

Ventilation efficiency of decentralized alternating residential ventilation units



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Decentralized alternating residential ventilation units are becoming increasingly widespread on the market. Some advantages, such as the comparatively simple retrofitting of existing equipment or relatively low investment costs, are obvious. But what about other aspects, such as ventilation efficiency, wind pressure stability and energy-saving potential? The publicly funded joint research project “EwWalt” is intended to answer some of the most urgent questions.

Keywords: ventilation efficiency, alternating, wind pressure susceptibility, heat recovery, dynamic pressure method

Mechanical ventilation is considered to play an important role in achieving the energy-saving targets for new construction and refurbishment of existing residential buildings, particularly in view of the possibilities for heat recovery and demand-based operation. In addition to the well-known ventilation units with continuous volume flow, decentralized alternating systems are increasingly being offered on the market, which are often also referred to as push-pull units. For heat recovery, heat storages are used with air passing them unsteadily in alternating manner (Figure 1).

In the extract air cycle, a storage mass is charged with the energy of the warm internal air. In the following supply air cycle, this energy is released again into the inflowing external air. Due to the necessary flow reverse, axial fans are typically used in these units. In order to achieve balanced air flows in relation to the room, at least two air flows are necessary, which work alternately in opposite directions. The two air flows can either be integrated in one casing (1 compact unit) or realized by two separate units which are coupled on the control side (2 single devices). In the second case, the devices can also be placed in different rooms.

Project “EwWalt”

In the case of alternating devices, there were still uncertainties as to how this concept should be evaluated in comparison to continuously operating devices due to a lack of science-based results. This applies to aspects such as ventilation efficiency, wind pressure susceptibility and the determination of energy parameters. These aspects were investigated in the publicly funded project “EwWalt – Energetische Bewertung dezentraler Einrichtungen für die kontrollierte Wohnraumlüftung mit alternierender Betriebsweise” (Energetic assessment of decentralized facilities for controlled ventilation with alternating operation). Under the leadership of RWTH Aachen University and with the project partners HLK Stuttgart and ITG Dresden, simulation investigations were carried out about indoor air flow effects, test methods for determining the characteristic values for the energetic evaluation were further developed and proposals for implementation in the standards were formulated.

Investigations on the function of alternating ventilation devices (based on numerical flow simulation)

CFD studies (Computational Fluid Dynamics) were carried out within the EwWalt project to compare the room air flows from the ventilation side, which are caused

