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Aspects of spiral heat exchanger efficiency in cooling systems

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Abstract. Spiral heat exchangers are designed to meet the most difficult heat transfer challenges. Whether it's frequent dirt removal or limitations related to pressure drop and installation space, they are the ideal solution to problems for liquid-liquid and two-phase loads. Robust, efficient and compact models keep installation and maintenance costs extremely low. Compared to other heat exchangers commonly used in similar applications, spiral designs offer a compact footprint and increased thermal efficiency. Built with unique features that prevent fouling, they can handle the toughest heat transfer challenges while ensuring the most reliable performance. They work consistently, with extremely low installation and maintenance costs.

Keywords: efficiency, heat, exchanger, spiral

1. Introduction

The energy economy, in general, started as early as 1973 with the first oil crisis during the 20-day war in the Arab countries. As a result of the sudden increase in the price of oil (by about 400%) and implicitly in the prices of all forms of energy, energy efficiency is continuously sought in all fields of activity, engineers fighting practically for every percentage of thermal efficiency. Work towards focuses, in the same sense of efficiency, on the energy recovery of the heat from the ventilation air, this operation being strict in most sectors of activity. Thus, the problem arises of the use of regenerative heat exchangers, which during the air exchange performed through ventilation return back most of the thermal energy that would otherwise be lost in the ambient environment.[1]

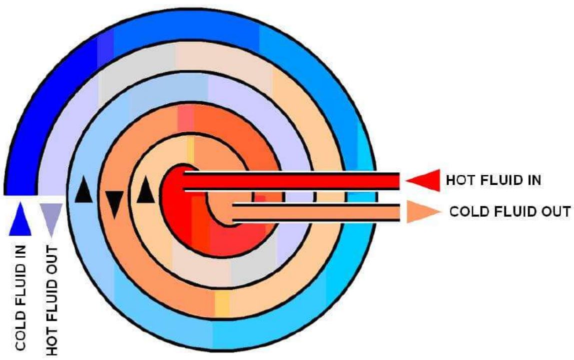


Figure 1. New heat exchange technology [2]

2. The regenerative air fan

The regenerative air fan, or with regenerative rotor, is a device used to ventilate indoor spaces, such as: warehouses, residential or commercial buildings. By operating the fan, air is drawn in through one end of the rotor and is then expelled in the other direction. During this process of air exchange, the flow of air passing through the rotor interacts with the surface of the rotor and with the walls of the casing, thus producing a heat transfer interaction and implicitly moisture between the incoming and outgoing air. The main advantage of a regenerative air fan is its ability to improve the energy efficiency of the ventilation system, reducing the heating or cooling costs of the building. The efficiency of a regenerative air fan refers to how efficient it is both in performing its function of ventilation and in recovering thermal energy or other characteristics from the exhaust air. [3]

The efficiency of a regenerative air fan can be evaluated from several perspectives:

1. Ventilation efficiency: This aspect refers to how well the fan can change the air in a space in a given time frame. The faster and more efficient this process is, the higher the ventilation efficiency.
2. Efficiency in heat recovery: For regenerative fans, a crucial aspect is the ability to recover heat from the expired air and transfer it to the fresh air entering the system. The more efficient this heat recovery process is, the higher the heat recovery yield.
3. Global energy efficiency: This includes all energy losses in the ventilation system, including those related to the fan motor, friction in ducts and filters, etc. The lower the energy losses and the more energy is recovered, the higher the overall efficiency of the fan.

The efficiency of a regenerative air fan can vary depending on technical specifications, design and usage. In general, it is important to take all these aspects into account when evaluating the performance of such a fan to ensure optimal performance and maximum efficiency.[4]

Figure 2. Regenerative air fan [5]

3. Spiral heat exchanger

In this work we propose a comparative study between a regenerative air fan with a spiral casing (fig 3) and an axial regenerative one (fig 2) with an emphasis on energy efficiency, although many more aspects can be taken into account: fan performance, costs of installation and maintenance, as well as adaptability to different types of applications. Here are some key points that could be included in such a study:

1. Energy efficiency: It can be evaluated how well each type of fan recovers thermal energy from the exhaled air and how efficient the transfer of heat and moisture is between the incoming and outgoing air. The spiral casing fan could offer an advantage in this regard due to its design that facilitates air circulation in a spiral pattern.

