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an experimental measuring method

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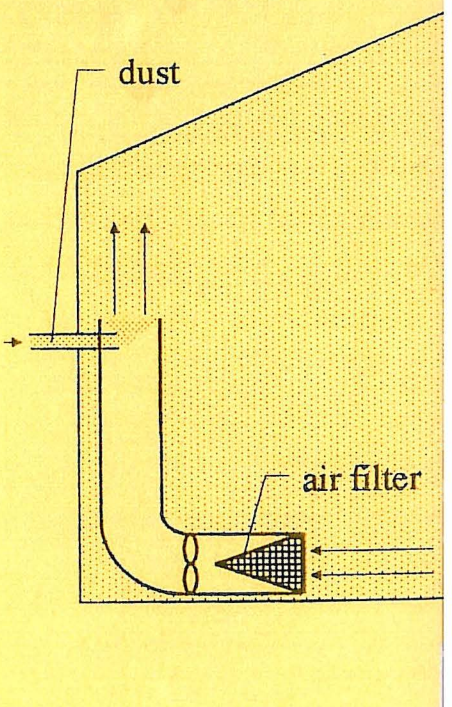

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Title:

DUST LOAD ON SURFACES IN ANIMAL BUILDINGS: AN EXPERIMENTAL MEASURING METHOD.

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Summary:

To investigate the physical process of particle deposition on and resuspension from surfaces in animal buildings, a test facility and a sampling method is established. The influences of surface orientation and air turbulence and velocity just as other parameters on the dust load on a surface are analysed.

It is found that the surface orientation is the parameter which influences the dust load most. The dust load is highest on the floor but some dust is also sampled on the walls and the ceiling. The measurements indicate that the air velocity has a non-linear influence and that the turbulence has a larger effect on the deposition than on the resuspension. Therefore high turbulence causes high dust load. However, the influence of turbulence and velocity are strongly dependent on each other and cannot be analysed in isolation.

INTRODUCTION

High concentrations of organic dust in animal buildings, primarily in swine buildings, have shown to cause health problems for both people and animals. To develop methods to eliminate dust related problems, there is, among other things, a need for better understanding of the mechanism behind dust deposition and resuspension. Dust deposition can reduce considerably the airborne dust concentration and, on the other hand, resuspension can increase the concentration for more than 100 % (Goddard et al. 1995).

The dust load is the amount of dust building up on the surface. The dust load is thus the balance between the mechanism of dust deposition on and resuspension from the surface. The deposition is defined as the rate of settling particles on the surface and the resuspension is the rate of removal of particles from the surface. Both deposition and resuspension are dependent on environmental conditions like air velocity and turbulence, on the surface conditions like orientation and roughness, on the type of particles and on other forces. Ideally, knowledge of both mechanism is needed, but as a first step the focus is on improved knowledge of factors that influence the dust load.

The purpose of this paper is to describe a facility to measure dust load on different materials used for differently orientated surfaces in animal buildings. Results from a first series of measurements is used as an example of the application of the facility and to show the suitability of the experimental set-up.

METHOD

Most of the basic information cannot be determined by measurements taken in actual animal buildings because of unknown elements such as the amount of dust present, air velocity and turbulence. This fundamental knowledge can only be attained when the experiments are carried out in a controlled laboratory environment.

Experimental set-up

A small wind tunnel with the dimensions 3.0x0.5x0.5 m is chosen as the experimental area (Figure 1). It is composed of three parts, namely, the inlet, the working section and the outlet.

The inlet, placed upstream of the working section, is well rounded in order to obtain a uniform velocity and turbulence profile in the working section. To produce different levels of turbulence in the experimental section, screens with different perforation levels can be installed at the wind tunnel inlet.

The dust load is measured on surface panels placed inside the experimental section facing up (floor), vertical (wall) and facing down (ceiling). They have each an area of 1.15x0.45 m and the distance to the wind tunnel inlet is 1m. To have good access to these panels the experimental section can be opened.

The air is drawn through the wind tunnel by a fan placed at the end of the outlet section with adjustable speed in order to adjust air velocity to pre-set values.

