pipes with an external diameter of tube 8 mm and a wall thickness of 1 mm.

Temperature of the incoming air in the heat exchanger 40 ° C, the estimated reference temperature 19.5 ^{o}C. Mass air flow inlet 43350 kg / h. Height passage for air in the heat exchanger 1.001 m, width 1.006 m Width shell side distance - 0,005 m.

When calculating the heat exchanger used two approaches - performed engineering calculations heat exchanger and conducted numerical modeling of heat and mass transfer using a CAD application package ANSYS Fluent 14.0.

Engineering calculation of the heat exchanger. Below is an engineering calculation of the heat exchanger poultry house ventilation system that runs as follows.

Select the number of rows of tubes, pcs:

$$n_p = \frac{l - S}{S + d_{тр.зв}}.$$

Find the volumetric flow rate of air, m^3/s:

$$G = \frac{G_m}{\rho \cdot 3600}.$$

The amount of heat transferred from air to water kW:

$$Q = \frac{G_m}{3600} \cdot C_p \left(T_1' - T_1''\right).$$

The velocity of the air at the beginning of the channel, m/s:

$$W = \frac{G}{F_{пер} \cdot \left(n_p + 1\right)}.$$

Equivalent diameter of the tube bundle, m:

$$d_{екв} = \frac{4 \cdot F_{пер}}{P_{пер}}.$$

Heat transfer coefficient for air, W/m^2 · ^{o}C:

$$\alpha = \frac{Nu \cdot \lambda}{d_{екв}}.$$

The value of the logarithmic average temperature ^{o}C:

$$\Delta T_{\text{лог}} \frac{\Delta T_{\text{мах}} - \Delta T_{\text{мін}}}{\ln\left(\frac{\Delta T_{\text{мах}}}{\Delta T_{\text{мін}}}\right)}.$$

Number of rows of tubes, pcs:

$$m = \frac{F_{\text{пуч}}}{F_{\text{пер}}}.$$

The total length of the heat exchanger, m:

$$L_{\text{тр}} = m \cdot d_{\text{тр.зов}}.$$

The calculation results are shown in the table.

Comparison of heat exchangers.

The main parameter heat exchanger	Traditional heat exchanger	The proposed heat exchanger
The amount of heat transferred from air to water, *kW*	248,09	248,09
The water temperature at the outlet of the heat exchanger, ^{o}C	14	13,5
The velocity of the air at the beginning of the channel, *m/s*	17,85	27,2
Heat transfer coefficient for air, $W/m^2 \cdot {}^{o}C$	88,46	229,28
The value of the logarithmic average temperature, ^{o}C	16,41	16,41
Equivalent diameter of the tube bundle, *m*	0,00673	0,00995
The total length of the heat exchanger, *m*	2,35	0,352

Modeling of mass transfer and heat exchanger for cooling air ventilated using CAD software ANSYS Fluent 14.0.

We consider stationary, turbulent flow of incompressible viscous gas. It is necessary to perform the adhesion of air to a solid wall or absence of gas slip on the surface. Thus, the boundary conditions are performed equal to zero gas velocity at the surface of the stationary walls.

The process of heat and mass transfer in the heat exchanger can be described by equations [2]:

• equation of motion projected on the axis Ox:

$$\frac{\partial v_x v_x}{\partial x} + \frac{\partial v_y v_x}{\partial y} = -\frac{1 \partial p}{\rho \partial x} + \mu\left(\frac{\partial^2 v_x}{\partial x^2} + \frac{\partial^2 v_x}{\partial y^2}\right);$$

• equation of motion projected on the axis Oy:

$$\frac{\partial v_x v_y}{\partial x}+\frac{\partial v_y v_y}{\partial y}=-\frac{1\partial p}{\rho\,\partial y}+\mu\left(\frac{\partial^2 v_y}{\partial x^2}+\frac{\partial^2 v_y}{\partial y^2}\right);$$

• the continuity equation:

$$\frac{\partial v_x}{\partial x}+\frac{\partial v_y v_y}{\partial y}=0.$$

where $\bar{v}=(v_x, v_y)$ - air velocity m / s, p - pressure Pa; ρ - air density kg/m3; μ - coefficient of kinematic viscosity m2/s.