2. Fan performance: Aspects such as airflow, static pressure, noise generated and physical dimensions of fans can be examined. The axial regenerative fan may be more compact and potentially easier to integrate into tight spaces, but the spiral casing fan may offer better heat transfer performance.
3. Installation and maintenance costs: The initial purchase costs, installation costs and long-term maintenance costs for each type of fan can be analyzed. For example, spiral casing fans may have higher initial costs, but can provide long-term savings due to improved energy efficiency.
4. Adaptability to different applications: One can evaluate how well each type of fan fits different applications, such as ventilation of residential, commercial or industrial buildings. Certain applications may benefit more from one type of fan than another, depending on the specific requirements of the environment.[6]

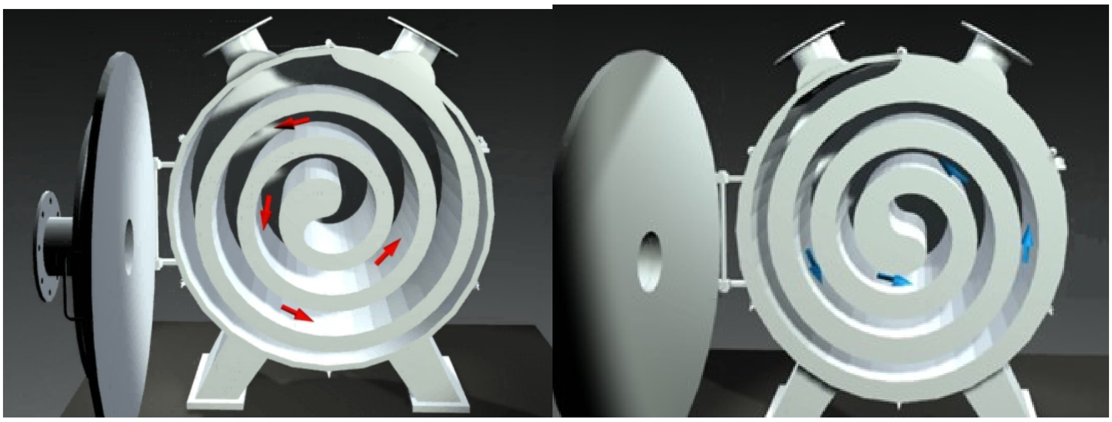


Figure 3. Spiral heat exchanger [5]

The specific materials used in the construction of a scroll casing regenerative air fan vary depending on the specific requirements of the application, the operating environment and the exact construction of the fan. However, here are some common materials used in various components of such a fan:
1. External Casing: A wide range of materials can be used for the fan's external casings, including stainless steel, aluminum, heavy-duty plastic, or even fiberglass, depending on the requirements for mechanical strength, corrosion resistance, and thermal insulation.
2. Regenerative rotor: The regenerative rotor is often made of a light and durable material such as aluminum, copper or stainless steel. Rotor surfaces are often textured or coated with a special coating to improve heat and moisture transfer.
3. Impeller Fins: Impeller fins are designed to direct airflow inside the casing in a spiral pattern. They can be made of plastic or metal, depending on the strength and efficiency requirements.
4. Bearings: Bearings are used to support the rotation of the rotor. They can be made of steel, ceramic or other materials, depending on the requirements for durability and functionality.
5. Insulation and gaskets: In some applications, thermal insulation and gaskets are used to reduce heat loss and ensure tightness between fan components. They can be made of materials such as polyurethane foam, silicone rubber or composite materials.
6. Motor: Fan motors can be made of steel, aluminum alloys or other metals depending on the power and durability required.[6]

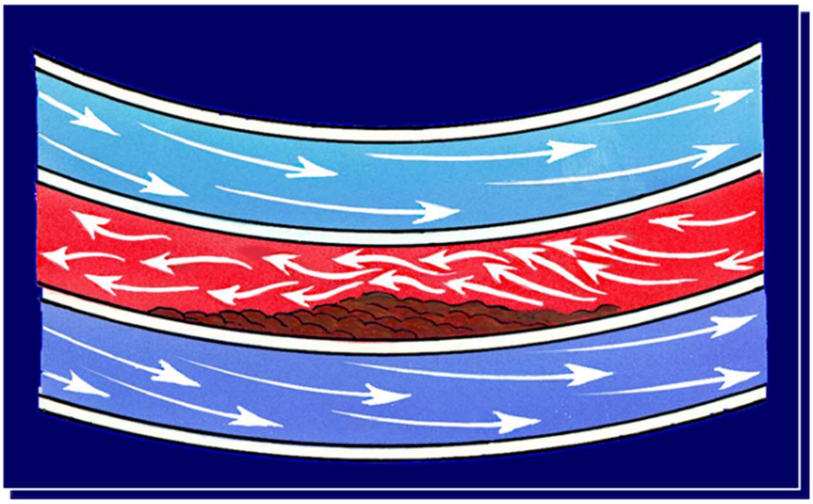


Figure 4. Single – channel = Self cleaning [7]

