EFFICIENCY OF THE HEAT EXCHANGER IN A PIG BARN

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Abstract. The article deals with the results of laboratory and field test obtained at the heat exchanger application in order to diminish the deficit of heat energy in a pig barn at cold weather conditions. The test was carried out with experimental heat exchanger, which is made from the cassettes of polyvinylchloride-cage boards with heat transition surfaces of 3.12 m^2 (test in a laboratory) and 100 m^2 (test in a piggery with 500 fattening pigs). The results of the test show, that this type of heat exchanger is able to operate at the outside air temperature till mines 20 ^{o}C and specify directions of further action for increase the efficiency of such kind heat exchanger's application.

Key words: heat exchanger, pig barn, temperature, energy.

Introduction

If the ventilation system for providing optimum microclimate in autumn-winter period in a pig barn is working with the necessary intensity, the deficit of heat often occurs. In order to avert such a situation usually electric heaters are used, but it results in the increase of the consumption of electric energy. The use of electric power can be decreased by applying heat exchangers for returning back into the barn the part of heat taken out. Heat exchangers, which are foreseen for the use in buildings of cattle breeding, are made, for example, by firm *Schonhammer* (Germany) and recommend using them also in pig barns [1]. Until present time in Latvia there heat exchangers are not set and therefore we do not have any experience about the efficiency of practical heat exchangers application for heat stability in piggeries.

Therefore, as the heat exchangers are widely used in many industries of production, the theoretical grounds of the methods of their calculation are comprehensively produced [2]. For all that, in the research about the processes of heat transition the foundation of the investigation is the simulation of the process. It gives the possibility to specify the heat transfer coefficients for the determined technical solution [3].

As more suitable material for our heat exchanger, the polyvinylchloride-cage (PVC-cage) boards are selected [4]. Their main advantages are endurance of corrosion in the aggressive environment of a pig barn and small specific mass. The authors of the article have begun research to extract concrete information about the character and intensity of heat transition in the heat exchanger, made from PVC-cage boards.

Materials and methods

In laboratory circumstances, the test was executed with the model of the heat exchanger. Its technical parameters are as following: length – 2.6 m; running area for each of air flows – 0.006 m^2; distance between next to the former surfaces of heat transition – 0.01 m; the surface area of heat transition – 3.12 m^2. The laboratory equipment used for the tests is presented in Fig. 1. For providing the necessary temperature and humidity of warm inside air, the preheater of a sectional type and vaporizer of water were used. For data acquisition the electronic measuring instruments of Greisinger type with accuracy: temperature – ±0.1 ^{o}C, relative humidity – ±1.5% and air flow speed – ±0.3 m/s were used and the obtained results in a computer registered.

For the test in production circumstances a heat exchanger with following technical parameters was made: length – 3.0 m, running area for each of air flows – 0.175 m^2, total area of heat transition surface – 100 m^2. The heat exchanger was installed in a fattening pig barn with 500 places (Fig. 2). Until now there in the barn no energy sources for warming up of incoming fresh and cold air were used. The airflow at the speed of 3-3.5 m/s through heat exchanger is provided by two 1 kW power radial ventilators, which are placed in the exteriority of the barn. For data acquisition the logger of HOBO H08-007-02 type has been applied. The accuracy for the temperature of air was ±0.4% and for relative humidity – ±5%. During the test in barn circumstances our attention was put also to the condition of heat transition surfaces – its possible coverage with dusts deposition and iced up at low outside air temperature.