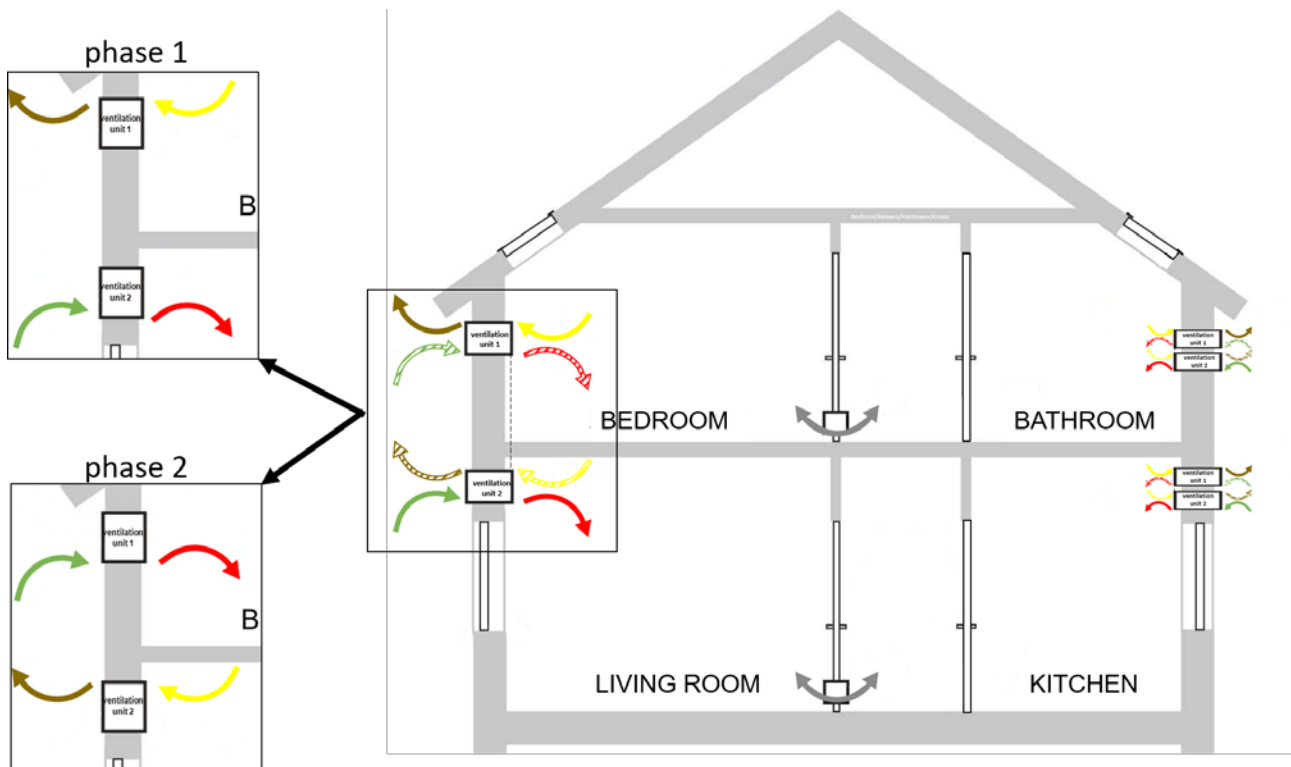


Figure 1. Functional principle of decentralized alternating ventilation units.

by decentralized alternating or continuous devices. With these calculations, it is possible to forecast the air flows that occur and, for example, to evaluate how long the air will stay in the building. These simulation methods were used in the EwWalt project to analyse the air exchange efficiency for all rooms in two different residential constellations (apartment & single-family house, see **Figure 2**). A small value for the air exchange efficiency, for example, indicates existing short-circuit flows.

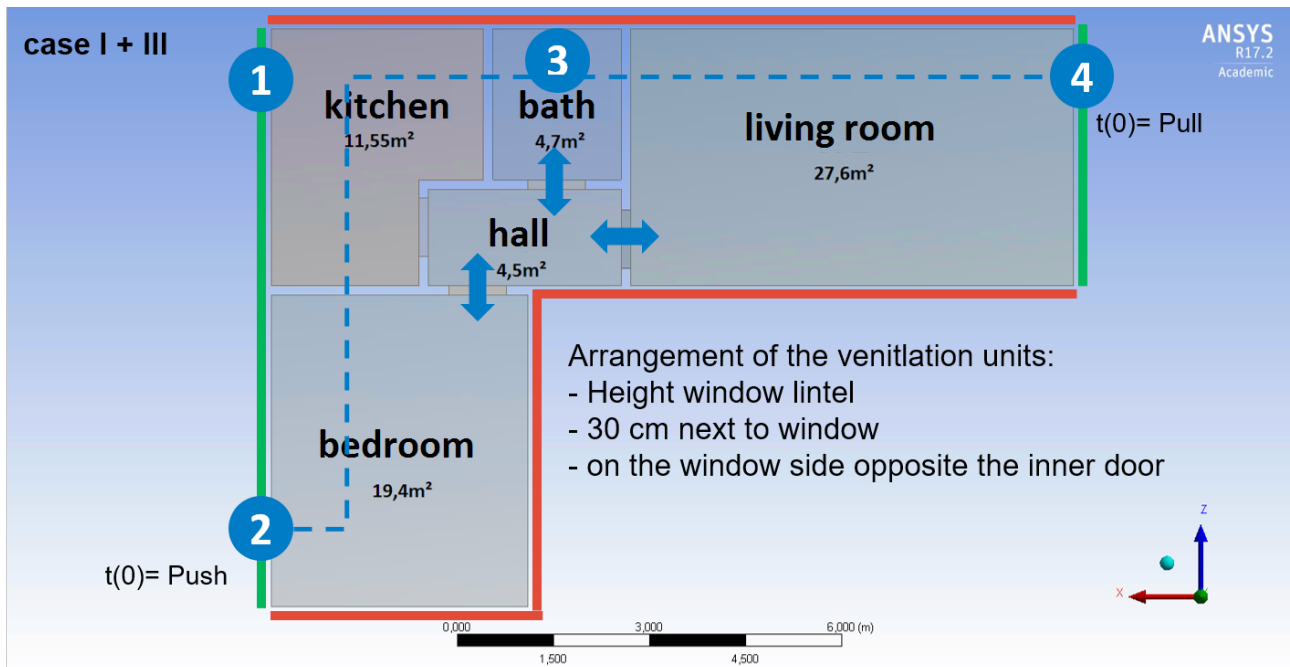
In order to achieve a broad informative value of the results, several parameter variations were carried out. On the one hand, the local position of the ventilation units in the living area was varied; on the other hand, the ventilation volume flows for partial load behaviour were reduced. It was also investigated to what extent wind pressure on the building facade or an active exhaust air system in the building influences the operation of the ventilation units.

