Energy economic suitability of the use of "air-air" recuperators with ribbing of pipes for exhaust air

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The issues of energy saving in buildings are considered by using recuperators to save heat and cold, lost when removing air from the buildings space and transferring some of the energy to the fresh air that is supplied into the premises. Such heat exchangers can be a part of the mechanical ventilation system, as well as stand alone and carry out partial (due to heat exchange) or complete heating of fresh air (by using a heat transfer agent or an electric heater).

Methods

the thermal efficiency may serve as energy characteristic of such recuperators, determined by the following formula: $\eta^{i}_{r.} = \frac{t_i - t_u}{t_f - t_u}$

Where t_i, t_f **- are the temperatures of fresh and exhaust airs before and after the recuperation,** t_u **is the temperature of the outdoor air.**

However with the value it is impossible to determine the average-seasonal values of the thermal efficiency. In order to determine the average seasonal thermal efficiency, considering the temperature-hours of each month and season, the following formula is proposed:

$\eta^{m.sez.}_{r.} = \frac{\sum_{j=1\div n} \eta^{m.sez.j}_{r.} \cdot z^{m.}_{t^{j}_{n.w.}}}{\sum_{j=1\div n} z^{m.}_{t^{j}_{n.w.}}}$ **where** $\eta^{m.sez..j}_{r.}$, $z^{m.}_{t^{j}_{n.w.}}$ **- thermal efficiency of the recuperator and quantity of hours of temperatures** $t^{j}_{н.в.}$ **for the given** j **month.**

Thermal efficiency, metods

- romising devices, since they are the most energy-efficient and small-sized.
- "Pipe in pipe" type recuperators with ribbing of pipes for the exhaust air are the most p"Pipe in pipe" type recuperators with ribbing of pipes for the exhaust air are the most promising devices, since they are the most energy-efficient and small-sized. When we have three-, four-pipe recuperators of a similar type have a thermal efficiency from 0.125 to 0.287, and 8- pipe ones have efficiency of 0.392 [20]. Calculations show that for ribbed one it is 0.125...0.185.
- The principal diagram of the recuperator is illustrated in figure 1
- Figure 1
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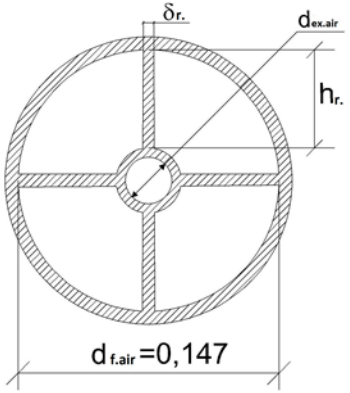

- .
- In this case, besides the abovementioned dimensions: $d_{eh.air} = 0.04,\ d_{\text{f.air}} = 0.147,\ L = 1.4$ m the description values are: the rib width - $\delta_{ed.}$ height - $h_{\text{ed.}}$, their quantity - $n_{\text{ed.}}$: If the values $\delta_{ed.}$ may be assigned in the conditions of the given problems, $h_{\text{ed.}}$ then may be obtained according to $d_{\text{eh,air}} = 0.04,\ d_{\text{f.air}} = 0.147$ $h_{\text{ed}} = \left(d_{f.air}^{in.} - d_{eh.air}^{out.air}\right)/2$

