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Compartmental air volume flow calculation

Numerical simulations help visualise flow characteristics. However the time required for this approach to calculations where livestock housing is concerned is enormous. The report indicates a possibility of solving the problem of house size or location associations through simple balancing of masses.

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Keywords

Compartment, natural ventilation, air flow calculation and simulation

Because of the size of houses for livestock, a type of spot-testing is the only way of measuring for gas concentrations, e.g. ammonia, or for odours. Tracer gas can also be considered instead of gas concentrations, and its regressive series used for the indirect calculation of air volume flows. For natural-ventilation (Nürtinger system, open-front barns) with long-drawn-out or large air exchange areas, alongside the uncertainty for positioning of measuring locations, the direction dependency on wind direction and velocity has an effect. Continuous alterations to these atmospheric parameters lead to differentiated regression behaviour of the tracer concentration on the individual measuring points. This differentiated regression behaviour is caused through transport processes of the tracer with the carrier medium air within the housing. To describe these transport processes it is necessary to intensively study the flow characteristics within a house or system.

The fundamentals

The mechanical characteristics of the flow apply for every case of circumvential or direct throughflow. The conditions for the maintenance of mass, impulse and energy form the basis for flow-mechanical observations. Helpful in visualising the gradual calculation of solutions for the variables in the maintenance equations is the instrument of numerical flow simulation. *Figure 1* shows a fully-developed flow field in a two-dimensional area of 2 m • 2 m. The air is pressured from above left directly under the compartment border with a constant velocity and flows freely outwards bottom right. At 0.66 m from the inlet is positioned an impermeable obstacle (partition wall). Commercially normal longitudinal-form, naturally-ventilated housing measure in general an average 20 m • 50 m. In such cases, a numerical iteration (step-by-step calculation) is not appropriate. To be able to achieve answers on interior tracer transport and thus air exchange, without this, the compartmentalisation system is used for the first time in this association.

The new application

A definition of the system is the starting point for every compartmentalisation. The term "system" describes a certain, limited, number of subsystems the defined conditional variables of which show, and are characterised through, a multiplicity of interconnected relationships. The subsystems are described as compartments. A compartment in this case is defined as a kinetic and homogenous self-contained unit [3] within which, e.g., a concentration can spread out rapidly and consistently. Thus the flow area shown in figure 1 is divided into (nine) compartments (*fig. 2*). In the centre of every virtual compartment the regression behaviour of the tracer concentration is determined at the same time. It is accepted that the value of the tracer concentration in the centre represents the average value over the total compartment [2] and that the material exchange within the compartment interior takes place more rapidly than the material exchange on the exterior.

Alongside the system measurements and the variable compartment parameters there are only two unknown factors: The tracer concentration and the alteration between two time steps during recording. With the given parameters, balance equations can be established for every compartment and for the total system in the form of a simple continuity condition, and the linear equation system solved with a suitable algorithm. The resultant values (coefficients of exchange) of a time step give the height and the direction