It is important that the materials used are carefully selected to ensure reliable and efficient operation of the fan in accordance with the specific requirements of the application and operating environment. A spiral casing regenerative air fan is a specific type of regenerative fan where the casings are designed in a spiral shape to improve air circulation. This spiral design is designed to maximize the efficiency of heat and moisture transfer between the incoming and outgoing air, so that optimal heat recovery is achieved. The principle of operation of a spiral casing regenerative air fan is similar to that of other regenerative fans. Air is drawn in along a spiral and is then directed into the casing in a spiral pattern where it interacts with the regenerative rotor. This process facilitates the transfer of heat and moisture between the incoming and outgoing air, thus contributing to improving the energy efficiency of the ventilation system (fig 4).

The advantages of a spiral casing regenerative air fan include:

1. Improved energy efficiency: The spiral design of the shell helps to increase the efficiency of heat and moisture transfer, allowing for more efficient heat energy recovery.
2. Improved Fan Performance: The spiral design of the case can improve air circulation and reduce flow disturbances, which can lead to better fan performance.
3. Reducing pressure losses: The spiral casing design can reduce pressure losses in the ventilation system, which can contribute to more efficient and quieter operation of the fan.

Scroll casing regenerative air fans are used in a variety of applications, including residential, commercial and industrial building ventilation systems, where efficient heat recovery and efficient air ventilation are desired.[8]

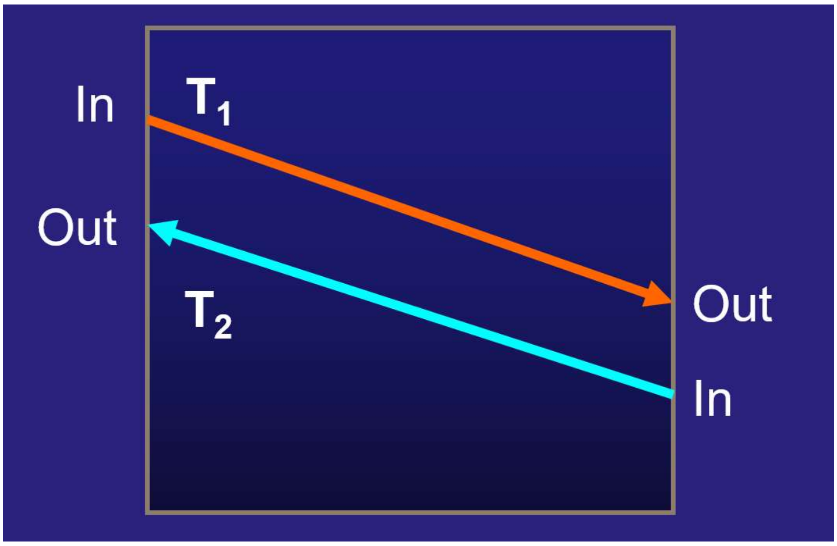


Figure 5. Counter – current flow high efficiency [9]

Medium logarithmic temperature:

$$\Delta t_{m1} = \frac{\Delta t_M - \Delta t_m}{\ln\left(\frac{\Delta t_M}{\Delta t_m}\right)} \tag{1}$$

Thermal balance equation:

$$G = \frac{Q \cdot 100}{\eta \cdot c_p \cdot (t_p - t_s)} \tag{2}$$

Thermal exchange surface:

$$S_{po} = \frac{Q}{k \cdot \Delta t_m} \tag{3}$$

4. Spiral heat exchanger simulation

The realization of the geometry of the heat exchangers in the Ansys-Fluent program was quite elaborate, because the module dealing with the design of the bodies borrows many functions from CAD (Computer Aided Design) design programs. For this simulation was built two heat exchangers, one spiral type and one with pipes. Was simulated heat transfer and performed a comparison of the results. The standard k-ε model is used to model turbulent flow to highlight the direction lines, velocity, pressure and temperature fields. The objective of the study is to determine the speed distribution, pressure and temperature of the air on the ventilation installation in order to be able to optimize the operation of the entire system. The standard k-ε model is based on the equation of motion model for kinetic energy (k) and its dissipation (ε). The governing equations are set out in the equations below for: conservation of mass or continuity equation (4), momentum equation (5), turbulent kinetic energy equation (6) as well as energy distribution (7). [10]

$$\frac{d\rho}{dt} + \nabla x(\rho\vec{u}) = 0 \tag{4}$$

where ρ $\left[\frac{Kg}{m^3}\right]$– density, t $[s]$– time, u $\left[\frac{m}{s}\right]$–fluid speed;

$$\frac{d\rho}{dt} + \nabla x(\rho u u) = -\nabla p + \rho g + \nabla x(\mu \nabla u) - \nabla x \tau_t \tag{5}$$

where p $[Pa]$– pressure, g $\left[\frac{m}{s^2}\right]$– gravitational acceleration, µ $[Pa \cdot s]$– dinamoc vascozity τ_t-turbulence loading divergence;

