Micro-meteorological data for sound propagation modeling

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Abstract

The common noise assessment methods for Europe (CNOSSOS-EU) has made a good decisions to reduce noise pollution in EU states, the so called can cause health problems for people and also for wildlife ,like hearing loss and stress, and high blood pressure . the noise pollution can made by many sources crafts, industries, traffic noise etc. The micro-meteorological factors are the major and the important factor influence the sound speed propagation because it depends essentially on them like the temperature when it increases or decreases then it happens the same to the sound speed propagation and where the wind is stronger,the effect is greater, until the wind becomes so turbulent that the wind itself becomes the dominant noise source in this paper we will measure the sound level using taken into account all the meteorological conditions.

1 INTRODUCTION

In cities the sound levels caused by noise from surface transport or other sources is often determined by nearby area, the meteorological conditions are the major factors influence the sound propagation, and these conditions are reflected in wind speed and wind direction, temperature, relative humidity and the cloudiness, all these factors which we mentioned depend on the time. in this paper we will be familiar with the the meteorological data which influence the sound speed propagation and that by using statistical tools and Weibull distribution to estimate and compute some meteorological factors and use data of some other factors. We will compute the wind speed distribution at each direction and also the stability classes and after all calculation we will end up with the sound propagation and its stability .

2 The importance of the micro-meteorology for the sound propagation

The meteorologists have measured the effect of the temperature and wind speed and relative humidity and the cloudiness (as indicator of stability) also on sound propagation, and they quantified and found highly sensitivity of the meteorological factors, For this reason it is desirable to accurately replicate temperature and wind speed profiles and other conditions in sound propagation models using either careful measurements or detailed simulations.

2.1 Surface layer profiles (wind, temperature, stability)

We can express The wind speed at two heights in terms of measuring wind speed at another height so the relationship is given as : $\frac{v_2}{v_1} = (\frac{h_2}{h_1})^\alpha$ where v_1 and v_2 are the wind speed at h_1 and h_2 respectively.

The wind speed based on the Monin-Obukhov similarity theory in source-receiver is given as follows :

$$u(z) = \frac{u^*}{k}[ln(\frac{z}{z_0}) - \Psi_M(\frac{z}{L})]$$

The equation $[ln(z/z_0)]$ represents the turbulence due to mechanical friction, the boundary layer stability conditions are classified in stability classes based on Monin-Obukhov length L. For stable and unstable atmospheric conditions, the correction value for the wind profile is calculated using:

$$\Psi_M(\frac{z}{L}) = \begin{cases} 2 * ln(\frac{1+x}{2}) + ln(\frac{1+x^2}{2}) - arctan(x) + \frac{\pi}{2} & forL < 0 \\ \frac{-5z}{L} & forL > 0 \end{cases} \quad (1)$$

and the temperature profile can be determined by the equation:

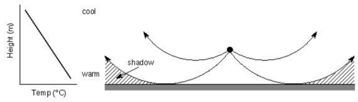
$$T(z) = T_0 + \frac{T^*}{k}[ln(\frac{z}{z_0}) - \Psi_H(\frac{z}{L})] + \Gamma$$

for the correction term of the temperature profile is given by:

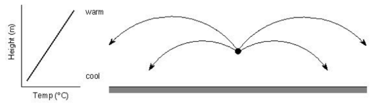
$$\Psi_H(\frac{z}{L}) = \begin{cases} 2 * ln(\frac{1+x}{2}) & forL < 0 \\ \frac{-5z}{L} & forL > 0 \end{cases} \quad (2)$$

where $x = (1 - \frac{16z}{L})^{\frac{1}{4}}$.
u^* the friction velocity in m/s
$T*$ is the temperature scale in K
L is the Monin-Obukhov length in m
Γ is the day adiabatic temperature gradient.

The wind direction affects the propagation of sound by refracting its waves and it changes at each direction, the wind direction is measured in degrees clockwise from true north (north = 0°, east = 90°, south = 180° and west = 270°) the following equation is formulated the wind speed at each direction: $U = u(z) * cos(\alpha)$ where U is the wind speed at the new direction and $u(z)$ is the true wind speed, and α is the angle between the wind vector and actual source-receiver line.



(a) The sound propagation at day time (unstable).



(b) The sound propagation at night time (stable).

The stability of the sound propagation depends essentially for the micro-meteorological conditions, the noise is large in a stable atmospheric conditions. During the day, the environment is more active then at night. Moreover, the wind speed near the ground is higher in an unstable atmosphere than in a stable one.

This example shows that if we are near the lake and a group of people sitting in the another side of the lake we can not hear them in the day time if we sit in the shadow area an that is because the wave closest to the ground is traveling the fastest and the wave sound above the ground traveling the slowest and we get the unstable sound propagation and and vice versa in the night time the temperature increases with height and sound also increases then we get the stability that means we can hear them.