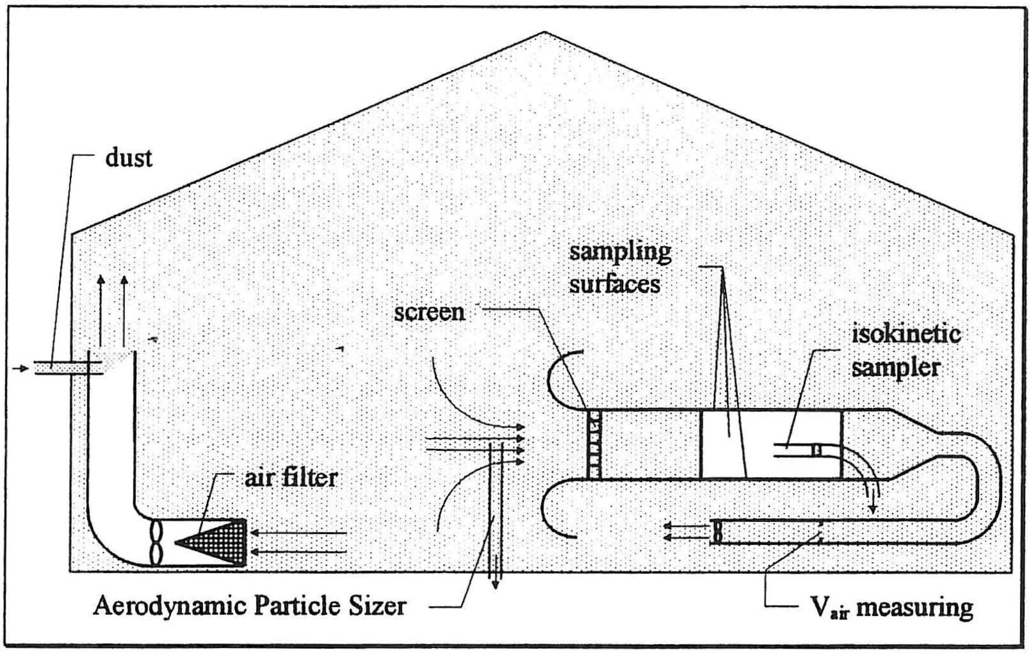

Figure 1 Schematic experimental set-up.

The wind tunnel itself is placed in a closed room where the dust concentration is controlled to stable levels. The dust is produced with a multi-point dust generator, developed by the Research Centre Bygholm (Takai et al. 1996). The dust is blown into the room and distributed with a ventilator. To get a constant dust level over the time, it is necessary to filter out the dust of the circulating air.

Measuring methods

The dust load on the experimental surfaces is measured by vacuum cleaning the sampling surfaces with a special cleaning head containing glass fibre filter which collects the particles (Figure 2). The amount of sampled dust is determined as the difference in weight of the filter before and after sampling.

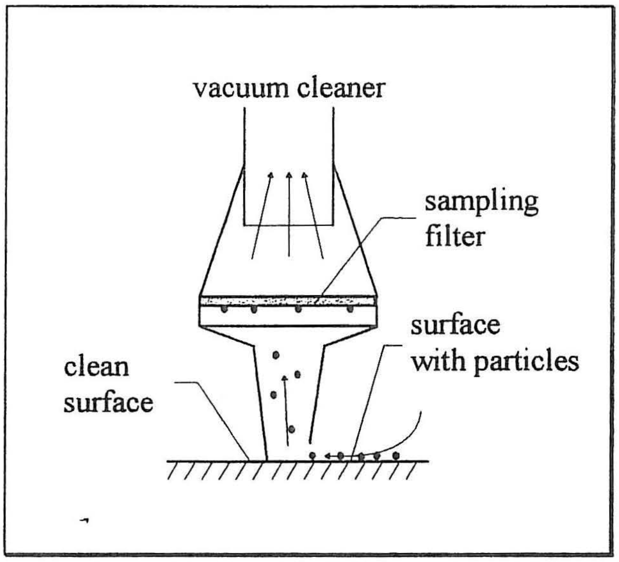

Figure 2 Dust sampling system with vacuum cleaner and glass fibre filter.

It is difficult to remove all the particle from the surface by vacuum cleaning, especially the small ones. To make sure that the amount of particles left on the surface after sampling can be neglected, i.e. the sampling efficiency is high, the tape technique described by Schneider et al. (1987) is used.

The airborne concentration at the wind tunnel inlet is measured by an Aerodynamic Particle Sizer (APS) and by isokinetic sampling inside the working section. The air velocity and turbulence over the cross-section of the working section are measured by Laser Doppler Anemometry (LDA). The turbulence is determined as the variance of the air velocity. Moreover, a reference velocity is defined by the air volume stream through the wind tunnel. The temperature of the air, the relative humidity and the electrostatic charge are also measured, but not controlled.

EXAMPLE OF THE APPLICATION

As an example of the application wood-fibre plates are chosen as surface material for all three orientations. By selecting the artificial dust, the main purpose is to get a similar size distribution as swine dust. Therefore talcum is chosen which is moreover cheap and easily available.

