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Rotor Concepts for the Counter Flow Heat Recovery Fan

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***Abstract*—**Decentralized ventilation systems should combine a small and economical design with high aerodynamic and thermal efficiency. The Counter Flow Heat Recovery Fan (CHRF) provides the ability to meet these requirements by using only one cross flow fan with a large number of blades to generate both airflows and which simultaneously acts as a regenerative counter flow heat exchanger. The successful development of the first laboratory prototype has shown the potential of this ventilation system. Occurring condensate on the surfaces of the fan blades during the cold and dry season can be recovered through the characteristic mode of operation. Hence the CHRF provides the possibility to avoid the need for frost protection and condensate drain. Through the implementation of system-specific solutions for flow balancing and summer bypass the required functionality is assured. The scalability of the CHRF concept allows the use in renovation as well as in new buildings from single-room devices through to systems for office buildings. High aerodynamic and thermal efficiency and the lower number of required mechatronic components should enable a reduction in investment as well as operating costs. The rotor is the key component of the system, the requirements and possible implementation variants are presented.

***Keywords*—**CHRF, counter flow heat recovery fan, decentralized ventilation system, renovation.

I. Introduction

VENTILATION is necessary both in new buildings and in the modernization of existing buildings to ensure adequate air quality. A mechanical ventilation unit is often used to provide a continuous and controlled air exchange and to reduce the energy loss. Especially in refurbishment but also in new buildings decentralized units are used to supply single rooms or dwellings with fresh air. Advantages of these systems are the compact ductwork and the simple installation. In addition, through a wall integrated installation floor space can be saved. For this area of application, the ventilation unit has to be designed as small as possible without influencing energy efficiency. Conventional systems consist of three components, 2 fans for outdoor/supply and extract/exhaust air and a counter flow heat exchanger. One possibility to achieve a more compact design is to combine these functions in one single component. This principle was implemented in the so-called Heat Recovery Centrifugal Fan (HRCF). A currently available system on the market of this type is the "Frivent Wärmerückgewinner," shown in Fig. 1. With this system, outdoor and extract air flow separated axially into the interior part of the fan. Through rotating porous foam, the airflows are blown out radially along the spiral casing. By passing the foam, the warm extract air transfers energy to the foam, which is absorbed by the cold outdoor airflow. At sufficient rotational speed and same flow rates, the temperature profile of the porous foam along the flow path remains constant in approximation. So the system works schematically as a cocurrent heat exchanger because of both outdoor and extracts air pass the foam from the inner part of the fan radially along the spiral casing. Occurring condensate of moist extract air can be recovered by the outdoor airflow at each revolution. Through this system-related property, devices for frost protection and condensate drain can be saved. These advantages make it possible to achieve a very compact design. The main disadvantage of the system is the limited thermal efficiency with a heat recovery rate below 50 % because of the cocurrent flow regime.

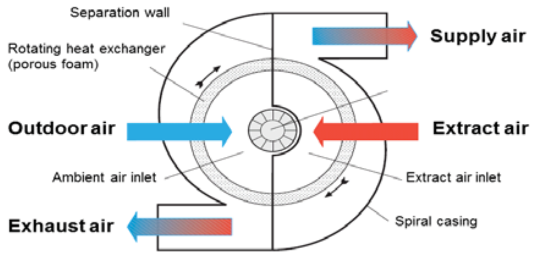

Fig. 1 Schematic drawing of the "*Frivent Wärmerückgewinner*" of Frivent GmbH [1]

II. Laboratory Prototype of the Modified Heat Recovery Fan

In order to combine the advantages of HRCFs with high fluid mechanical and thermal efficiency, the Counterflow Heat Recovery Fan (CHRF) was developed. Similar to the already available systems both airflows are generated by one cross flow fan, which simultaneously acts as regenerative highly efficient counterflow heat exchanger. With this, system outdoor and extract air are no longer sucked axially. They pass through the cross flow fan radially but in different levels, perform a level change inside the internal structure and are blown out again radially through the cross flow fan similar to the HRCF. The CFD-calculation of the flow field is shown in Fig. 2. In this case, the numerous blades of the cross flow fan are responsible for the heat recovery. In [3] the first analytical fluid mechanical and thermal calculations for the design of the CHRF were presented. In order to reduce the internal leakage, to enable flow balancing and to implement a summer bypass mode further development and calculations were performed and presented in [4]. Flushing chambers implemented inside the internal structure shown in Fig. 3 reduce the occurring leakage because of transported air in between of the fan blades. The transported air flows through the flushing

