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FEATURES OF NATURAL AND ARTIFICIAL AIR MOVEMENT

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ABSTRACT

Features of natural wind and artificial airflow are related to human thermal sensation. Based on the existing records of natural wind and artificial air movement, their turbulent intensity of velocity fluctuation, energy spectra, probability distribution of velocity are compared and analyzed. The results show that the slope of the spectra of natural wind is different from that of artificial airflow, that the spectra of natural wind in low frequency range are abundant, comparing with the spectra of artificial airflow, and that the probability distribution of natural wind is a skew and for artificial wind is roughly a Gaussian. Finally the possible reasons for those differences and the relationships between human thermal sensation and different air movements are initially discussed.

KEYWORDS

Natural Wind, Artificial air movement, Turbulent intensity, Spectrum, Probability Distribution, Thermal sensation

INTRODUCTION

Air movement including natural wind and artificial airflow could be of interest for improving indoors thermal environment in warm climate. The effect of air movement on human thermal sensation is to enhance the heat and mass transfer from human body surface to the surrounding in most cases.

The investigations on the effect of the air movement on human thermal sensation have been studied for many years and can be categorized into two phases: the first concerned about cool air draught as the indoor air temperature was lower than 26°C, for example, Madsen(1984), Fanger and Christensen(1986), Fanger, etc.(1988); The second mainly concerned to find out the suitable air velocity at which people would feel acceptable in a warm climate by using its cooling effect to offset high air temperature, for example, Rohles(1974), Marc Fountain and Fred Bauman, etc.(1994), Tanable, Kimura(1994), Edward Arens and Tengfang Xu, etc.(1998). Concerning the effect of air movement on human thermal sensation, the mean air velocity was considered as the only parameter at beginning. In the research of cool air draught, the turbulence intensity was found to be an effective parameter, which affects human thermal sensation. Thereafter it was pointed out that the turbulence intensity did not considered the frequency distribution of a fluctuating air movement. In order to identify the air movements with the same turbulence intensity but different frequency distribution, the probability density function and energy spectra were used. In recent years, furthermore, the airflow direction has been concerned as a factor, which affects thermal sensation, for example, Fanger(1988), E.Mayer and R.Schwab(1988).

In order to take the advantage of the cooling effect caused by either natural wind or artificial airflow, it is necessary to characterize the main features of natural wind and fluctuating airflow and to find out the difference between their features by using the parameters above cited. Since natural wind has been well accepted and adapted by the majority of people, the feature of natural wind should certainly have special attention, so that the artificial airflow could be simulated as a natural mode in the feature.

AIR MOVEMENT RECORDS

The air movement records used in this analysis are consisted of three parts. The first part (referred to as natural wind) was measured at a frequency of 10 Hz with a hot-wire anemometer which was mounted on 1.2 m mast above ground outside a building. The total number of the samples is 83.

The second part (artificial airflow No.1) was logged at frequency of 10 Hz with a hot-wire anemometer. The airflow was produced by different devices which include different fans, different outlets with fans in it. The number of the samples is 29.

The third part (artificial airflow No.2) is similar to the second part. But the fans or the blades of the wind outlets can be oscillated around a center. The number of the samples is 10.

RESULTS

Turbulence intensity

The instantaneous air velocity of a fluctuating air movement can be expressed as: $v = v' + \bar{v}$.
Where v' is the velocity fluctuation, and $\bar{v}$ the mean velocity. The turbulence intensity, Tu, is the standard deviation divided by the mean velocity

$$Tu = \frac{\sqrt{\overline{v'^2}}}{\bar{v}}$$

Tu provides the information on the average magnitude of the velocity fluctuation over an interval of time. Fig.1~2 show the relationships between Tu and mean velocity for natural and artificial air movement.

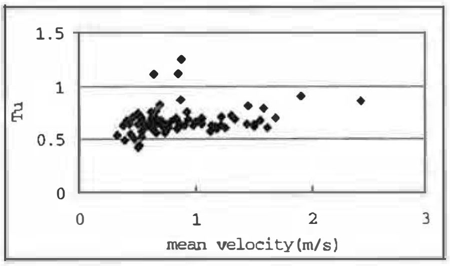

Fig.1 Natural Wind

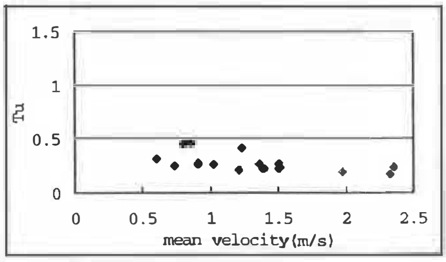

Fig .2 Artificial Airflow No.1

From comparison it is found that the turbulent intensity of natural wind is bigger than that of the artificial airflow No.1. Artificial airflow No.2 shows higher *Tu* because of the oscillating effect. The turbulence intensity of natural wind in the range of 0.5-1.5m/s is twice as high as that of artificial airflow No.1.