Boundary conditions:

• conditions of neprotikannya follows:

$$x=0; v_x=0; x=L_x; v_x=0;$$
$$y=0; v_y=0; y=L_y; v_y=0;$$

• conditions of adhesion follows:

$$x=0; v_x=0; x=L_x; v_x=0;$$
$$y=0; v_y=0; y=L_y; v_y=U.$$

where Lx and Ly - by length and channel width m, U - air velocity m / s.

Now there are many models of turbulence. However, none of the known models are not universal for all existing classes of flows. Optimal model of turbulence depends on the type of flow, the accuracy solutions available computing resources and more. With the variety of turbulence models generally are the most common form - RANS (Reynolds-averaged Navier-Stokes) models, which include family k-e models. In the considered case, select the standard k-e model (KES) [3-5].

$$\frac{\partial}{\partial t}(\rho k)+\frac{\partial}{\partial x_j}\left(\rho k\left(U_j-U_{g.j.}\right)\right)=P_k+P_b-\rho\in+\frac{\partial}{\partial x_j}\left[\left(\mu+\frac{\mu_t}{\sigma_k}\right)\frac{\partial k}{\partial x_j}\right]$$

$$\frac{\partial}{\partial e}(\rho\in)+\frac{\partial}{\partial x_j}\left(\rho\in\left(U_j-U_{g.j.}\right)\right)=\frac{C_{\in 1}P_k-C_{\in 2}\rho\in+C_{\in 3}P_b}{T_t}-$$

$$-C_{\in 4}\rho\in S_{kk}+\frac{\partial}{\partial x_j}\left[\left(\mu+\frac{\mu_t}{\sigma_\in}\right)\frac{\partial\in}{\partial x_j}\right]+S_\in$$

A large number of hydrodynamic and thermal engineering problems solved by using commercial software packages. The estimated net is created directly in the package or imported from another editor. Now the software packages are two types of networks: tetraidalna and Cartesian. Tetraidalna grid allows you to create cells that are similar in form to the settlement area boundaries and areas with large gradients of velocity and temperature, which allows a good model near-boundary layers. At the same time, creating tetraidalnoyi grid is very time consuming. Using Cartesian grid can create only rectangular cells, which can lead to poor solutions of near-boundary layer, but the Cartesian grid is more simple in its creation. There are several methods that can solve the transport equation in the near-boundary layers in the presence of high gradients of flow parameters. Examples of such methods is technology and technology ALPS pidsitochnoho permission geometry, implemented in complex software ANSYS. Technology ALPS (Adaptive mesh locally crushed) can split selected cells in all directions at a given number of times (to adapt to a given level). Thus for cells that are close mesh crushed so that the size of two adjacent cells did not differ by more than a factor of 2. Breakage of cells can be set both in body and on the surface. Technology pidsitochnoho permission geometry of the body automatically the same as the shape of the surface. The appearance of such a grid for multiple pipes and surface element shown in Fig. 2.

