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RESEARCH ON EFFICIENCY OF HEAT RECOVERY IN THE CROSS-PLATE HEAT EXCHANGER MADE OF PLASTIC

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Abstract: The article content the results of study of heat exchanger. Exchanger was made of plastic material: polystyrene. The measurement results were used for efficiency analysis of this type of heat exchanger as an alternative to the commonly used heat exchangers made of aluminum.

Keywords: heat exchanger, heat recovery

1. INTRODUCTION

The article presents an analysis of the results of the research on the cross-counterflow type heat exchanger made of plastic. This type of exchanger could be an alternative to the classical heat exchanger made of aluminum. Changes were made in Polish law according to the regulation of the Minister of Transport, Construction and Maritime Affairs of 5 July 2013, respecting the technical requirements to be met by buildings and their location forces using heat recovery in intake-exhaust ventilation systems, for the size of the supply air stream a height of 500 m^3/h. For these changes, a necessary consequence of the consumer market response is increased demand for small air handling units. High aluminum prices on world markets (1834 USD/Mg - the average price for the last 12 months) and the research for new solutions to the energy issue, gave rise to a new exchangers base made of plastic. They are much cheaper to make, and by an appropriate design they are close with their parameters to the aluminum heat exchangers. Experiments proves that air handling units working with ex-

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changers constructed of plastic have comparable parameters for the same size of the external air flow and exhaust with lower price.

2. CHARACTERISTICS OF PLATE HEAT EXHANGERS

Construction of plate heat exchanger is simple, their high reliability is related to the absence of moving parts and high durability of both the structure and the heat exchanger. Price to effectiveness ratio of exchangers undoubtedly affect their widespread use in case of both cold recovery in summer and heat recovery in the winter. The efficiency of these heat exchangers frequently reaches values of 70% for equal streams intake and exhaust air, in the case of counterflow heat exchangers this parameter can be up to 95%. However, in this kind of solution, larger stresses occur and the stability is somewhat shorter compared with co-flow exchangers.

Thermal power of plate heat exchanger for the specific geometrical dimensions depend on:

- the surface area of the membrane separating the exhaust and intake air streams,
- the mean temperature difference for the entire surface area of heat exchange,
- heat transfer coefficient values for the elements of heat exchange that separate the membrane of abounding exhaust and intake air streams,
- specific heat of heat carrier,
- the mass flow of heat carrier,
- the ratio of both air streams volume.

Plate heat exchanger is characterized by the best price to efficiency ratio in comparison to other heat recovery systems, hence it is a common equipment for mechanical ventilation for heat recovery in buildings with a lower standard. This solution allows a significant reduction of heat consumption, and consequently - the costs of the building management. The disadvantage of plate heat exchangers is a large ratio of volume of the device to the individual air flow which significantly affect the size of the air handling units equipped with heat recuperation, in opposition to the central equipped with other devices for heat recovery (Rosiński, 2008).

3. CHARACTERISTICS EXCHANGER MADE OF PLASTIC

The research was placed in a heat exchanger ventilation unit, allowing the recovery of heat implemented by forcing air flow in counterflow, through the cross heat exchanger. Process for heat recovery in the test unit is based on the use of a heat exchanger in which the heat exchange through the membrane which is separating the streams of the heat intake and exhaust, flowing in relation to each other in counterflow. The air flow was forced by two fans arranged in a air handling unit, one on the side of supply air and one on the exhaust side. The tested heat exchanger is made entirely of polystyrene from foil to the casing, thus reducing the cost of its production, while maintaining its properties: thermal conductivity and durability of the structure. The length and width of the heat exchanger is 366 mm, and its height may be in the range from 150 mm to 500 mm (height of the test exchanger 500 mm).Heat exchangers can be applied to air temperatures range from -20 to + 50°C. The weight of the exchanger is 5 kg and the heat exchange surface is approximately 36 m^2. The volume of the heat exchanger is 51 liters. The heat exchanger may take the air flow of up to 500 m^3/h.