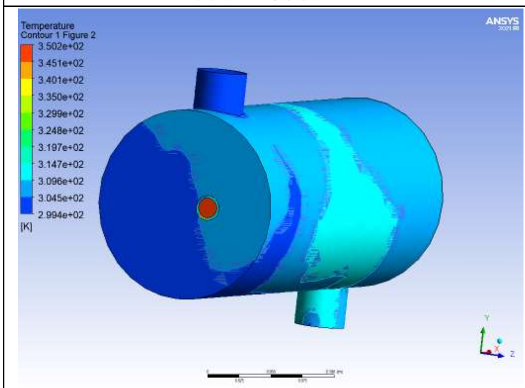
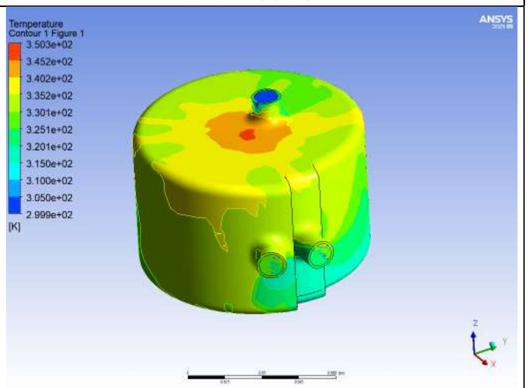
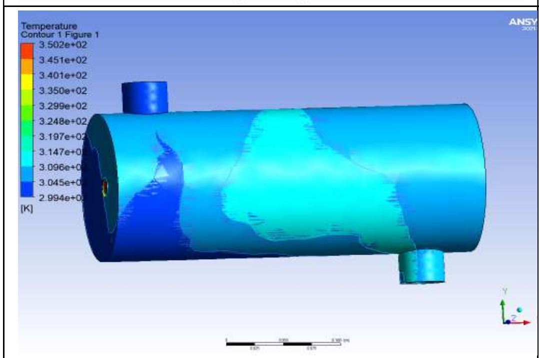
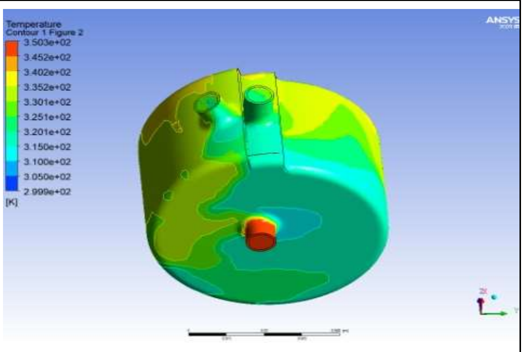
$$\frac{\partial(\rho k)}{\partial t} + \frac{\partial(\rho u k)}{\partial x} = \frac{\partial}{\partial x}\left[\mu + \frac{\mu_t}{Pr_k}\right]\frac{\partial k}{\partial x} + \mu_t G - \rho\varepsilon + S_{k,p} \tag{6}$$