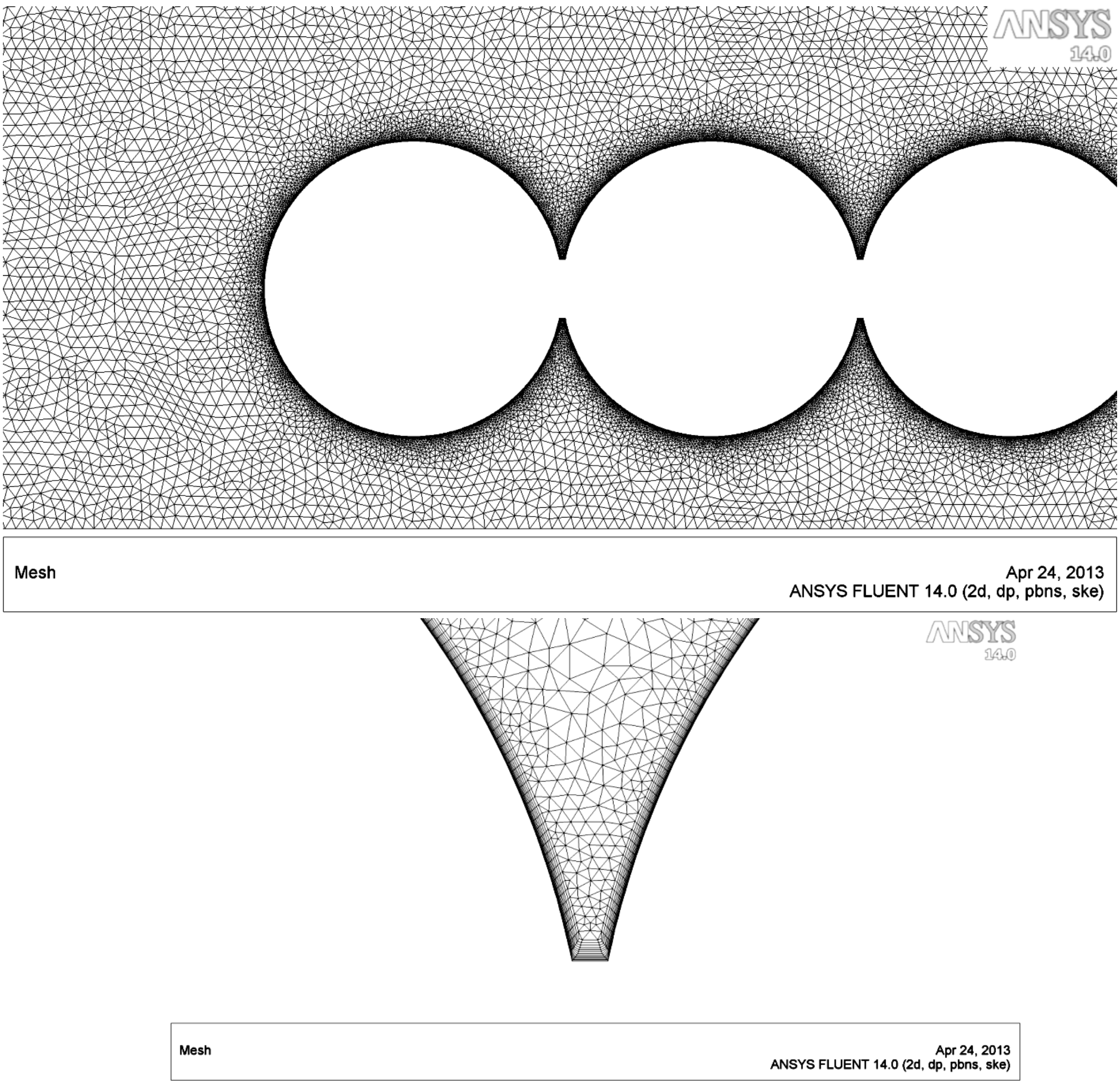

Figure. 2. 2D mesh, top view.

Results solutions shown in Fig. 3-6. In Fig. 3 shows the temperature distribution in the heat exchanger element for two adjacent rows of tubes.