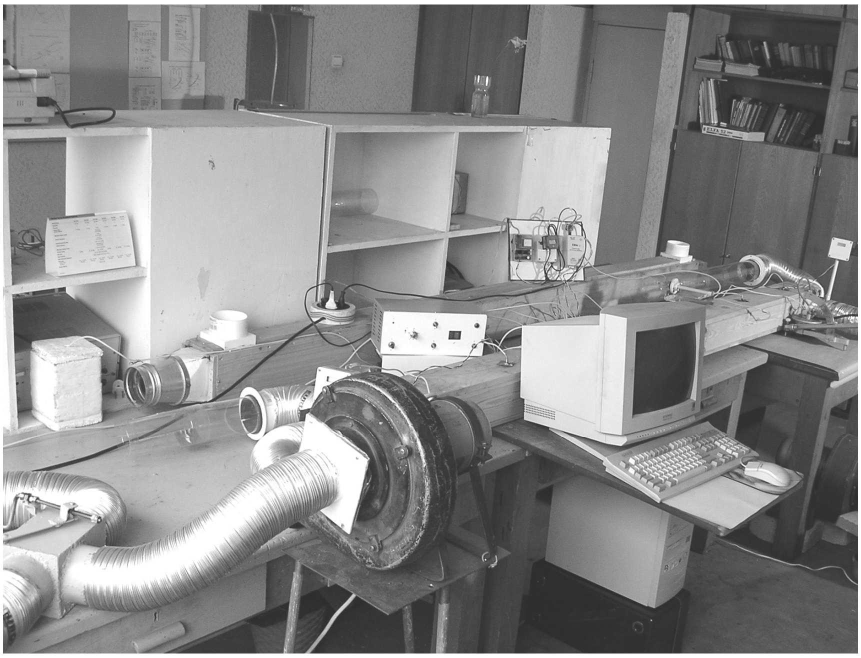

Fig. 1. **Heat exchanger model test in the laboratory**

Fig. 2. **Experimental heat exchanger testing in the fattening pig barn with 500 animal places**

Results and discussion

Considering the measurements of the temperature, relative humidity of air and speed of air streams, by means of coherences 1-5 the characterizing indexes of the work of the heat exchanger were calculated. The power of the heat exchenger

$$Q = v \cdot F_v \cdot \gamma \cdot \left(T_4 - T_3\right), \tag{1}$$

where v – speed of the cold air flow, m/s;
F_v – cross section area of the cold air flow, m^2;
γ – cold air density, kg/m^3;
T_3 – outside air temperature, ^oC;
T_4 – cold air temperature after warming, ^oC.

Coefficient of heat transition

$$k = \frac{Q}{F \cdot \Delta T}, \tag{2}$$

where F – area of heat transition surface, m^2;
ΔT – difference of air flows temperatures, ^{o}C.

Temperatures rate

$$z = \frac{\Delta T}{T_1 - T_3}, \tag{3}$$

where T_1 – inside air temperature, ^{o}C.

Cold air warming rate

$$\eta_t = \frac{T_4 - T_3}{T_1 - T_3}; \tag{4}$$

Effect of moist warming inside air

$$M_{mg} = \left(\frac{T_4 - T_3}{T_{4s} - T_3} - 1\right) \cdot 100, \tag{5}$$

where T_{4s} – corresponding end temperature of cold air at small relative humidity (without condensation).

The laboratory test results of the model of the heat exchanger are presented in Table 1. The coefficient of heat transition in case of moist air in comparison with dry air has the tendency of increase. It can be explained with that on the surfaces of heat transition there the layer of condensate has appeared, which increases the heat transmission in comparison with a dry surface. The increase in air relative humidity rises the rate of air warming and other parameters also.

Table 1

Results of heat exchanger's laboratory test at the speed of air flow 4 m/s in dependence on the relative humidity of inside air

Relative humidity of inside air, %	Coefficient of heat transition k, W/m^2·^{o}C	Rate of temperatures z	Rate of air warming η_t	Effect of moist air M_{mg}, %
20 – 25	14.5	0.44	0.57	0
70 – 75	16.6	0.46	0.68	13.8
80 – 85	17.2	0.46	0.71	18.9

The parameters placed in Table 1 enable to calculate the power of such type of heat exchanger by the use of expression

$$Q = F \cdot k \cdot z \cdot (T_1 - T_3) \tag{6}$$

and the temperature of warmed air by formula

$$T_4 = (T_1 - T_3) \cdot \eta_t + T_3. \tag{7}$$

During the trials of the experimental heat exchanger in the fattening pig barn the outside air temperature changed from +5 ^{o}C to -27 ^{o}C. The average temperatures on separate 5-days periods are given in Fig. 3.

The change of external air temperature influences the intensity of its warming up and the temperature of air in the barn also. In Fig. 3, the curves of the alteration of heat exchanger power in corresponding days are presented, too.