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chambers and is conducted back to the main flow. The flow balancing and summer bypass mode were implemented by flaps with integrated iris diaphragms, which are responsible for the level change of the outdoor and extract airflow before passing the fan. If the flow rates are balanced, the iris diaphragms are closed, and the whole flow is conducted by the flap. If there is a difference, one iris diaphragm opens and enables a part of the flow to enter the fan without being conducted by the flap until the balancing is achieved again. By entering the fan, this part of the flow no longer interacts with the fan blades schematically as a counter flow, but as a concurrent heat exchanger, by leaving the fan, the flow regime remains the same. If both flaps are turned, both airflows enter the fan at the opposite level. Do not perform a level change inside the internal part and are blown out along the spiral casing in the same way as during the normal mode. Through this mechanism, the outdoor as well as the extract air pass the cross flow fan on different levels and thus no heat recovery occurs. The flow balancing can still be performed by the iris diaphragms but the part of the flow, which enters through an iris diaphragm, interacts with the second flow and exchanges thermal energy. Based on the calculations in [4], [5] the laboratory prototype shown in Fig. 4 was developed by rapid prototyping and investigated. Flow rates of 60-70 m³/h were achieved by implementing a fan with 30 blades at rotational speeds of 10.3-13 Hz; higher speeds were not tested for stability reasons with respect to the used rapid-prototype process. The comparison of the measurement with simulation results at different external pressure drops is shown in Fig. 5.

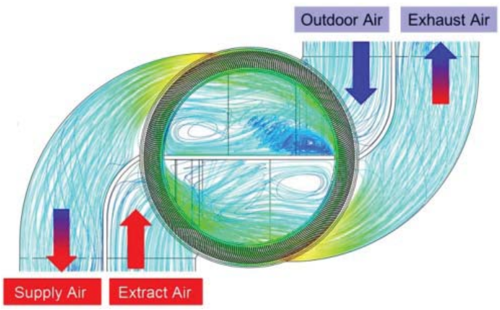
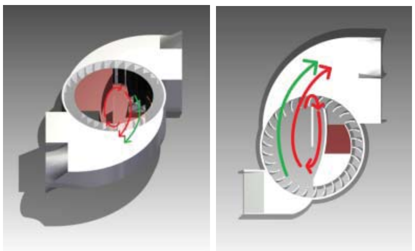


Fig. 2 CFD - calculation of the CHRF [2]



(a) (b)

Fig. 3 (a) Developed concept of the CHRF with implemented flushing chambers within the internal structure (b) A section showing the lower flushing chamber. The conduction of the main flow (green) and the recirculation of the flow carried by the fan blades are shown [5]

Fig. 4 Laboratory prototype of the Counterflow Heat Recovery Fan (CHRF) [2]

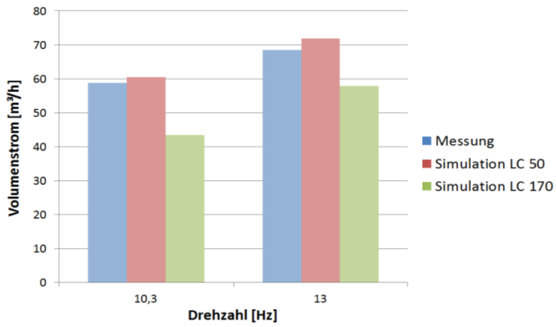


Fig. 5 Laboratory measurement (blue) and simulation results with an external pressure drop of 5 Pa (red) and 16.8 Pa (green) (at 50 m³/h) at each duct. For the comparison, a cross flow fan with 30 blades was used [5]