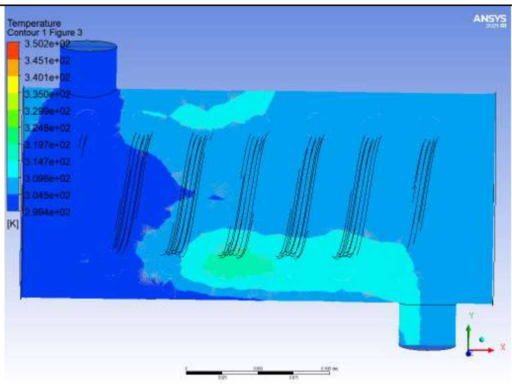
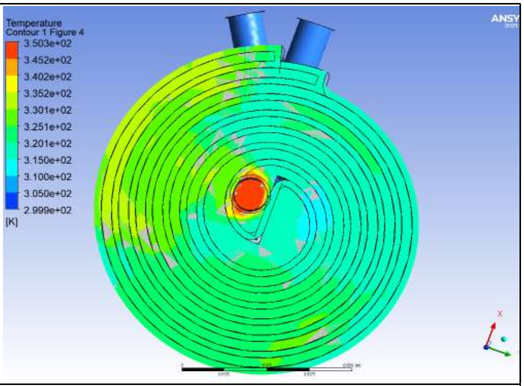
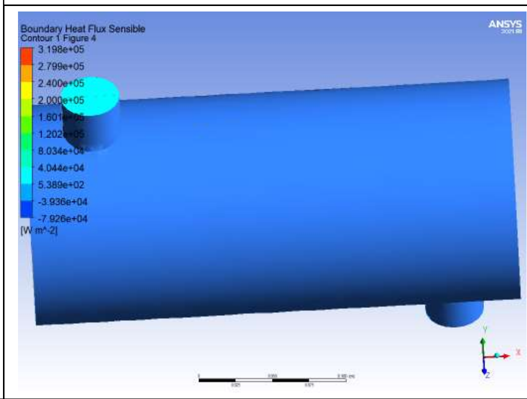
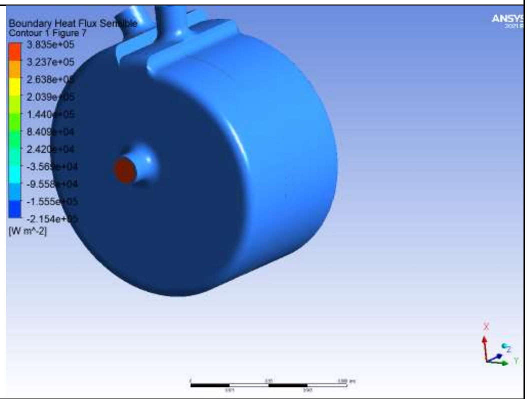
$$\frac{\partial(\rho \epsilon)}{\partial t} + \frac{\partial(\rho u \varepsilon)}{\partial x} = \frac{\partial}{\partial x}\left[\mu + \frac{\mu_t}{Pr_\varepsilon}\right]\frac{\partial \varepsilon}{\partial x} + \frac{\varepsilon}{k}\left[C_1 \mu_t G - C_2 \rho \varepsilon\right] + S_{k,p} \tag{7}$$

In equations 6 and 7 we have: C1 and C2 - empirical constants, Pr - the Prandtl number for the kinetic energy, S – the source term defined by the user, G – the turbulence of the kinetic energy calculated in equation 8.

$$G = \left(\frac{\partial u_i}{\partial x_j} + \frac{\partial u_j}{\partial x_i}\right)\frac{\partial u_i}{\partial x_j} - \frac{1}{\rho^2}\frac{\partial \rho}{\partial x_j}\frac{\partial \rho}{\partial x_J} - \frac{2}{3}\left(\frac{\rho k}{\mu_t} + \frac{\partial u_i}{\partial x_J}\right)\frac{\partial u_J}{\partial x_j} \tag{8}$$

Table 1. Heat exchangers comparation

Parameter	Pipe heat exchanger	Spiral heat exchanger
	299.4 – 350.2 K	**299.9 – 350.3 K**
Temperature [K]		
		

		
Heat flux [W/m^2]	**Max 319800 W/m^2**	**Max 383500 W/m^2**
		

5. Conclusions

Ansys offers a complete range of simulation solutions, engineering suites that provide access to almost any area of engineering simulation that requires a design process in advance. Organizations around the world trust Ansys to deliver the best value for their engineering simulation software investment. Following the fluid flow simulation for the 2 types of exchangers, was conclude that was some small differences between the spiral exchanger and the pipe exchanger. Both heat exchangers had air as the working fluid. Was also mentioned the fact that the initial calculation parameters were the same in the simulation. In the design of an installation, both the theoretical calculation and the simulation of the results obtained through it are combined in specialized programs. The optimal design and economic efficiency of the installation depends very much on obtaining conclusive results both theoretically and in the field of simulation and practice. As shown in table 1, the interval of temperature for pipe heat exchanger was between 299.4 – 350.2 K against de spiral heat exchanger between 299.9 – 350.3 K. Also, the maximum of heat flux for pipe heat exchanger was 319800 W/m^2 against de spiral heat exchanger with maximum 383500 W/m^2. It can be seen that the simulated values are quite close for the fluid temperature. For the thermal flow, the difference in values was greater and the higher efficiency of the spiral exchanger can be deduced.

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