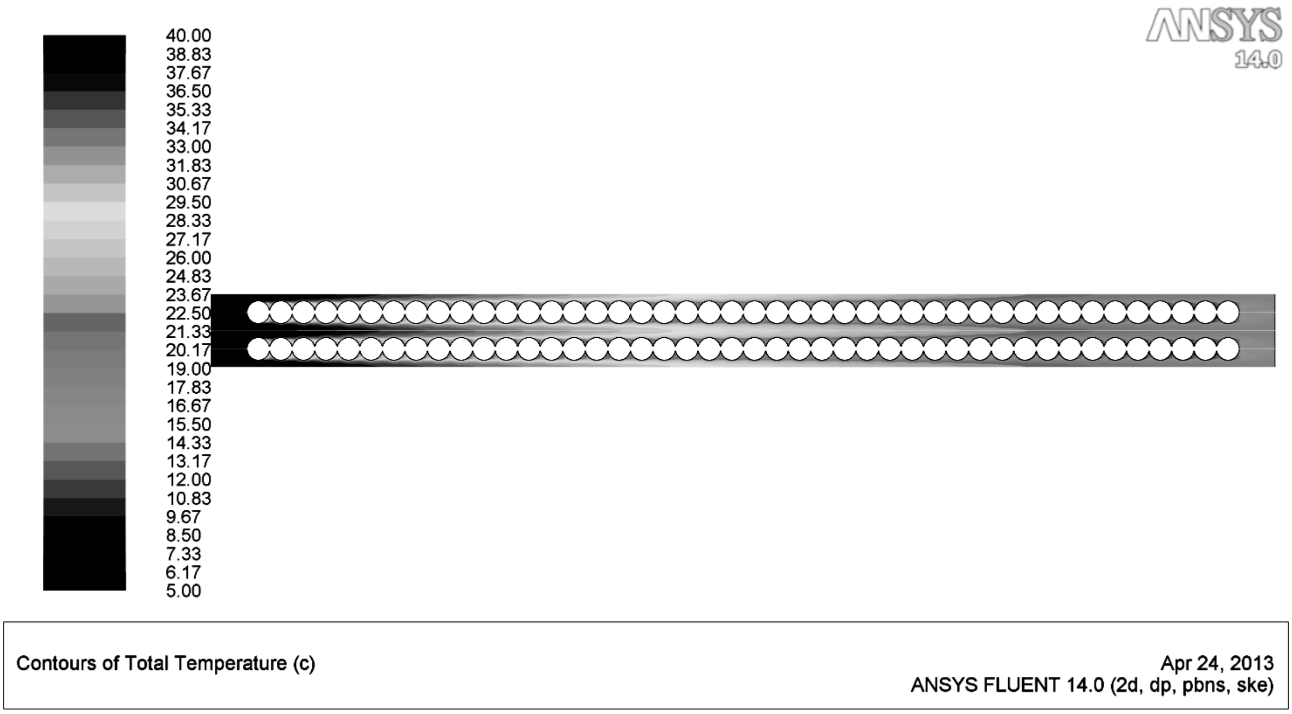

Figure. 3. Changing the overall temperature in the channel ^{0}C.

In Fig. 4 shows the distribution of average values of air temperature in the center of the channel.

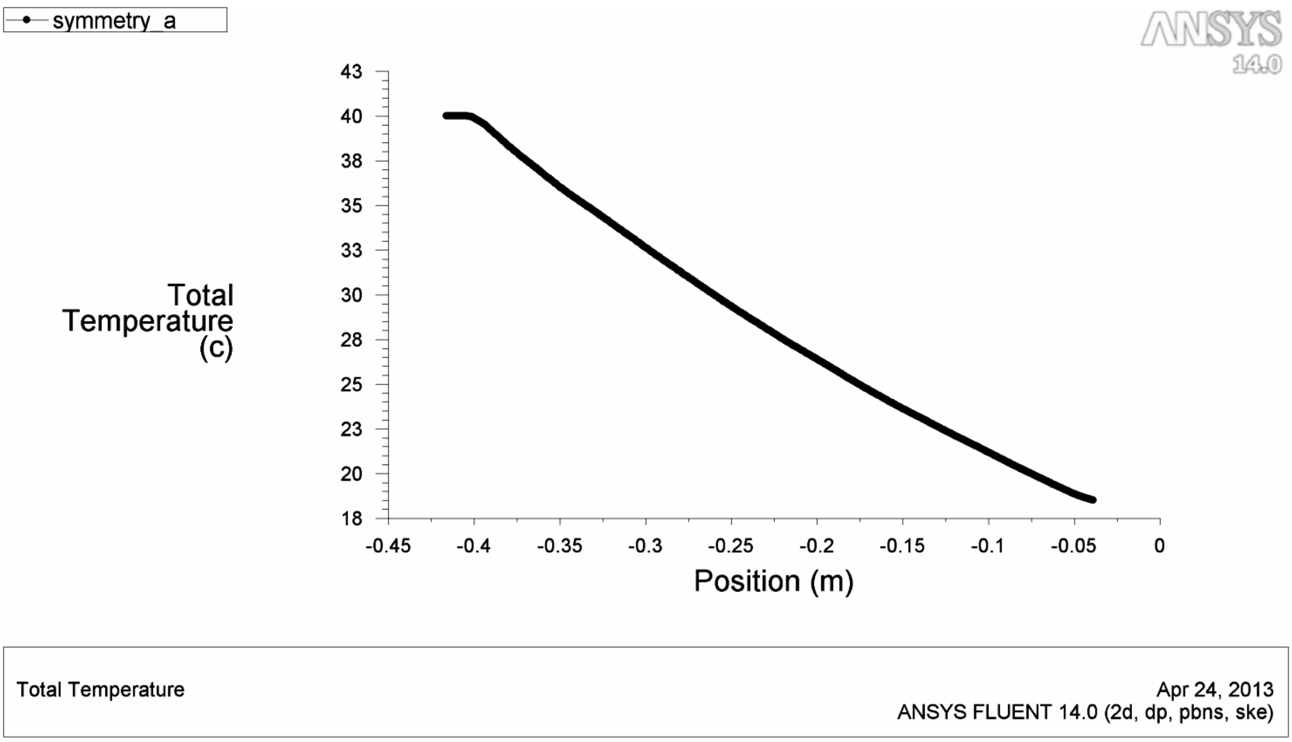

Figure. 4. Total internal temperature channel ^{0}C.