metods

- As a result of the ribs and their number, the section of the fresh air pipe will decrease: $f_{f.air}^{l.sec.}$ and the flow speed: $\omega_{f.air}^{ed.}$ accepting $f_{f.air}^{l.sec.} = V_{f.air} / \omega_{f.air}^{ed.}$ for the decision of $\omega_{f.air}^{ed.}$ we will have
- $\omega_{f.air}^{ed.} = \dfrac{4 \cdot V_{f.air}}{\pi \cdot A'}$ where A' will be determined: $A' = \left(d_{p.oq} - d_{h.oq}\right) \cdot \left(d_{p.oq} + d_{h.oq}\right) - \dfrac{4}{\pi} n_{ts} \cdot \delta_{ts} \cdot \left(d_{p.oq} - d_{h.oq}\right) / 2$
- According to [21], when we have a process of "pipe in a pipe" and a ribbed pipe rinse with longitudinal flow of fluid, it can be accepted that we have a circular pipe and a criterion for turbulent flow motion; it will be defined by the following expression:
- $\dfrac{Nu_{1ed\,\infty}}{Nu_{paip\infty}} = \left[1 - \varphi(\mathrm{Pr}_l)\right] \cdot \left(\dfrac{d_2}{d_1}\right)^{n(\mathrm{Pr}_l)} \xi$ (4), (4) is applicable when we have the condition:

$$0^4 \prec \mathrm{Re}_{l,d_э} = \frac{\omega \cdot d_{eq}}{\nu_l} \prec 10^6 \qquad d_{eq} = d_2 - d_1$$

- For the latter, according to [18], we have the expression , and if placed in the furmula of double-pipe heat exchanger (4), we $Nu_{paip\infty}$ will have the value we were looking for.
- At the same time, in the formula of definition, when $Nu_{1ed\infty}$, the following $n_{ed} = 12...36$ value should also be taken into account: $\psi = 1.2ehp\left(-0.25 \cdot n_{\mathrm{ed}}\right)$
- More accurate values may be obtained if the diameter equivalent to d_{eq} is defined from the expression $d_{eq} = \dfrac{4 f_{f.air}^{l.sec.}}{u}$ Where $u = \pi d_{\mathrm{f.air}} - n_{\mathrm{ed}} \delta_{\mathrm{ed}}$

Metod

Then we will define the values , and the heat amount, transferred in the heat exchange process, in case of the air anti - flow movement [21, 22] will be: $Q = \alpha_{eq} F (t_o - t_{l2})$, , $\alpha_{eq} = \frac{\alpha_{ed} F_{ed} \eta + \alpha_w F_w}{F}$

- α_{ed} is the heat exchange given coefficient, α_{ed} , α_w are the coefficients of heat exchange processes taken place by the ribs ad bearing wall, W/m^2, deg., F_{ed}, F_w are the areas of walls, without ribs and ribbing, $F = F_{ed.} + F_w$ is the total area, m^2, η is the ribbing coefficient and is defined through the graphs, given in [21], according to the selected rib profile.
- As a result, according to [21], taking into account other thermal resistances, the heat, transferred in the heat exchange process will be determined by the following formula:
- $$Q_{ed} = \frac{t_{ed1} - t_{ed2}}{\frac{1}{\alpha_w F_w} + \frac{\delta_ц}{\lambda_{ed} F_{ed}} + \frac{1}{\alpha_{eq} F}} ,$$
- In order to use the graphs given in [21], the decisive magnitude is the value, describing the rib.
- $$U = \left(\frac{2\alpha_{f.air}}{\lambda_w s_{ed}} \right)^{1/2} \cdot (r_{f.air} - r_{ex.air})^{3/2} \qquad s_{ed} = \delta_{ed} h n_{ed}$$
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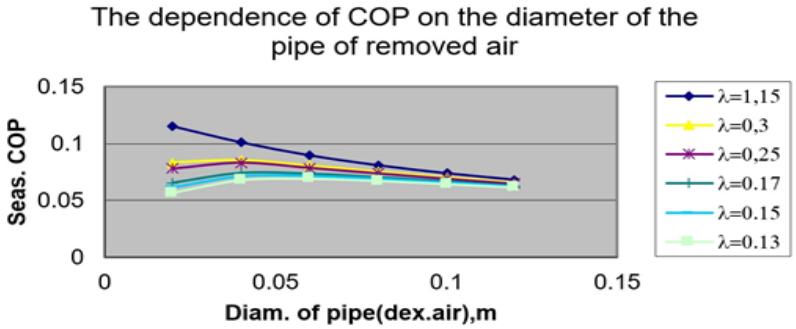
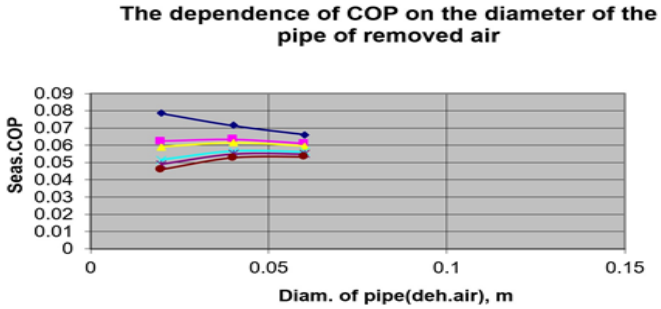
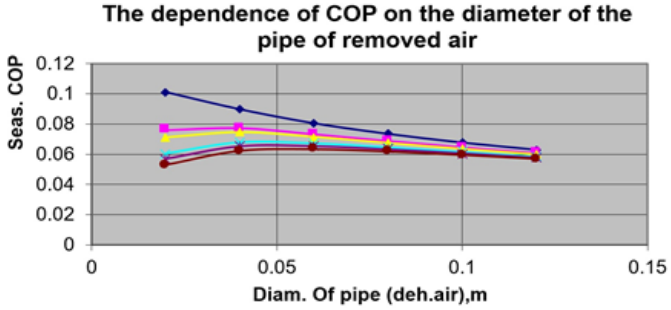
Results and Discussion

