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Tracer gas experiment for local mean ages of air from individual supply inlets in a space with multiple inlets

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ABSTRACT

We investigate the supply characteristics of incoming air via individual inlets in a ventilated space with multiple inlets. Theoretical considerations are given to determine the relations between the local mean age (LMA) of the total supply air and the individual LMA of each supply air inlet. Tracer gas experiments are conducted in a simplified livestock model with two supply inlets and one exhaust outlet. Transient concentration responses at internal points are measured after tracer gas injection one inlet at a time, and for simultaneous tracer injection at both inlets. The spatial distributions of LMAs and steady concentrations are obtained by tracer injections from each supply inlet, which demonstrate the supply characteristics of the individual inlets in the space. We have found that the overall LMA is the weighted average of the LMA by each inlet, and the weighting factor for the average is the corresponding steady state concentration at a given point. Experiments repeated for various airflow rates show that the nondimensional steady concentrations remain nearly constant regardless of the total airflow rate, but are greatly influenced by the airflow ratio between inlets. The local mean ages are found to increase proportionally with respect to the nominal time constant. Experimental procedures and results are verified by the fact that the total LMA measured at the exhaust is in good agreement with the theoretical nominal time constant of the space.

1. Introduction

The indoor environment is important to occupants in residential buildings and animals in livestock buildings. Ventilation and heating are the only measures that can be applied to control the indoor environment of animal buildings in most cases. Ventilation needs to be provided continuously to eliminate heat and moisture, and dust and gas contaminants generated by animals and materials in the space. Livestock ventilation can improve comfort, animal welfare, behavior, and health [11]. More importantly, ventilation affects factors such as the conversion ratio, growth rate, and mortality [3].

It is often required to quantify the ventilation characteristics from supply inlets. It is necessary to distribute supply air evenly throughout the space, or to supply fresh air quickly to a certain region in the space. The concept of ventilation effectiveness has been introduced to quantify the ventilation performance of a building space. Ventilation effectiveness has been defined in various ways including the concentration ratio and decay rate. However, the concept of air age has been widely accepted in defining ventilation effectiveness as representing the time duration for the air at an inlet to reach a point within the space [9]. The air diffusion effectiveness currently adapted by [1,2] is based on the concept of air age. It has been reported that the distribution of local mean age in a space can be obtained by a steady state calculation when there is a uniformly-distributed generation of contaminants in the space, rather than by time-incremental unsteady calculations [4].

Studies of ventilation effectiveness have been conducted for a wide range of applications including livestock [8], aircraft [10], and general buildings [12,6,5]; however, these studies mainly focused on cases with a single supply inlet, or multiple inlets that can be considered as a single inlet without distinguishing the individual inlets. When there is more than one supply inlet, the supply characteristics from one inlet are different from the others. In some cases, an individual inlet needs to be distinguished so that incoming air can be traced independently. Depending on the location within the space, the contribution of an inlet to local ventilation performance is different from one point to another. The effect of each supply inlet is expected to be dependent on the relative inlet airflow rates and airflow patterns in the space.

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