III. Rotor Concepts for the CHRF

The rotor is the key component of the CHRF ventilation system. To attain a high heat recovery rate, numerous thin fan blades would be required. At the development of the first laboratory prototype, shown in Fig. 4, the fan was manufactured with an inner diameter of 205 mm and an outer diameter of 255 mm by rapid-prototyping. The 300 blades of the fan are 0.85 mm thick. A section of 25 blades was investigated in the laboratory to measure the pressure drop and to evaluate the numerical simulation models. A defined airflow is conducted axially inside the fan and is blown out through the section of 25 blades. The static pressures inside the fan depending on the flow rate of the measurement and for two different simulation models are shown in Fig. 6.

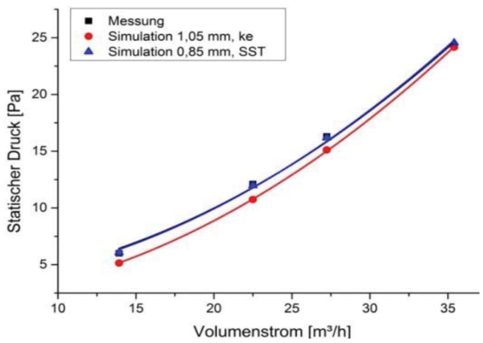


Fig. 6 Laboratory measurement of the pressure drop of a 25-blades section of the 300-blades fan with axial air intake with a blade thickness of 0.85 mm and comparison with simulation models [6]

By using the k-epsilon turbulence model, the measured pressure drop can be approached by increasing the thickness of the fan blades in the model to 1.05 mm. By using the shear-stress model, the simulated pressure drop is in good agreement without changing the blade thickness.

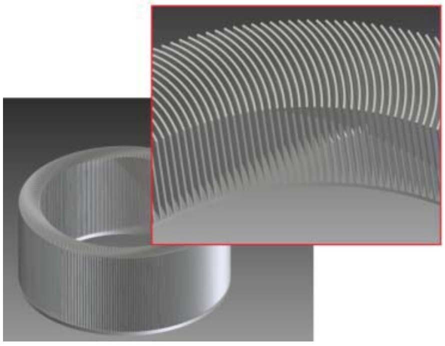


Fig. 7 Design of the fan with 300 blades with tapered cross-section of the flow path along the blades

The disadvantage of this fan is the tapered cross-section of the flow path along the blade. The larger exit angle of the fan blade leads to a smaller available flow cross-section at the outlet as long as the blade thickness is not negligible, in spite of the larger circumference. This property complicates the production of the fan because the pressure drop should come as low as possible. In Fig. 7, the design of the fan with 300 blades and the tapered flow cross-section is shown. One possibility to avoid this problem is to reduce the number of fan blades and to implement a porous material between the blades. The aerodynamically optimized fan blades generate the flow rates while the porous foam is mainly responsible for the heat recovery. The concept is shown in Fig. 8.

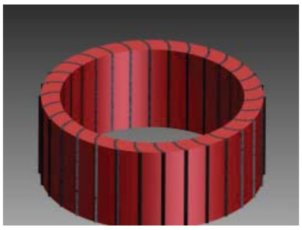


Fig. 8 Fan model with 30 blades (black) for the ventilation and porous foam in between the blades (red) to increase the heat recovery rate

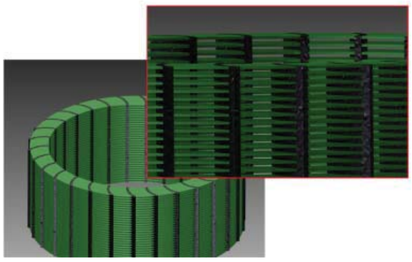


Fig. 9 Fan model with 30 blades (black) for the ventilation and horizontal thin layers (green) to increase the heat recovery rate

Through this model, no tapering flow cross-section occurs. An alternative concept that has this ability is shown in Fig. 9. Similar to the previous model the flow rates are generated by a cross flow fan with about 30 blades. To increase the heat recovery rate, additional horizontal layers are implemented between the blades.