Since many different aspects like ventilation openings inside the building and wind pressure effect the volume flow rates which can be delivered by the ventilation devices, the so-called imbalance first had to be evaluated. For this purpose, the examined buildings were conceived as a duct network in a second simulation study, in which all ventilation components were modelled as flow resistances. This

pressure-volume flow model calculates the final volume flows at all ventilation units, which are caused by disturbances such as wind pressure and ventilation system for bathrooms without windows. It was developed within the Modelica modelling language and coupled with the CFD model for the interior flow (**Figure 3**). The values for the effectively conveyed volume flows from the duct network simulation could thus be used as boundary conditions in the flow simulation.

The results coming from the duct network simulation showed that, for example, if the ventilation units were placed unfavourably across corners, relatively large pressure differences would be present at the ventilation units. The axial fans installed primarily in alternating ventilation units have flat pressure-volume flow characteristics, which means that even a slight pressure fluctuation has a strong influence on the volume flow conveyed. In partial load conditions and in case of strong wind, the volume flow can decrease to zero, which has a considerable influence on the heat recovery rate.

In contrast, the following CFD simulations under the various conditions all showed similar behaviour for ventilation effectiveness. Thus, a mixing ventilation characteristic with the typical air exchange efficiency



room height: 2,5m

legend

ventilation unit:

overflow possibility:

interconnection: - - -

Figure 2. Floor plan and exemplary device constellation of the examined apartment.

of 0.5 was available in the individual rooms, almost independent of geometry, thermal conditions, volume flow and imbalance. Here, alternating ventilation units did not differ from continuously operated ones. Previous doubts that areas could be found in alternating operation – especially in corridors – that would not be supplied with fresh air by premature reversal of the ventilation direction could thus be eliminated.

Metrological investigations for further development and assessment of currently applied test methods for determining characteristic values

A great challenge during the test is the unsteady mode of operation during heat recovery. Therefore, it is not possible to use the methods known from continuously operating devices to determine characteristic values such as heat recovery, balance or air volume flow. For this reason, the air volume flow of continuous operation, which can be measured using a conventional method, has been used for simplification reasons up to now. The reduction of the mean volumetric flow due to the start-up and shut-down processes during the switching is neglected. In the EwWalt project a method was developed to measure the mean air volume flow also in alternating operation with comparable accuracy. The volume flow of the two strands is recorded over time using a dynamic pressure method (Figure 4).

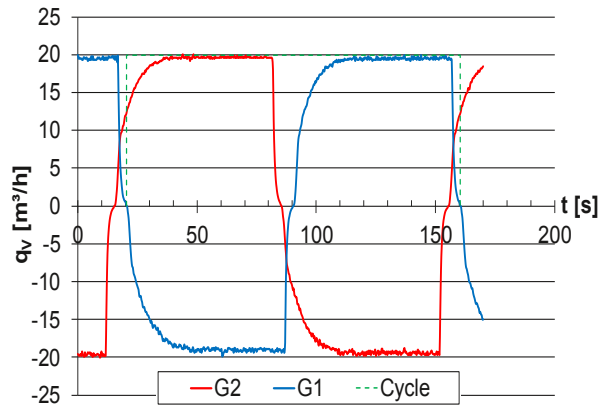


Figure 4. Example of volume flow curve measured in alternating operation.

An average volume flow in alternating operation can be determined from the measured curve. Comparative measurements have shown that in this case the average volume flow in alternating operation was approx. 85% of the volume flow in continuous operation. This method can also be used to determine the imbalance in alternating operation. This is a precondition for correct measurement of heat recovery.

Two methods are currently used to measure heat recovery. One method is described in EN 13141-8 *Ventilation for buildings - Performance testing of components/products for residential ventilation - Part 8: Performance testing of non-ducted mechanical supply and exhaust ventilation units (including heat recovery) for mechanical ventilation systems intended for a single room: 2014* (direct method),

