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Simulation of the efficiency of improved regenerative decentralised ventilators Vents TwinFresh

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Abstract: The work is devoted to modelling Twin Fresh ventilator efficiency. The main aim is to simulate heat exchanged in a heat regenerator in variable conditions. The mathematical model is based on Navier-Stokes equations for laminar flow. The model is designed to achieve an adequate time for calculation and sufficient precision. The results show high efficiency of heat recovery in the order of 97.4%.

Keywords: heat regeneration, heat recovery, CFD, temperature coefficient of efficiency

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Introduction

The main task of developing systems for microclimatization is reducing power consumption without reducing the ambient climate quality on premises. Utilization of the wasted heat from exhausted airflow is necessary. There are a large number of devices that can achieve this: plate recuperators, recuperators with intermediate heat mediums, regenerative heat recovery units etc. In recent years, decentralized ventilation has become common. Unlike combined extract-and-input ventilation installations, decentralized ventilation systems do not need bulky equipment and a network of ducts that require a lot of space and investment in the premises. One such device is a regenerative ventilator. Blauberg ventilators and TwinFresh vents are market leaders in their fields.

This work considers TwinFresh ventilators (Fig. 1). According to the user manual (User’s, 2019), the first speed mode of the ventilator (slow mode) is $L = 10$ m^3/h, the second speed mode is $L = 20$ m^3/h and the third speed mode is 30 m^3/h.

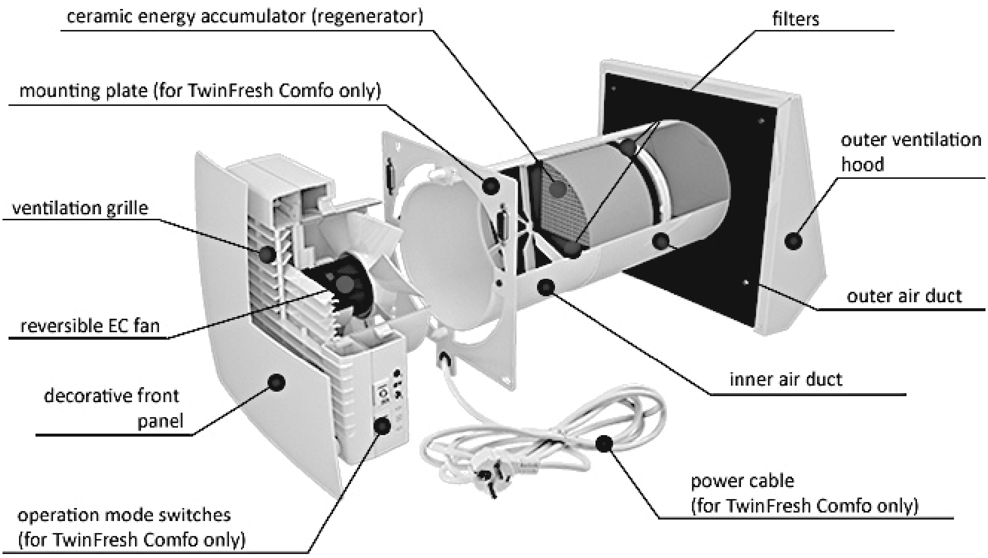

Fig. 1. Scheme of the ventilator TwinFresh (Ventilators, 2019)

1. Design of the model in SolidWorks

To estimate the operational efficiency of the regenerative ventilators, a simulation in the SolidWorks software was created. It should be noted that the airflow in the ducts of the ventilator is laminar. (Mileikovskyi & Vakulenko, 2019). The design features for different ventilator models were given by the Vents company:

- the length of a typical regenerator $\ell = 0{,}15$ m;
- the diameter $D = 0.14$ m;
- the cross-cut of the duct has an hexagonal form;
- the material is ceramic.

In the first stage of design, a complex heat regenerator model was designed (Fig. 2). It was protected on all sides by an “Insulator” (suitable material without any heat conduction). However, due to a large number of cells in the calculation, the calculation took a long time and was not completed.