4. THE METHODOLOGY OF THE RESEARCH PROCESS

During the experiment specific thermodynamic parameters of air, i.e. temperature and relative humidity of the external air and the exhaust air (room temperature) was determined. After starting the calorimetric chambers parameters was established in a computer program which was controlling operation of devices. Parameters was set on 5ºC and 45% relative humidity for intake air and 24ºC and 31% relative humidity for exhaust air. After stabilization of air parameters, measurements were made in four sections: outside air, air removed from the room, air at the exhaust and air at the supply to the room. During the measurements all the measured values of temperature, relative humidity were recorded and pressure drop across the regenerators was controlled. Two cold rooms (also called calorimetric) were used, which were designed to provide the recuperator air with thermodynamic parameters simulating the conditions in the room (air removed) and outdoor air (air drawn).

Cooling chamber "Winter" was built in three sections. First section is a part where supply air hits. In this section, it is cooled to a temperature lower than outside air temperature. The lower temperature is the result of a simple analysis associated with inertia of higher adjustment of the cooling system relative to the heater controlled by the inverter, supposed to heat up the air, which is hitting the exchanger, to the outside air temperature. Between each of the sections there is perforated mesh of appropriate size in order to reduce the flow, so that air in the third and final section has obtained a laminar flow. In the second section is heater with the appropriate angle outflow on the floor and the ceiling. This heater have to mix the air inside the second section and its heat up the whole cross-section, make air parameters equal as far as possible. In section 3 mixed air with laminar flow goes to air supply ventilation duct. Then air passes through the velocity stack, and then returns back into chamber and looping system.

In the hot chamber called "Summer" air brought to the first section, as exhaust air is heated and moistened adiabatically through nozzles which sprayed pressurized water. Humidified air goes to the second section, where it is further heated and mixed throughout the cross-section, then goes through third section to air handling unit as removed air. Then air is returning to hot chamber looping the cycle.

5. SCHEME OF TESTING-BENCH

This chapter presents the of testing-bench together with the location of temperature sensors and relative humidity in the four cross-sectional planes. Bench is testing heat exchangers efficiency. In fig 1. we can see construction of the plate heat exchanger.

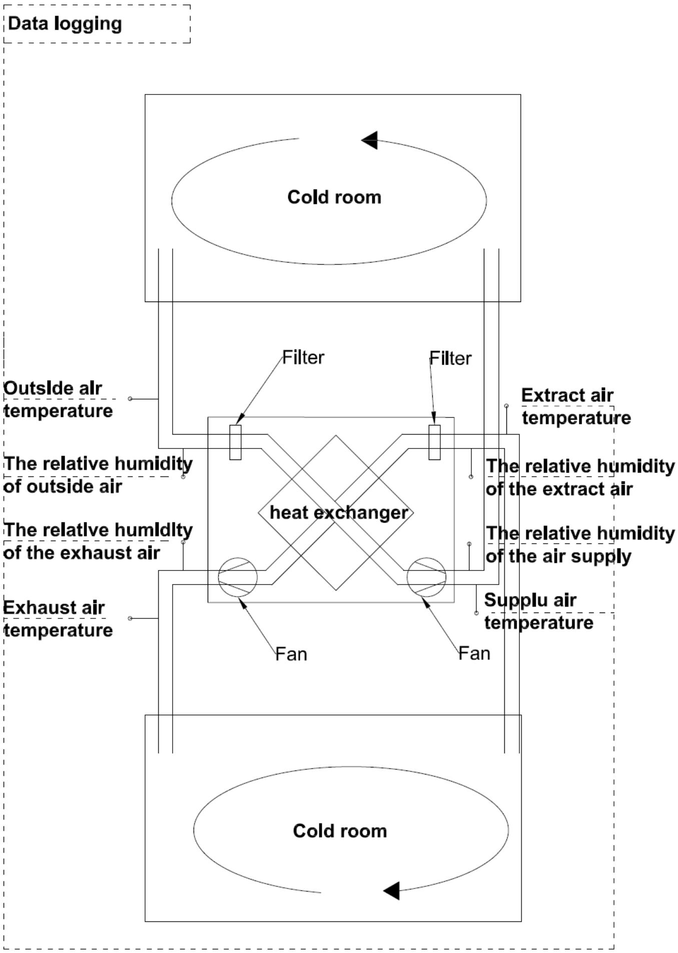

Fig. 1. The scheme of the testing-bench for heat exchangers and construction of the plate heat exchanger

6. MEASUREMENT OF PARAMETERS ON THE BENCH

The temperature of the air entering the unit and effluent from the control was measured using temperature sensors Genesis GPE-DA-160-Pt100-KLA.In each connector a sensor was placed in the position marked on the diagram (Fig. 2), from which a temperature signal obtained in the cross section.