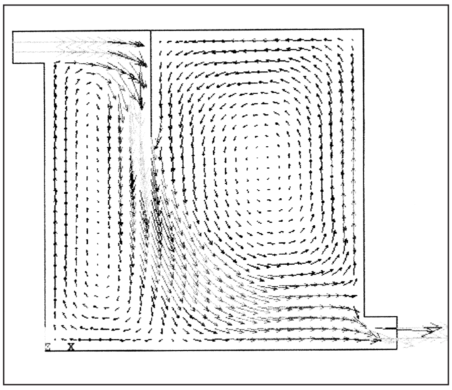

Fig. 1: Calculated air flow pattern in a 2m • 2 m room by numerical simulation

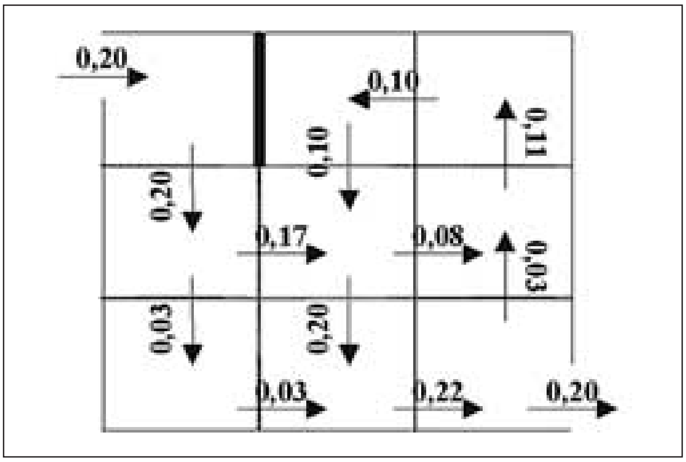

Fig. 2: Calculated air flow pattern of the 13th time step in a 2 m • 2 m room by compartmentalisation

Fig. 3: Open stable with long sidewall openings (Nürtinger System)

(symptom) of the air volume flow between the compartments and the total system. These are shown by the arrows in figure 2. Contrary to numerical flow simulation, the results here were not determined by iteration. The equation system (matrix) is revised after every time step, i.e., after every result is determined. For this, it is necessary to gather together as many time steps as required for the solving of the equation system. The principle method of approach is comprehensively described in [1].

Practical calculation

In the theoretical example shown, the results from compartmentalisation can be checked through the numerical approach. In real housing, the numerical system is only able to be applied in a limited way. Therefore no reference method is available. However, the declarative strength of calculation models can be estimated through previous "calibrating" applied to calculable examples.

Figure 3 shows a naturally-ventilated house for feeding pigs (Nürtinger System). The house is 63 m long and 14 m wide with a ridge height of 5 m. 21 measuring points were installed in the house and it was therefore subdivided into 21 individual compartments. The method of approach is identical to that in the example shown in figure 1. The coefficients of exchange were determined by the regression series of the tracer concentration, the length and direction of which are marked in *figure 4*. Also marked are the possible agitation and flow directions which are only able to be given via the symptoms from the calculated exchange coefficients. Alongside the results for the air volume flows for the total building, the internal flow characteristics can be estimated and the openings characterised as inlets or outlets. Should alterations to the wind velocities or directions occur, these can be seen through changes of the symptoms in that the equation system is set anew after each time step.

Conclusion

Because of the size of farm livestock housing, measurements of tracer concentrations nowadays can only be carried out in point form. The total volume flow has to be determined from these point measurements. Through the use of a compartmentalisation method, the location dependency of a concentration measurement can be neglected. There then remains only the time variability of the tracer concentration. Under consideration of the flow mechanics basic law (in this case: maintenance of mass) a linear equation system was constructed and solved. The calculated exchange coefficients characterise the air volume flows in the house as well as the internal flow paths. This represents an improvement in the air volume flow calculations for naturally ventilated housing, in that up until now only integrative methods were applied. The basic requirements for applying compartmentalisation in the medium air is the simultaneous recording of the tracer concentration at all available measurement points.

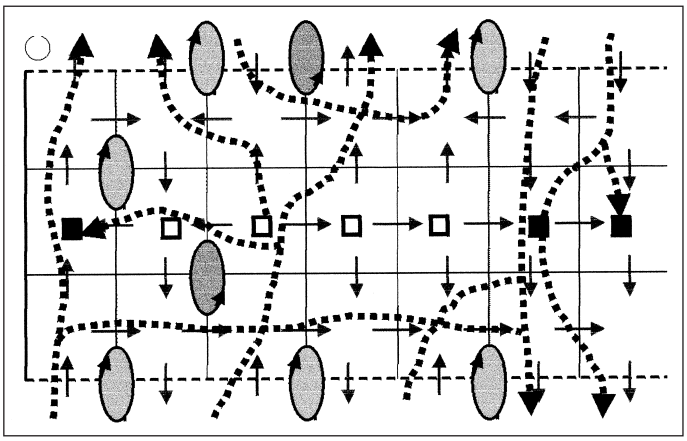

Fig. 4: Probable air flow pattern at the 13th time step in an open stable (Nürtinger System)

Literature

Books are signified with •

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