To limit the number of nodes, a quarter of the structure with boundary conditions “symmetry” or only two rows of ducts with boundary conditions “periodicity” was chosen (Figs. 2, 3). Neither of these options solved the problem because of the high number of nodes. The problem was solved by considering the central duct and half of all adjacent ones with boundary condition “periodicity” (Fig. 4).

Hence, because of the high number of central ducts (over five hundred), the edge effects are low. In fact, a structure with an infinite number of ducts was simulated. As the airflow in ducts is laminar, and also the ducts are symmetric and equal, the velocity profile in them will be symmetrical and equal.

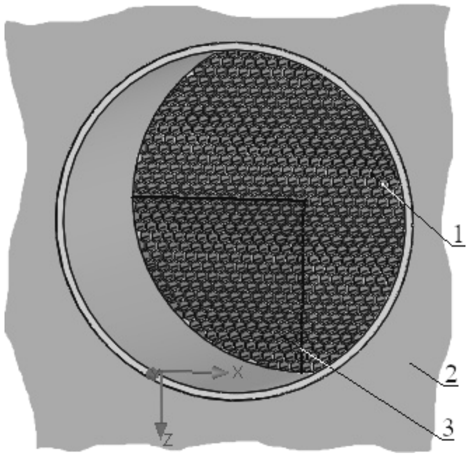

Fig. 2. Heat regenerators in general: 1 – ceramic heat regenerator; 2 – "insulator"; 3 – the estimated area (*own research*)

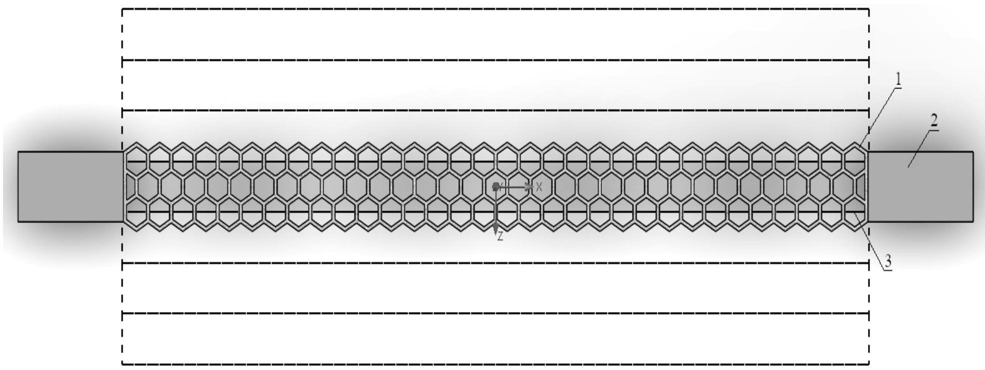

Fig. 3. Two-channel model: 1 – ceramic heat regenerator; 2 – "insulator"; 3 – the estimated area (*own research*)

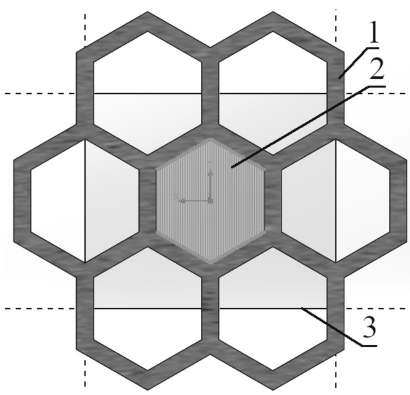

Fig. 4. Model of one duct and six adjacent ones: 1 – ceramic heat regenerator; 2 – sketches for averaging the temperature at the beginning and end of the channel; 3 – the estimated area (*own research*)

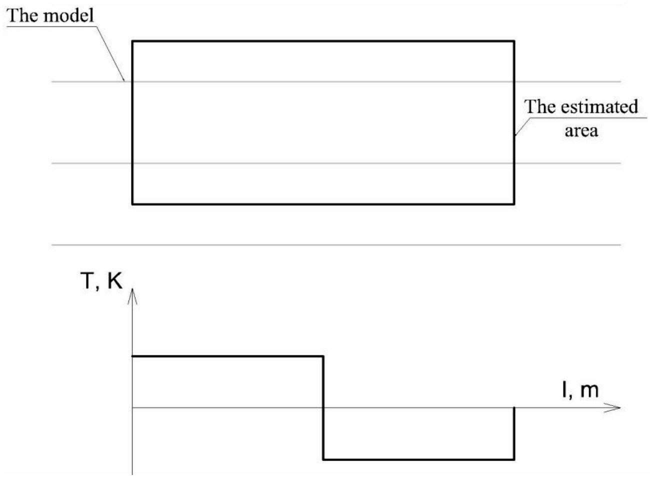

Fig. 5. Scheme of setting the air temperature in the model depending on the length (*own research*)