2.2 Sound speed profiles

Sound propagation is basically dependent on the sound speed and temperature and relative humidity. In the direction of sound propagation the relation between the sound speed $c(z)$, temperature profile $T(z)$ and wind speed profile u(z) in dependence of height z is given by: $c(z) = c_0\sqrt{\frac{T(z)}{T_0}} + u(z)$. Now the equation of sound propagation influences by all the factors of the meteorological data can be formulated as follows :

$$c(z) = A * ln(1 + \frac{z}{z_0}) + B * z + c_0$$

where c_0 is the sound speed at height $z = 0$
A coefficient of the logarithmic term (m/s)
B coefficient of the linear term (1/s)
the profile coefficients A and B can determined as follows: during the day time (stability classes which are depend on the cloudiness S1 at most 2/8 oktas, S2 from 3/8 to 5/8, and S3 6/8 to 8/8 oktas) :

$$B = \frac{u^* cos(\alpha)}{L * C_{vk}} + (\frac{c_0}{2 * T_{ref}})(\frac{0.74 * T^*}{L * c_{vk}} - \frac{g}{c_p})$$

during the night time (stability classes S4, S5) :

$$B = \frac{u^* cos(\alpha)}{L * c_{vk}} + (\frac{c_0}{2 * T_{ref}})(\frac{4.7 * T^*}{L * c_{vk}} - \frac{g}{c_p})$$

but A still the same during all the day :

$$A = \frac{u^* cos(\alpha)}{c_{vk}} + (\frac{c_0}{2 * T_{ref}})(\frac{0.74 * T^*}{L * c_{vk}})$$

T_{ref} is the reference temperature = 273 K
α is the angle between wind direction and the direction of sound propagation.
c_{vk} is the Von Karman constant = 0,4
g is the Newton's gravity acceleration = 9,81 m/s
c_p is the specific heat capacity of air at constant pressure, 1005 J/kg K .

3 Meteorological dataset

In our research we took a data set from a station in Budapest we take into consideration all the meteorological data wind speed and direction, temperature, relative humidity and the cloudiness in hourly time.

3.1 The stability classes of the sound propagation

We found the equations of A and B than we can express the stability classes of the sound propagation, 25 classes of stability (5 class from A and 5 from B) each pair of component from A and B describes a stability class of the sound, and from those classes we can summarize that into three classes in (T_d ,T_e,T_n) the time of each class is very important to come up with the two classes at the end whether it can be stable class or unstable class of sound propagation but before we do all this computation we take all the meteorology condition into account then we calculate the gradient of sound propagation

$$\frac{\partial c}{\partial z} = A \cdot \frac{1}{z+z_0} + B$$

from this equation we can get the stability of the sound by take the values of A and B (A=-1, -0.4 , 0, 0.4, 1 and B=-0.12, -0.04, 0, 0.04, 0.12) if the $\frac{\partial c}{\partial z} \geq 0.07$(m/s)/m then we get the stability which is bad situation for us e.g if B=0 and vice versa if $\frac{\partial c}{\partial z} \leq 0.07$(m/s)/m we get the instability which is good for us And this is embodied if the B=-0.12 where the height $z = 4\ m$ and the roughness length $z_0 = 10\ cm$.

3.2 The wind speed distribution

Weibull and Rayleigh distributions are the commonly used in the micro-meteorological data ,we consider the Weibull distribution to model the wind speed by using the probability density function, and cumulative function of Weibull by the assistance of the gamma function we will get the mean value and the standard deviation of the sound speed.

3.2.1 The probability density function

$$f(v) = (\tfrac{k}{c})(\tfrac{v}{c})^{k-1} e^{-(\frac{v}{c})^k} \qquad k, c > 0,\ v \geq 0$$

f: the probability of observing wind speed v
c: Weibull scaling parameter
k: the dimensionless Weibull shape parameter.

3.2.2 Cumulative function of Weibull distribution

$$F(v \leq v_0) = 1 - e^{-(\frac{v}{c})^k}$$

where F represents the probability of the wind speed v to be lower than a certain

value v_0.
The mean wind speed v_m and the standard deviation σ are defined as follows:

$$v_m = c * \Gamma(1 + \frac{1}{k})$$

and the standard deviation is given by:

$$\sigma = c * [\Gamma(1 + \frac{2}{k}) - \Gamma^2(1 + \frac{2}{k})]^{\frac{1}{2}}$$

where the gamma function is given as:

$$\Gamma(n) = \int_0^{\infty} e^{-t} t^{n-1} dt$$

4 The sound level

After calculating the stability classes and summarize them into two classes whether stable or unstable then we find the noise level formula defined :

$$L_{LT} = 10 * log(p * 10^{\frac{L_F}{10}} + (1-p) * 10^{\frac{L_F}{10}})$$

L_F:the sound level for near neutral and unstable stratification (which is good for us)
L_H:the sound level for homogen stratification (which is bad situation)
p: the probability for good situation.

5 Conclusion

The sound propagation is strongly depend on the meteorological factors. In this paper different meteorological effects were studied continuously. The wind speed and the temperature are the most important variables which influence the sound propagation. The increase in the mean wind speeds increases the sound speed, thus how exactly the temperature effect the sound, as we have studied before in this paper, if the temperature changes the sound do also with the high z, Computing the sound includes the stability classes of cloudiness by estimating the coefficients A and B, as the relative humidity. the previous parameters play a huge role in knowing the stability of the sound propagation. We compute the 25 stability classes based on A and B and that by using the data set of the meteorological in Budapest and Algiers then we end up with 2 classes the stable class and the unstable then we compute the probability of each class finally we study the sound level.

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