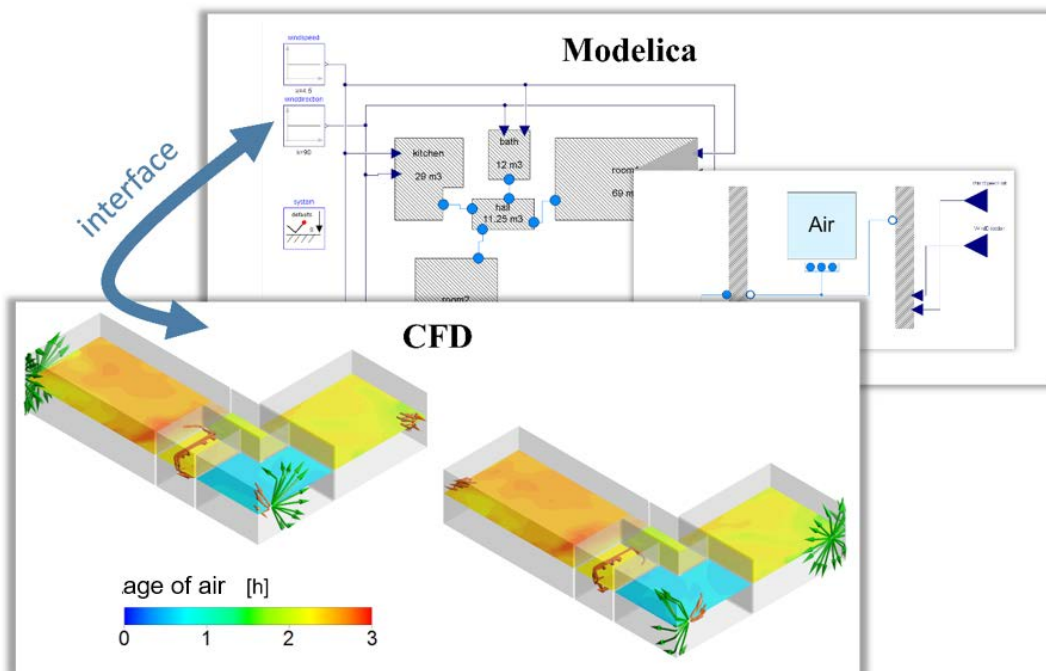


Figure 3. Interface between pressure-volume flow simulation and flow simulation.

the second method is used for DIBt (Deutsches Institut für Bautechnik – German institute of building technology) approval (purge air method). Both methods were examined in detail in the EwWalt project. For the direct method, the comparison measurements showed an increased measurement uncertainty of more than 8% due to the inhomogeneous temperature distribution of the air leaving the device (**Figure 5**).

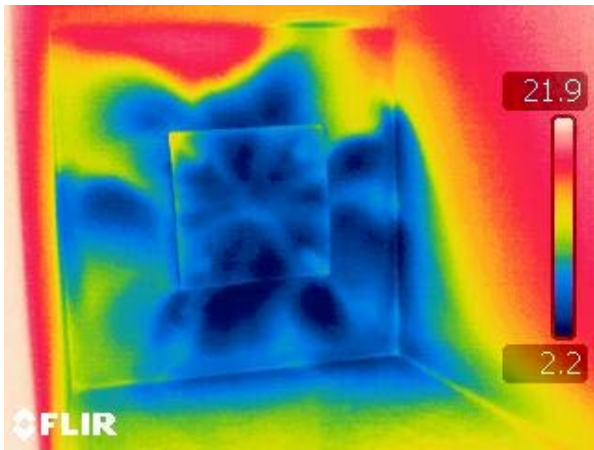


Figure 5. Qualitative visualization of the temperature distribution at the outlet of the device.

This uncertainty is prevented in the purge air process by homogenizing the air by mixing and turbulence before temperature measurement. A previously carried out inter-laboratory test of the DIBt resulted in a comparable exactness with this procedure as with the procedures for continuously working devices. The purge air method was further developed on the basis of the previously measured average volume flow to eliminate systematic disadvantages for compact units. With the help of the disbalance measured in alternating operation, the result of the thermal test can now also be corrected in analogy to the measurement of the continuous devices. During the comparison measurements, further parameters such as the purge air volume flow and the speed were optimized, so that the accuracy of the process could be further improved. A complete description of the purge air process provided the basis for its inclusion in the revision of the standard EN 13141-8 which is currently ongoing.

Results

The EwWalt research project was able to answer some of the most urgent questions on the classification and evaluation of decentralized alternating residential ventilation devices.

The recently achieved scientific results are based on investigations of the function of alternating ventilation

devices based on numerical flow simulations. It was found that in all cases there is mixed ventilation practically independent of the room design. About the imbalance of the ventilation units and consequently also the effects of interference pressures (e.g. due to wind) on heat recovery, a correlation with the steepness of the unit characteristic curve could be demonstrated.

Parallel to the simulation, methods for the experimental evaluation of alternating ventilation devices were developed. With the developed method for air flow measurement in alternating operation it is possible for the first time to measure the effective air volume flow relevant for the design as well as the imbalance in alternating operation. For the determination of heat recovery, the direct method described in EN 13141-8 and the purge air method used for DIBt approval were analysed and compared in detail. Test boundary conditions are defined for the methods to improve the measurement uncertainty and comparability of the results.

From the results, useful characteristic values for standardization were identified and proposed for standardization work, e.g:

- a description of the purge air procedure for testing alternating ventilation units,
- a detailed representation of a standard-compliant design of alternating ventilation units about the positioning of the components and determination of the volume flows for typical constellations,
- an evaluation algorithm including characteristics for dual use of air,
- a normative concept for the consideration of start-up processes during alternating operation,
- an algorithm for considering wind pressure stability as a function of climate data in the efficiency of heat recovery, and
- further information on current standardization.

In the framework of the project, further topics essential for the well-founded evaluation of alternating ventilation units, such as moisture recovery, wind susceptibility or comfort evaluation, have been identified which should become the subject of further research activities. ■

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