These facts enable the simulation of half the ducts with due accuracy at boundary conditions "periodicity" or "symmetry". Because of porous filters at both ends, the initial flow is even without vorticity.

The operating regime of the heat regenerator is time-dependent. There is a problem to simulate the changing air direction because of the absence of a feature to change the boundary condition "inlet opening" and "outlet opening" automatically. To solve this problem the "external task" was used. It allowed the changing of the flow direction in time. For this, the computational domain is manually defined to immerse the lateral faces into the model (Figs. 2-5). As the "initial and ambient conditions", the velocity components are used. An attempt to set the air temperature according to time duration was not successful. The air temperature is used only for the air particles that emerged outside the model.

If the temperature at a certain time moment is the same for all particles that come into the model, then on both boundaries considerable temperature difference arises because of very small fluctuations. If only one particle appears at the wrong side due to rounding errors, it causes significant flow disturbance by gravitation. Therefore, the temperature is only set depending on the coordinate along the duct axis. Because there are no air sources within the model, the continuity equation should be used. Then, starting from the second iteration, the temperature will be used only for the air that comes through the model edges. For half the length of the model, the outside air temperature of 253.15 K is set. For the other half, the inside air temperature of 293.15 K is set.

Changing movement direction according to the manufacturer's specification is performed every 70 s. For correct modelling and avoiding the appearances of parasitic disturbances and flow turbulence, it is necessary to simulate the transient process of fan reverse. The manufacturer does not provide the specification of the actual transition process. Therefore, two seconds as the time of switching are chosen due to the absence of disturbances. The time step of one iteration is 0.01 s.

The average air and solid temperature [K] as the "global goals" were set. For determining the efficiency of heat recovery, it is necessary to calculate the coefficient of temperature efficiency (Barkalov & Karpis, 1982):

$$E = (T_{c,2} - T_{c,1})/(T_{h,1} - T_{c,1}) \quad (1)$$

where:
$T_{c,1}$ – outdoor air temperature [K],
$T_{c,2}$ – air temperature after the heat recovery unit [K],
$T_{h,1}$ – indoor air temperature [K].

To obtain the temperature at the boundaries of the calculation area, sketches have been drawn as evenly spaced parallel segments (Fig. 4) that evenly fill the whole cross-section. The temperature table was exported to a spreadsheet program using the "XY plot" command. This temperature table should be averaged proportional to the length of each segment.

To stabilize ventilators, 10 cycles of air inlet-outlet was done and only then the results could be analysed.

2. Results of the simulation

As a result of the simulation, we obtained charts of the regenerator and air temperature change [K], dependent on the time [s] (Figs. 6 and 7). The charts show that 10 iterations are enough to stabilize the regenerator operation as the next cycle almost repeats the previous one. The simulation showed a high efficiency of heat recovery (Fig. 8). The average temperature effectiveness is E = 97.4%, which meets the requirements for heat recovery devices.