The distribution of the velocity field in the channel of the heat exchanger shown in Fig. 5.

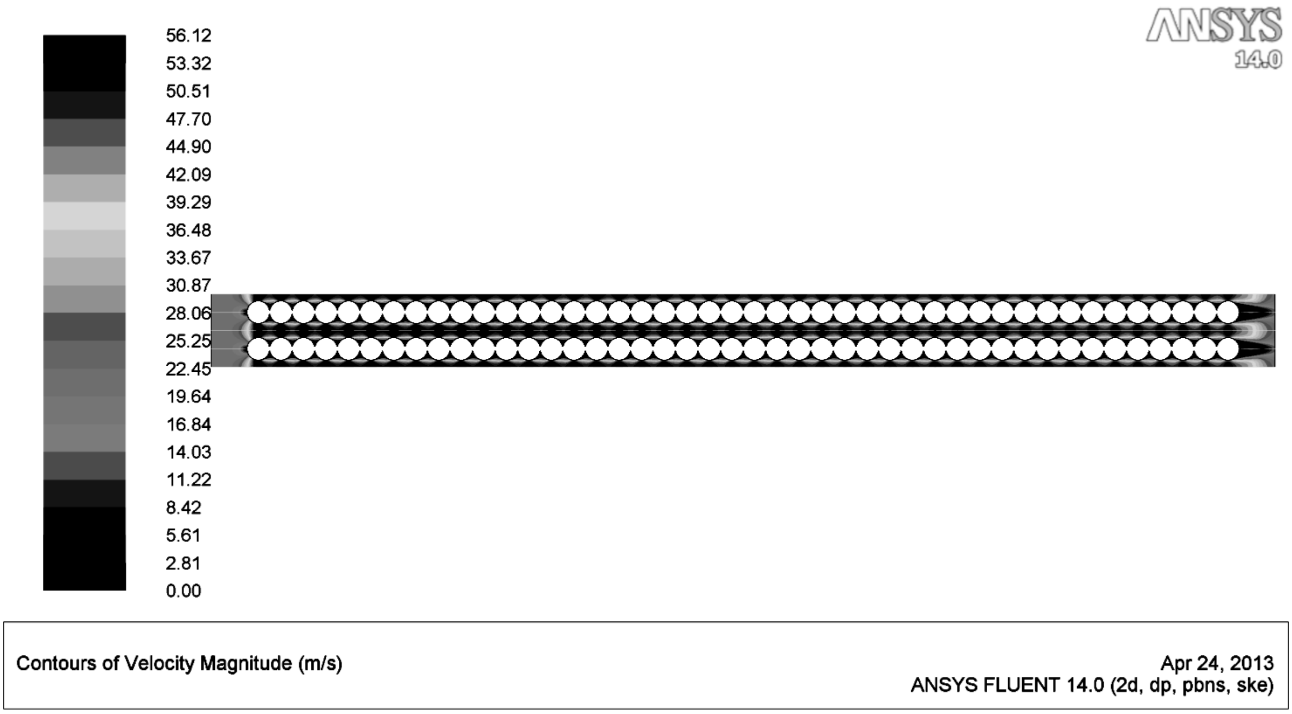

Figure. 5. Air velocity in the channel, m / s.

Detailed distributions of the velocity vector to channel element shown in Fig. 6.