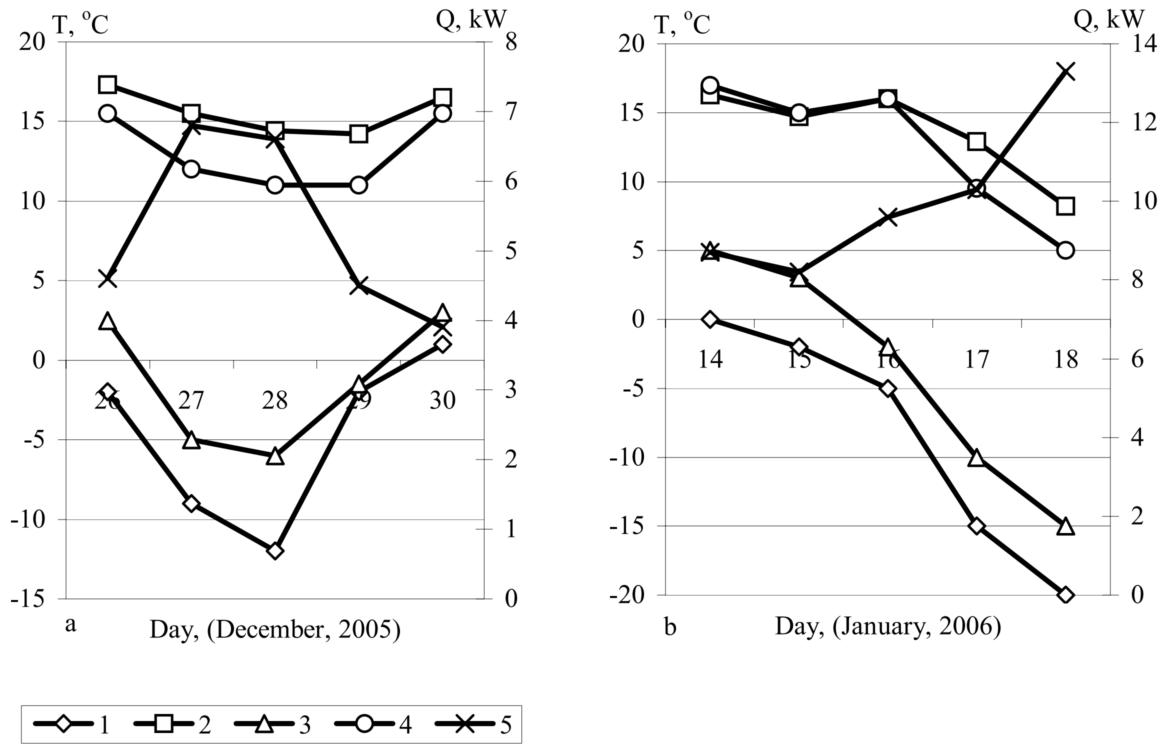

Fig. 3. **The heat exchanger power on separate 5-day periods**: 1 – average temperature of external air; 2 – average temperature of air in barn; 3 – average temperature of air flowing into the heat exchanger; 4 – average temperature of warmed up air; 5 – power of the heat exchanger; a – December 26-30, 2005; b – January 14-18, 2006

In Table 2 the average values of data obtained during the experimental heat exchanger exploitation are collected depending on the temperature of external air at mean relative humidity of inside air 75%. The main amount of information in December 2005 and in January 2006 are obtained at the outside air temperature till -8 °C. The measurements of the temperature within intervals above -8 °C shows, that when air temperature outside of the pig barn subsides, the temperature inside the barn and warmed up air falls also. At the same time the power of the heat exchanger increases from 6.3 kW to 11.2 kW.

Table 2

Main data of experimental heat exchanger exploitation in a 500 fattening pig barn depending on the external air temperature at the average relative humidity of inside air 75% and average speed of air flows 3.3 m/s

Interval of external air tempera-ture, °C	Amount of days in a period	Inside air temperature T_k, °C	Temperature of warmed-up air T_4, °C	Temperature of getting cold air T_2, °C	Coefficient of heat transition k, $W/m^2 \cdot {}^oC$	Power of heat exchanger Q, kW
+5 … +2	7	17.0	14.6	10.9	13.8	7.3
+1 … -1	5	16.9	14.9	11.5	14.6	8.7
-2 … -5	11	15.6	12.9	8.8	13.9	9.7
-6 … -8	4	12.9	11.4	6.4	18.9	12.2

At low temperatures of external air the data are obtained only in separate days and they can be only illustrative. At the temperature of external air -20 °C the cold air flowed into the heat exchanger with the temperature -15 °C and was warmed up till +3 °C. The air temperature in the barn fell down till +10 °C. The going out through the heat exchanger inside air got cold to 0 °C, it is, iced up began. When the external air temperature fell down under -20 °C the device was switched off (Fig. 3b). The heat exchanger resumed its work after the increase of external air temperature above -15 °C.