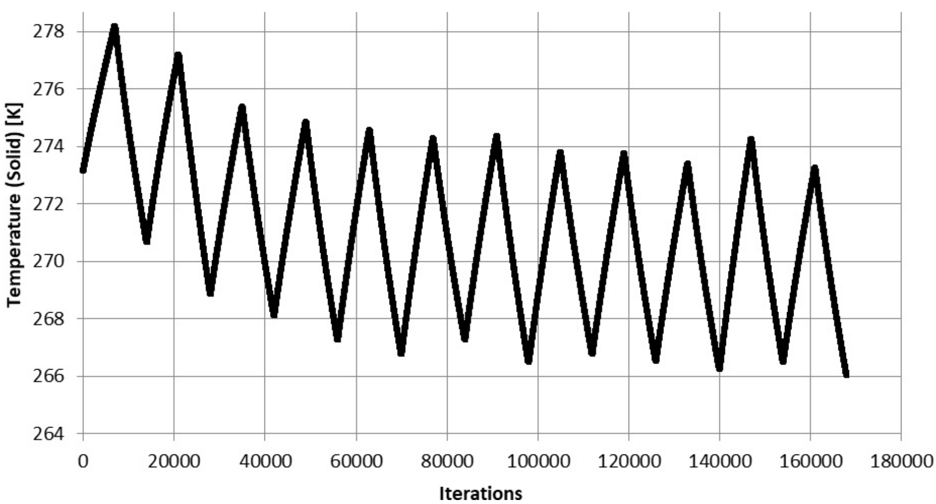

Fig. 6. Chart of regenerator's solid temperature changes in time (*own research*)

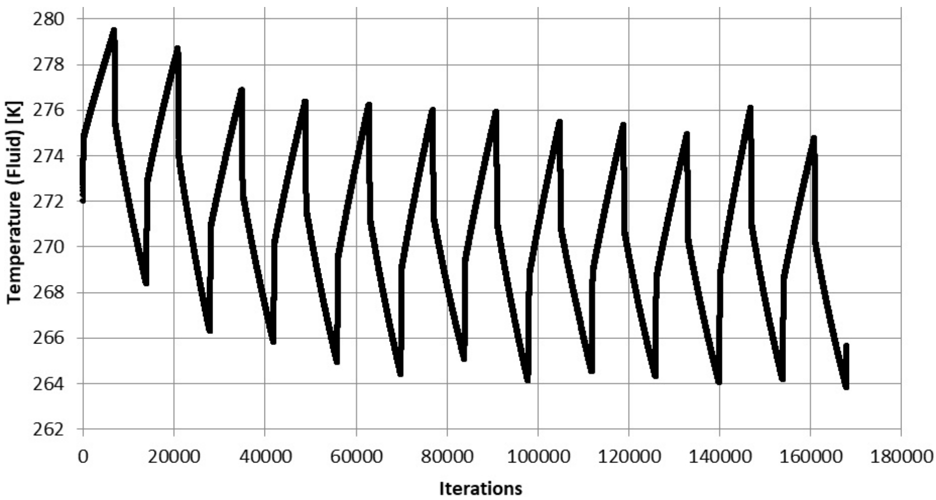

Fig. 7. Chart of regenerator's fluid temperature changes in time (*own research*)

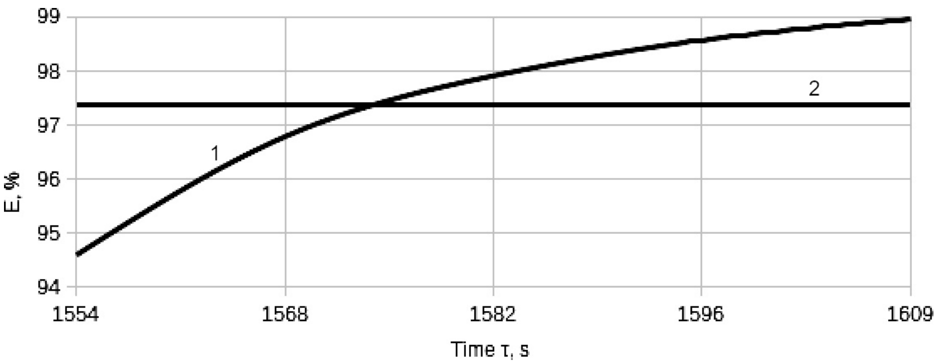

Fig. 8. Temperature coefficient of efficiency [%]: 1 – time dependence τ [s], 2 – the average value (*own research*)

Conclusions

A simulation of a TwinFresh ventilator's efficiency with the modified heat re-generator showed high efficiency of regenerative ventilators during the whole work cycle, between 95-99%. The average efficiency is 97.4%. These parameters meet current requirements for heat recovery equipment. Therefore, the ventilators are recommended for different types buildings.

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