IV. Conclusion

The concept of the CHRF to combine the generation of both flow rates and the heat recovery in only one single component was successfully realized with the first laboratory prototype. To achieve high heat recovery rates numerous of fan blades would be required. To avoid a large pressure drop because of the tapered flow bath along the fan blade other fan concepts are investigated. Solutions to this problem could be found by reducing the number of fan blades to optimize the ventilation efficiency and by implementing additional heat exchangers between the blades. For this concept, a porous material or horizontal thin layers would be suitable. The successful development of a rotor with a high heat recovery rate and a low-pressure drop is an important step to obtain a fully functional complete system. Through the scalable concept, the CHRF could be designed for low flow rates for single room devices as well as for high flow rates for use in classrooms or industrial buildings. Through the combination of fans and heat exchanger in one single component and the resulting small dimensions of the device, the CHRF can be installed wall integrated. By that, especially in renovation usable floor space can be saved. Possible solutions for a wall-integrated installation are shown in Figs. 10 and 11.

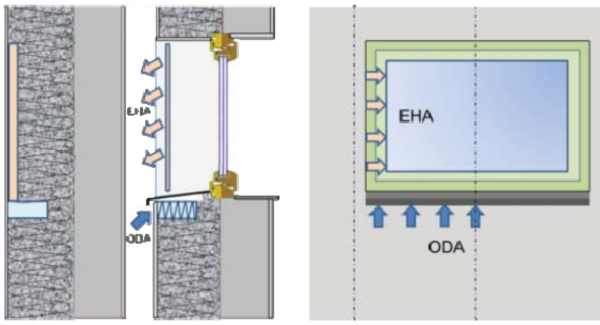


Fig. 10 Wall integration of the system within the insulation, outdoor air intake below the windowsill, exhaust air outlet in the reveal [5]

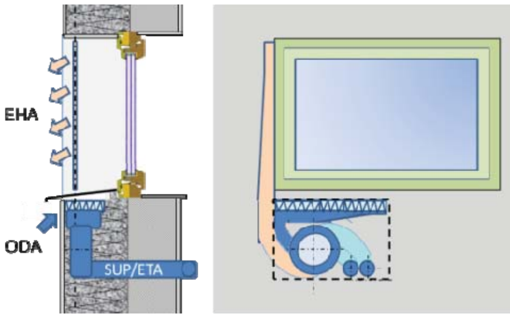


Fig. 11 Sections of the integrated wall system on the device level [5]

The outdoor air intake is below the windowsill, the exhaust air outlet is located in the reveal, and the ventilation system is installed in the insulation layer. Low investment and operating costs of the CHRF should enable the wide use in building modernization as well as in new buildings.

REFERENCES

[1] Frivent, "Schematic Drawing of the "Frivent Wärmerückgewinner" Frivent GmbH.
[2] J. Zgaga, D. Lanthaler, C. Speer and R. Pfluger, "Development of a Decentralized and Compact Comfort Ventilaton System with Highly Efficient Heat Recovery for Minimal Invasive Refurbishment of Buildings," Proceedings 35th AIVC Conference, 2014.
[3] R. Pfluger, C. Speer, W. Feist, J. Weger and J. Zgaga, "Entwicklung Eines Hocheffizienten Ventilators mit Integriergter Gegenstromwärmerückgewinnung für den Einsatz in der Gebäudemodernisierung," Bauphysik, 2013/4, pp. 242-249, 2013.
[4] C. Speer, R. Pfluger, W. Feist, J. Zgaga and D. Lanthaler, "Entwicklung Eines Dezentralen Kompakten Lüftungssystems für den Einsatz in der Minimalinvasiven Gebäudesanierung," Bauphysik, 2014/5, pp. 236-242, 2014.
[5] C. Speer, R. Pfluger, J. Zgaga, D. Lanthaler, F. Recla and W. Feist, "Entwicklung und Messtechnische Untersuchung eines Dezentralen Kompakten Wärmerückgewinnungsventilators," Bauphysik, 2015/3, pp. 179-185, 2015.
[6] C. Speer, "Simulation und Entwicklung eines hocheffizienten Wärmerückgewinnungsventialtors," Dissertation, (in press).