For measuring the relative humidity in the connector the relative humidity transmitters INTROL type: EE31 were used. This transmitters characterized by high accuracy, stability and low hysteresis.

The measurement of the pressure drop was performed using a transmitter to measure low and differential pressures Model DP-10.

For the registration of air temperature, pressure and relative humidity data logger was used. The measured values were recorded every 2.5 seconds.

Measurement of the air stream flowing through the heat exchangers were performed using the quadrant nozzle with a diameter of 80 mm throat made in accordance with the PN-93 / M-53950/01.

7. INTERPRETATION OF RESULTS

In the section drawings of air parameters change in the characteristic points, and changes in the value of air flow during the measurements are shown. The summary of them is a graphical representation of the results of measurements marked on Molière chart.

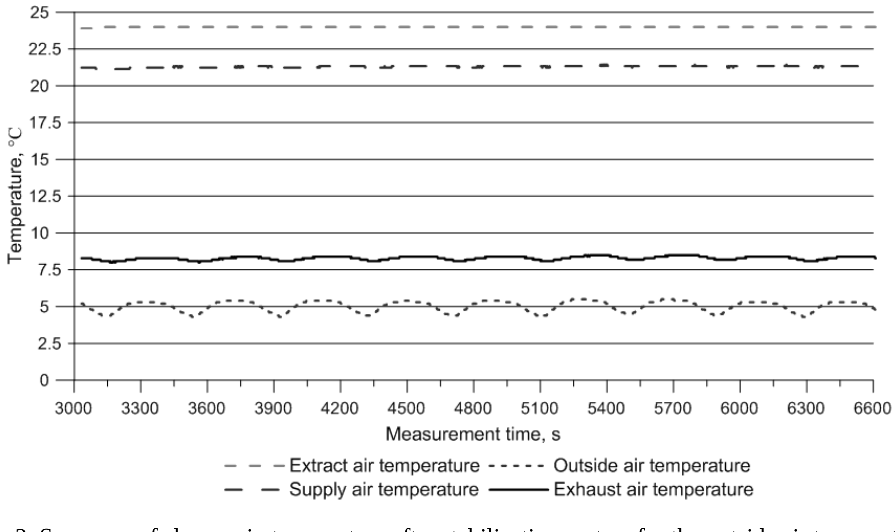

Fig. 2. Sequence of changes in temperature after stabilization system for the outside air temperature of 5°C and 24°C – temperature of removed air

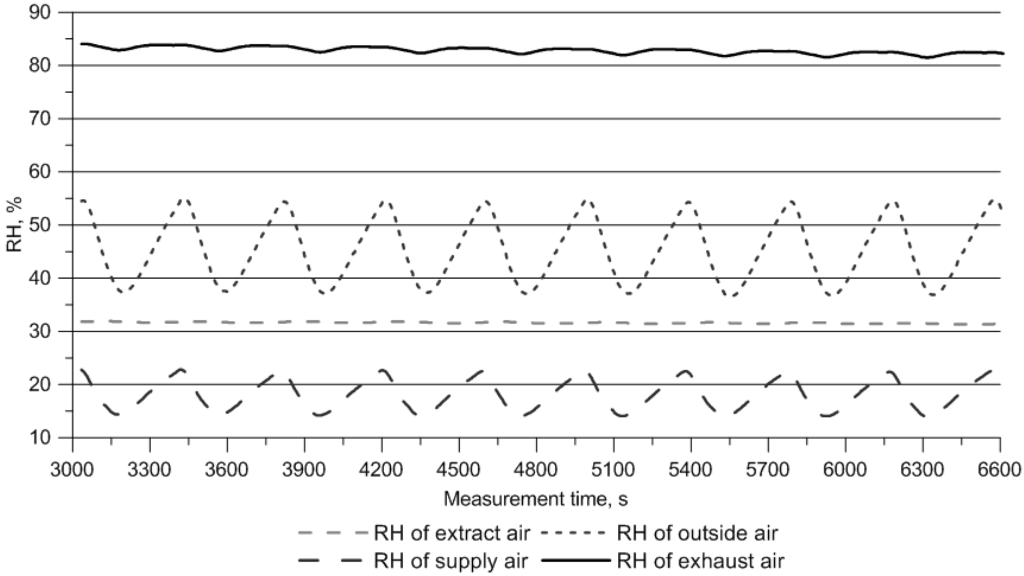

Fig. 3. Sequence of changes in relative humidity of the outside air for the outside air temperature of 5°C and 24°C – temperature of removed air