- According to the developed calculation method and the prepared computer program, corresponding calculations have been made for the cities of RA, the influence of different factors on the seasonal heat efficiency has been investigated.
- At first, the regularity of the seasonal heat efficiency dependence on the number of ribs, the heat transfer coefficient of the material used, and the diameter of the exhaust air pipe have been determined (fig. 2, a,b,c):







Results and Discussion

- The figure 3 shows that the value of the material heat conduction coefficient in the case of a double-pipe one does not have a particular effect on its seasonal coefficient. In the case of cardboard it is 0.125308, for metals it is 0.125323, and its curve is close to the straight line. In the case of a recuperator with a ribbed pipe, we have a significant difference: in the case of cardboard, in particular, for it is 0.127961...0.155252, for metals it is 0.125323 ... 0.159469:
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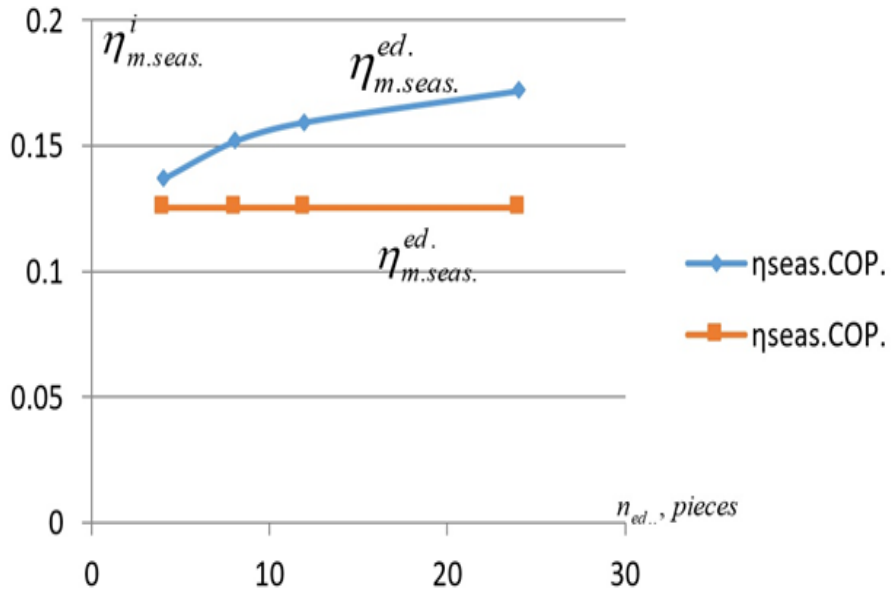