The experiments are carried out in summer and winter conditions, i.e. a relative humidity in the air of around 60 % resp. 30 % and an air temperature of around 26°C resp. 22°C. Different velocities from 0.1 m/s to 1.1 m/s and two nominal turbulence levels, namely 20 % (low) and 60 % (high), are chosen.

During the experiments, the amount of dust in the air is around $5x10^5$ particles per litre air. This gives a reasonable amount of dust on the surfaces by running the experiments for 30 minutes. Since all experiments are carried out with the same duration, no estimation about the time dependence of the dust load can be made.

RESULTS AND DISCUSSION

The first series of experiments show that it is possible to measure the dust load on the surfaces with the presented experimental set-up. The applied method gives reproducible results.

The verification of the sampling efficiency with the tape technique demonstrates that only very few and small particles cannot be picked up by the vacuum system. Hence the sampling efficiency referring to the mass of the dust is high.

In Figures 3 the dust load is shown as a function of the air velocity under summer conditions with a variation of the surface orientation and, for the floor, of the turbulence and relative humidity.

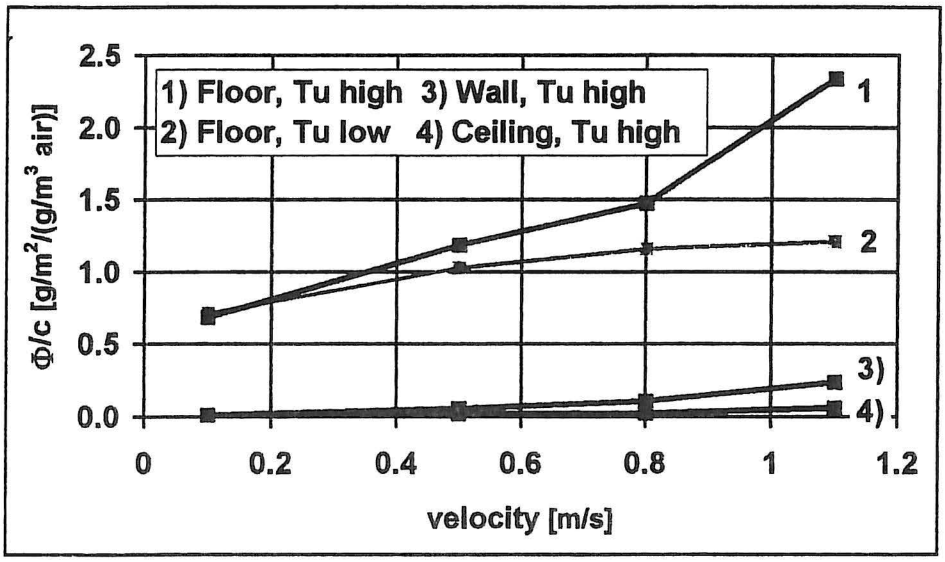

Figure 3 Dust load on three different surface orientations.

The parameter which influences the dust load most is obviously the surface orientation. Actually the surface orientation describes the gravity force normal to the surface. Therefore, no dust would be deposited on the wall and the ceiling without turbulence or other forces. As expected the highest dust load is found on the floor, but unlike assumed in most models in literature, the dust load on the walls and ceiling is not equal to zero. Considering the whole area which is covered by the walls and the ceiling, the influence of these surfaces on the airborne dust concentration can not be neglected at all.

The influence of the turbulence and the velocity cannot be analysed separately from other parameters since they are dependent on each other. A more detailed discussion about this phenomenon and about the influence of the relative humidity can be found in Lengweiler et al. (1998). However, it seems that the dust load depends on the combined effect of both turbulence an velocity because at a higher velocity more particles are transported which can be deposited by the turbulence.

Comparing the wind tunnel experiments with animal buildings, a reference material has to be chosen which has a well defined surface structure, e.g. stainless steel. To get more detailed knowledge about the building up of the dust load, the mechanical processes of deposition and resuspension have to be analysed separately, just as parameters like the electrostatic force. A problem of the method is that a compromise between maximum dust load on the floor and minimum dust load on the ceiling has to be made. A too small amount of dust just as a too high amount gives a high inaccuracy by weighing the sampling filter. Another disadvantage is that several experiments have to be done for analysing the time dependency on the dust load.

CONCLUSIONS

The following conclusions are drawn from this research:

(1) Dust loads on surfaces can be measured by the method proposed in this research under different environmental conditions, but a refinement of the method is necessary and also possible;

(2) The surface orientation is the most important parameter for the dust load, however the dust load on the walls and ceiling may not be neglected;

(3) Other parameters cannot be analysed separately from each other;

(4) A refinement of the method is necessary to measure deposition and resuspension individually.

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