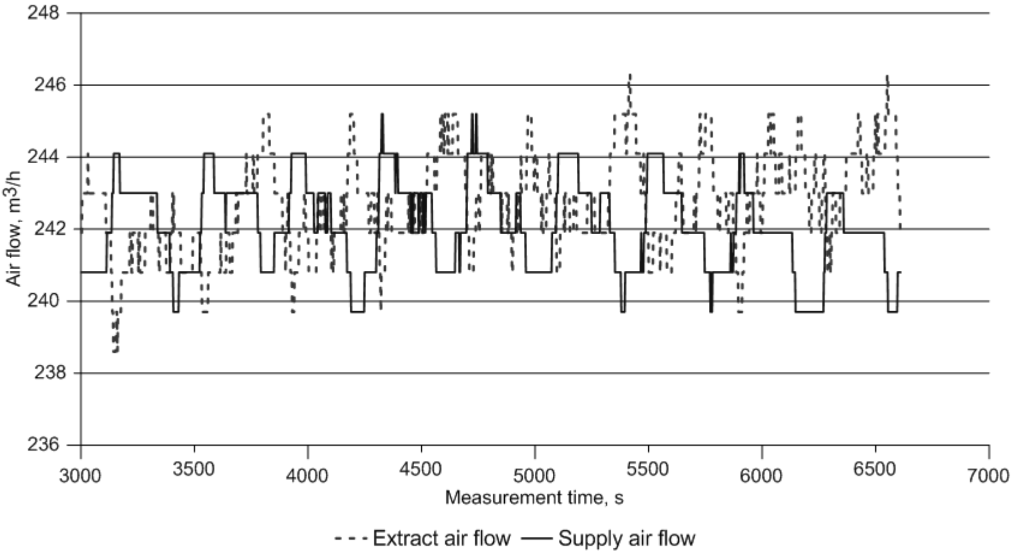

Fig. 4. Sequence of changes of air flow for exhaust and outside air for the outside air temperature of 5°C and 24°C – temperature of removed air