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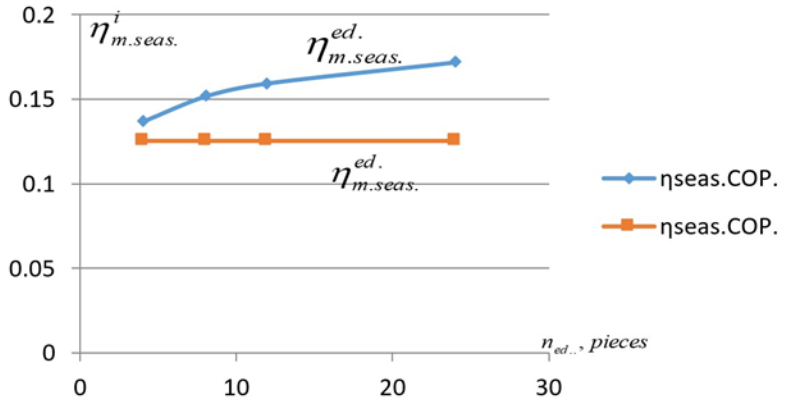
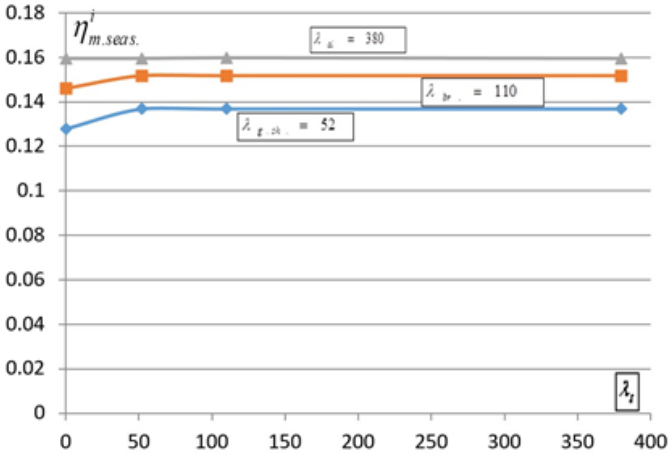
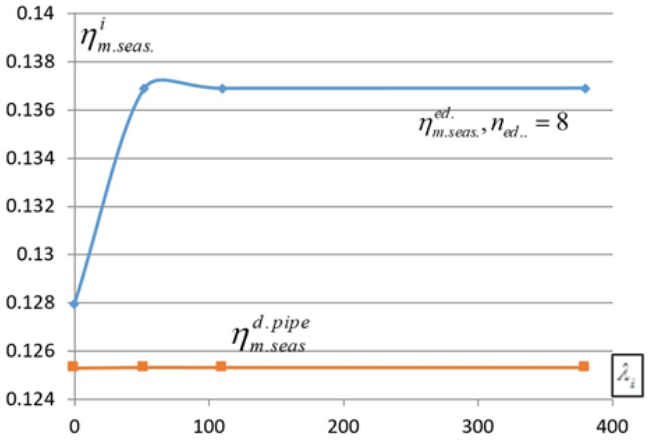
Results and Discussion







Conclusion

- - the study of the structure of recuperators shows that the stucture of their ribbed internal pipe should be improved;
- - in the case of ribbed and double-pipe heat efficiency - the total length of the recuperator is reduced by about 22 ... 25%, which will cheapen it and the costs for ribbing and will be compensated, and shortening will make it convenient, easily fitting into the wall;
- - in case of metal type selection for the recuperator with ribbed pipe we should be guided by the cheapness of the metal;
- - in the case of a cardboard rib, the recuperator remains 2.1% more efficient, so there is no need for ribbing in case of using cardboard.
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