The probability distribution function

In general the probability distribution of a true random variable should be Gaussian distribution. If there is something, which affects the random process, the probability distribution will be deviated from

TABLE 1

	Natural wind	Artificial airflow No.1	Artificial airflow No.2
Skewness	1.41	0.12	1.51
Kurtosis	3.1	-0.04	2.92

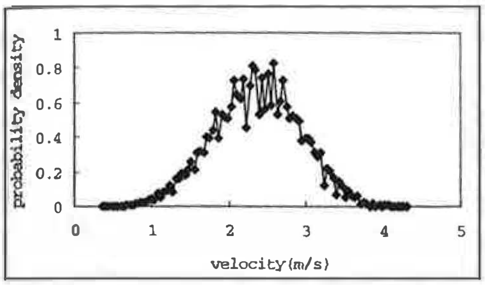

Fig.3: The distribution of the artificial airflow

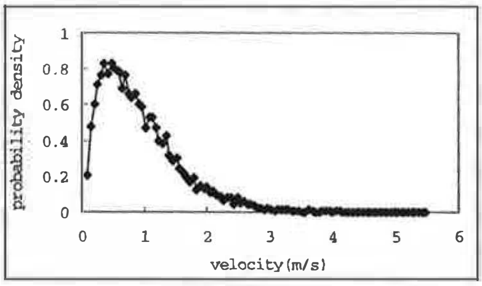

Fig.4: The distribution of the natural wind

the Gaussian and the deviation degree can be evaluated by the parameters of skewness and kurtosis. The average skewness and kurtosis of different air movements are listed in table 1.

It can be found from the Table 1 that the deviation of the probability distribution of natural wind is obvious. Fig. 3 and Fig 4 are two typical examples. The deviation of the probability distribution may be caused by the intermittence of the turbulent flow and different surroundings may have certain impact on the distribution.

Power spectra

The turbulence intensity of air movements represents the amplitude of velocity fluctuations. But fluctuations with different frequency may have different influences on human sensation. The power spectrum density, $s(f)$, is a suitable function which describes the energy distribution of the fluctuation with frequency. This can be expressed as follows:

$$\overline{v'^2} = \int_0^\infty s(f)df$$

For discrete series of the fluctuating velocity, the power spectra can be calculated with the help of Fourier transform. Fig 5 is the comparison of the power spectra of the natural wind and the artificial airflow No.1.

It is obvious that the spectra shown in Fig. 5 have different features. The analysis of the spectra can be done in two ways: the one is the difference of the spectra distribution with frequency and the other is to compare the total fluctuation energy.

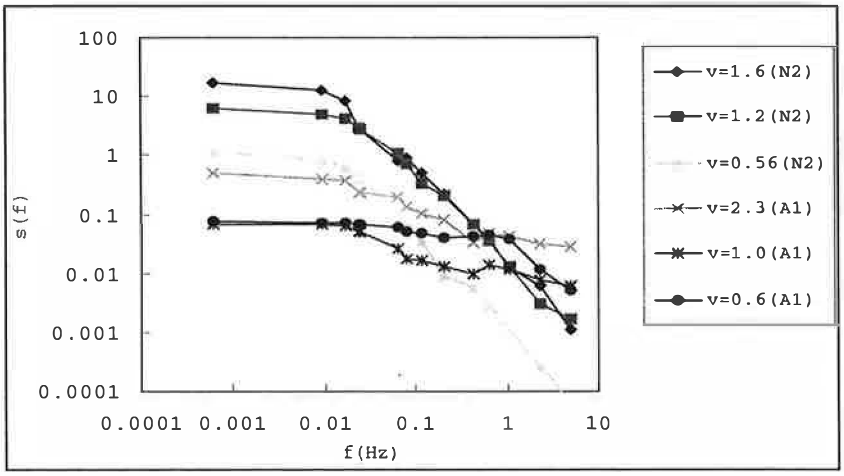

Fig5 The spectra of the natural wind in comparison with the spectra of artificial airflow
(N2 represents the natural wind and A1 represents the artificial airflow No. 1)

The spectra density of natural wind in low frequency range is much higher than that of the artificial airflow. It is found from Fig. 5 that there is a turning point around 0.003~0.04 Hz for the spectra of natural wind. Therefore the spectra curve can be treated as lines below and above the turning point respectively. The slope of the spectra curve goes gently in the low frequency range above the turning point and drops sharply in the high frequency range. But the slope of the spectra curve of the artificial airflow generally is flat. Since the concrete spectra indicate the distribution of fluctuation energy, it is clear that the main part of the fluctuation is in low frequency range for natural wind and high frequency range for the artificial airflow. This difference can be identified clearly by using the parameters of f50 and f90 which representative the 50% or 90% of the total fluctuation energy (in the measuring range) below a certain frequency respectively. Table 2 lists the slope of the spectra curve and the frequency corresponding to f50 and f90.

TABLE 2

	Natural	Artificial No.1	Artificial No.2
B1*	-0.57	-0.2	
B2*	-1.52	-0.9	
F50**	0.03	1.1	0.2
F90**	0.44	3.4	1.2

*B1 is the slope of the spectra curve below 0.03Hz and B2 is above 0.03Hz
**For artificial airflow the turning point is 0.3Hz

DISCUSSION

The difference between natural wind and artificial airflow exists nearly in every aspect. The turbulent intensity and the spectra surely provide the information of the velocity fluctuation. Fig. 5 shows that the spectra of natural wind, even with the lowest velocity (0.56m/s), is still bigger than those of artificial airflow in low frequency range. The velocity fluctuation of artificial airflow is comparatively monotony because of the shortage of the fluctuation with lower frequency. Although the spectra of two air movement modes are not discernable in the high frequency range, it is still realized that the spectrum function could not be considered as consistent with each other. Possibly this is the main reason why people enjoy the natural wind pattern, which displays in a random and uncertain manner.

CONCLUSION

(1) The comparison shows that there are many difference between the feature of natural and artificial air movement. The feature of the natural wind is random and changeable. By using f50, f90, B1, B2 and the turning point, an artificial airflow can be distinguished from natural wind.

(2) The important feature of natural wind is the spectra, different from artificial one in the lower frequency range.

(3) Further studies in the impact of the effect of natural wind on human thermal sensation in warm climate are needed.

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