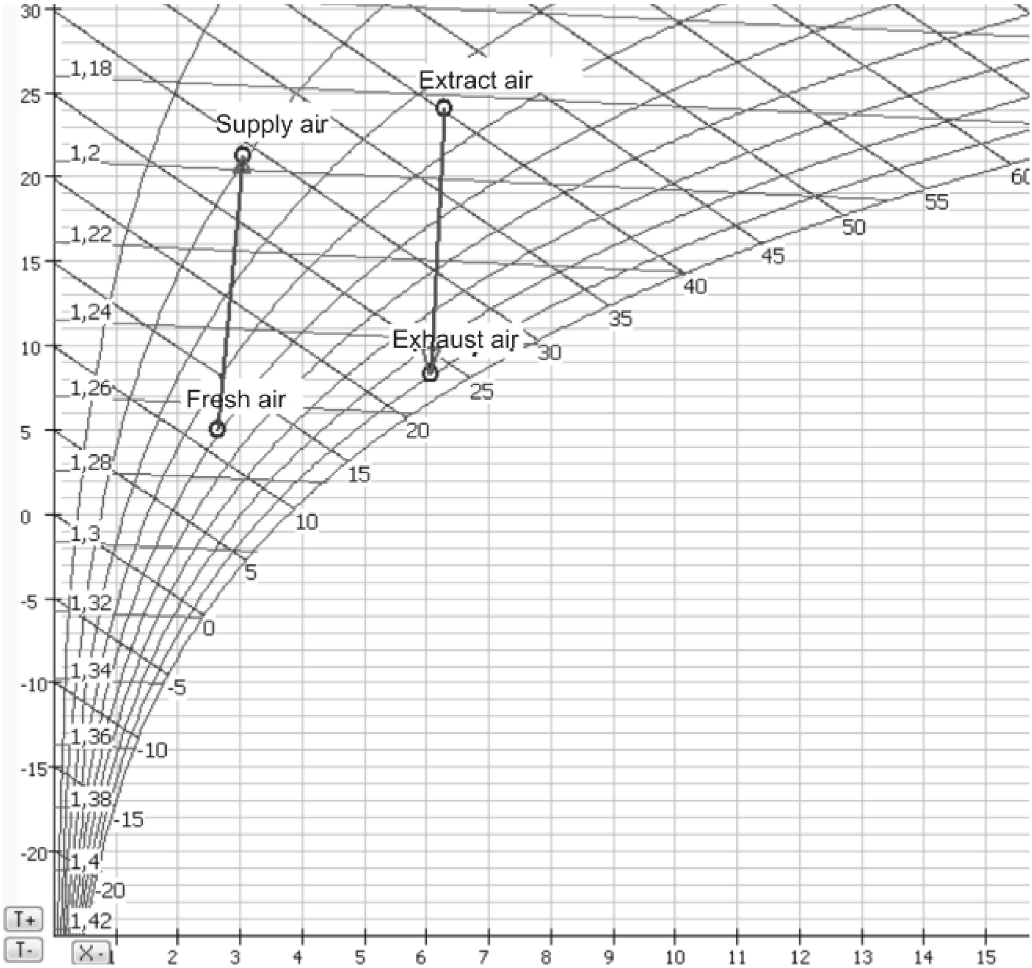

Fig. 5. Changes of air flowing through the heat exchanger for the outside air temperature of 5°C and 24°C – temperature of removed air

Tab. 1 Provide readings of averaged measurement results for a steady state. In Tab. 2 calculated enthalpies and specific humidity air for four characteristic points of the air necessary to determine the overall efficiency of heat recovery and temperature was set. Tab. 3 and 4 presents the results of measurements of temperature, i.e.: the efficiency and total effectiveness, the key value in order to evaluate the efficiency of heat recovery.

Table 1. Relative humidity temperature values for points from charts.

	The parameters of the supply air		Exhaust air Parameters		Parameters of the exhaust air		Condition of outside air	
	Temperature	The relative humidity	Temperature	The relative humidity	Temperature	The relative humidity	Temperature	The relative humidity
	ºC	%	ºC	%	ºC	%	ºC	%
Series 1	21.26	18.12	24.02	31.52	8.28	83.04	5.03	45.49

Table 2. Enthalpy and humidity values for points from charts.

	The parameters of the supply air		Exhaust air Parameters		Parameters of the exhaust air		Condition of outside air	
	Specific humidity of the	Enthalpy	Specific humidity of the	Enthalpy	Specific humidity of the	Enthalpy	Specific humidity of the	Enthalpy
	g/kg	kJ/kg	g/kg	kJ/kg	g/kg	kJ/kg	g/kg	kJ/kg
Series 1	2.85	28.60	5.88	39.10	5.67	22.59	2.48	11.28

Table 3. Effectiveness of sensible heat recovery.

	The supply air temperature	Exhaust air temperature	The extract air temperature	Outside air temperature	Thermal efficiency heat recovery
	ºC	ºC	ºC	ºC	%
Series 1	21.26	24.02	8.28	5.03	85

Table 4. The total heat recovery efficiency.

	The supply air enthalpy	Exhaust air enthalpy	The exhaust air enthalpy	Outside air enthalpy	Total heat recovery efficiency
	kJ/kg	kJ/kg	kJ/kg	kJ/kg	%
Series 1	28.60	39.10	22.59	11.28	62

8. SUMMARY

Exchanger were tested in winter conditions, for the average air flow control of 240 m^3/ h (fans operating at 50%). It can be concluded that the heat exchanger has a high efficiency of heat recovery at low temperatures. Temperature efficiency of 85% (for external temperature of 5°C) has been shown. Total efficiency was 62%, which can be assessed as high efficiency of counterflow heat exchangers. During the measurements a slight decrease of flow in air handling unit was recorded. This decrease was driven by additional slight increase in resistance caused by water condensing on the walls of the exchanger, and thus a slight narrowing of the free cross-sectional area of exchanger. The confirmation of this phenomenon was the lowest recorded exhaust air temperature amounting to 8.4°C. To summarize it could be said that the panel used in the cross-counterflow heat exchanger made of plastic, received a high efficiency heat recovery, thus competing with the classical plate heat exchanger. By using triangular channels, arranged in such a way that each of them is surrounded by parallel channels in which the air flows in counterflow, there is an increase in the surface on which energy can be effectively transmitted, captured and reused. Thanks to this structure, high efficiency of heat exchanger is obtained, which at a reasonable price and a long service life allows for a very short return on investment.

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