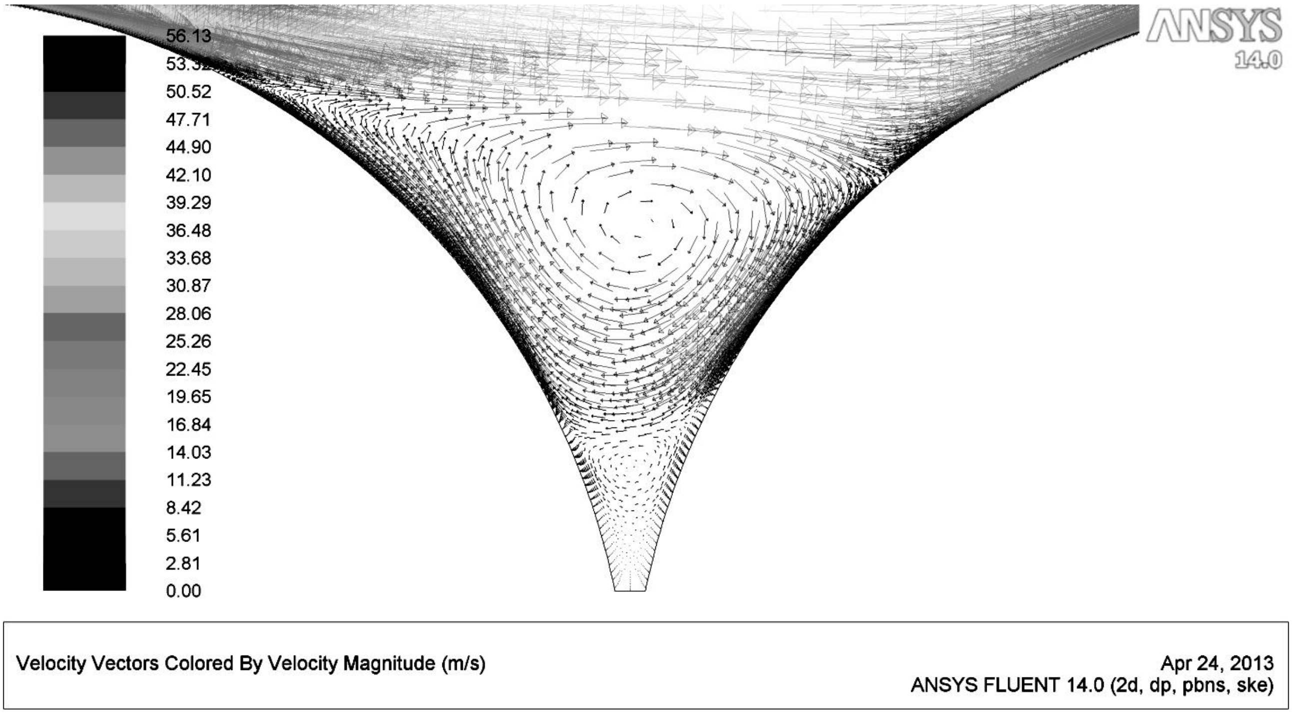

Figure. 6. Velocity vector, m / s.

Studies.

Thus modeling of mass and heat transfer using the application package can determine all the local hydrodynamic and thermal characteristics of the flow in the channels of the heat exchanger. This, in turn, allows you to select the optimum geometry of the heat exchanger.

In carrying out engineering calculations obtained data fully confirmed by calculations using CAD software package ANSYS Fluent 14.0. According to calculations conducted air velocity at the inlet of the channel is 27.3 m/s, inlet temperature 40 °C, on the output of 19.5 ^{o}C. Heat transfer coefficient on the surface - 229.3 W/m2 · °C. The value of the logarithmic average temperature of 16.4 ^{o}C. The total length of 0.352 meters exchanger.

In the above calculations, the calculation was carried out with conventional cylindrical geometry and tube heat exchanger with the staggered arrangement of tubes to compare the results of which are given in the table. Using the results of their conduct comparative analysis. As follows from the calculations of heat transferred from air to water, the water temperature at the outlet of the heat exchanger, the value of the logarithmic average temperature and equivalent diameter did not significantly differ. The coefficient of heat transfer to air heat exchanger for new construction increased 2.5 times and the length of the heat exchanger decreased by 6.5 times.

Conclusions

1. An engineering calculation and tube heat exchanger design for a new cooling poultry house ventilation system. We found that its overall dimensions significantly better performance compared with the known constructions.
2. Numerical modeling of hydrodynamics and heat transfer in the heat exchanger of a new design using CAD software ANSYS Fluent 14.0. Try the local distribution of the velocity field, velocity vectors and temperature.
3. As a result of engineering and numerical calculations proposed a new, efficient design of the heat exchanger to cool the air in the poultry house for the summer season.

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The mathematical modeling of mass and heat transfer in a recuperative heat exchanger to cool the outside air entering the poultry houses is performed. There are performed the engineering calculations and numerical modeling of hydrodynamic and thermal processes using CAD software ANSYS Fluent 14.0 for heat exchanger. The distribution of velocity, pressure and temperature in the heat exchanger, heat exchanger are found.

Heat exchanger, mathematical modeling of heat and mass transfer, engineering calculation.