Journal of Environmental Sciences Vol.16, No.4, pp.576—580, 2004

ISSN 1001—0742
CN11—2629/X

Article ID: 1001-0742(2004)04-0576-05 **CLC number**: X121 **Document code**: A

A new approach of drawing airport noise contours on computer based on Surfer

ZHANG Bang-jun[1,*], GUO Chun-yan[1,2], Di Guo-qing[1]

(1. Department of Environmental Science, Zhejiang University, Hangzhou 310028, China. E-mail: bjzhang@mail.hz.zj.cn; 2. The Radiation Monitoring Technical Center, SEPA, Hangzhou 310012, China)

Abstract: Noise contours are used to describe the extent of airport noise pollution and to plan land use around airports. The L_{WECPN} (weighted equivalent continuous perceive noise level) recommended by ICAO (International Civil Aviation Organization) is adopted as airport noise rating parameter in this paper. With the help of various mathematical models in the software Surfer, noise contours can be drawn automatically by the completed program in Visual C++ Code. Corrections for thrust, velocity, atmospheric temperature, humidity and lateral ground attenuation are also considered in the new method, which can improve the efficiency of drawing contours. An example of its use for drawing noise contours of an airport in Zhejiang Province of China is proposed and the predictions and the measurements show agreements well.

Keywords: airport; noise contours; weighted equivalent continuous perceive noise level(L_{WECPN}); Surfer

Introduction

Airports are symbols of cities' modernization. However, the noise produced by aircraft operations represents a serious environmental problem because of the increase of the type and number of aircrafts in airports and the expansion of the city itself. How to reduce aircraft noise level is a crucial task for aviation departments, environmental protection agencies, and specialists in designing and planning airports. Compatible land use around airport is an efficient way to control airport noise, and noise contours are adopted as tools for land use planning and accessing the reactions of communities around airports.

The aircraft noise pollution has become a serious problem since 1950s in the world and scholars have been searching the rating parameters that represent the characteristics of aircraft noise since then. In 1960s, many countries had their own specific method for quantifying and assessing aircraft noise in the vicinity of airports. The standard of aircraft noise for environment in China has been customized since 1983. A great deal of measurements of aircraft noise around several airports in Beijing and Shijiazhuang and social surveys on reactions of people around Beijing airport were taken. The experiments on subjective evaluation of aircraft noise were also carried out indoors and we customized "Measurement method of aircraft noise around airport" and "Standard of aircraft noise for environment around airport". The results indicated that L_{WECPN} concludes not only aircraft noise level, number of flight operations, flight time durations but also reactions and subjective evaluation of people around airports. So it is an effective measure of aircraft noise not only in physical but also in psychological evaluation.

The research on drawing airport noise contours in China began in late 1980s, when the reference information in this field was rarely little and the rating parameter adopted was the day-night-average sound level L_{dn} which was inconsistent with the index recommended by "Standard of aircraft noise for environment around airport". In 1990s the program of calculating noise contours for a certain airport was available in which a single interpolation was invited to satisfy its own needs. These programs cannot be put into practice extensively because of its poor compatibility. Research on models used for assessing aircraft noise abroad began relatively early and there are corresponding applied soft wares in environment impact assessment of airport. The validity of NEF (Noise Exposure Forecasting) system adopted by Canada in forecasting aircraft noise impact and predicting communities' reactions has been proved in practice. Because their airport noise rating systems vary greatly from ours, we cannot draw airport noise contours by means of their models and soft wares directly. It is essential to set up an effective method of drawing airport noise contours, which is practicable in China.

Surfer is a contours drawing tool that is devised to apply in the research of geography initially. There are scholars searching its application in environmental protection work because of its predominance in contours drawing. Wei Wenfei has made use of Surfer to draw noise contours of Longyan in Fujian Province of China. The ADMS (Atmospheric Dispersion Modeling System) provided by CERC (Cambridge Environmental Research Consultants) includes a tool to call Surfer, which can express the distribution of air pollutants in contours.

This paper presents a new method to draw airport noise contours in China, which utilizes various mathematical

* Corresponding author

models in Surfer and draws noise contours automatically in Visual C++ code. Noise contours can be drawn according to the topography, scheduled flights, airport types and departure or approach flight paths and so on. The new method can improve the efficiency of drawing contours and the predictions and the measurements show agreements well.

1 The introduction of software Surfer

Surfer is a contouring and 3D surface mapping program produced by Golden Software that runs under Microsoft Windows. The gridding methods in Surfer can produce regular data from random XYZ data and convert the data into accurate contours based on its interpolation mathematical models. It provides 10 traditional gridding methods for contour drawing: Inverse Distance, Kriging, Minimum Curvature, Modified Quadratic Shepard, Natural Neighbor, Nearest Neighbor, Shepard's Method, Polynomial Regression, Radial Basis Functions, Triangulation. Choosing suitable gridding method and setting the gridding parameters appropriately in terms of the data source and the drawing requirements, we can get the contour presentation we expect exactly. Therefore, the interpolation mathematical model is the core of drawing contours.

Besides drawing contours, Surfer has other functions as follows: (1) Surfer provides an impressive three dimensional display of the 3D surface; (2) surfer includes a full-featured worksheet similar to Excel for creating, opening, editing, and saving data files, which can process the original data completely such as calculating data statistics, sorting, performing data transformations and calculating based on column etc.; (3) exporting files in various formats, of which the DXF format files can be utilized by other software.

Surfer supplies six function modules: GRID (the gridding of original data), TOPO(drawing contours), SURF (drawing the 3D surface), VIEW(displaying on monitor), PLOT (drawing) and UTIL (utility functions). A brief introduction of GRID and TOPO that involved in this paper is given here. First of all, the original data (the coordinate value X, Y and the corresponding property value Z) cannot be used to draw the contours directly unless they have been interpolated with the GRID module. Gridding can convert random original data into regular data within the area the original data is dispersed according to one of its gridding methods(interpolation mathematical models). Then the TOPO module converts the data provided by GRID into accurate contours.

2 The basis of drawing airport noise contours

The study provides a method to draw airport noise contours automatically through calling Surfer in Visual C++. Combining Surfer in Visual C++ to draw contours can avoid the poor compatibility caused by a single interpolation method. In practice, the method given in this paper can draw contours of not only noise levels but also distribution of pollutants in water and in air as long as the boundary conditions are defined.

2.1 Model of airport noise prediction

2.1.1 Principal descriptors of L_{WECPN} and prediction formula

L_{WECPN} is based on formula of the following form:

$$L_{WECPN} = \overline{L_{EPN}} + 10\lg(N_1 + 3N_2 + 10N_3) - 39.4. \quad (1)$$

Where N_1 is the number of flight operations for aircraft from 7.00 to 19.00 hours on a given day; N_2 is the number of flight operations for aircraft from 19.00 to 22.00 hours on a given day; N_3 is the number of flight operations from 22.00 to the next 7.00 am; $\overline{L_{EPN}}$ is the mean effective perceived noise level of a prediction point for N aircraft operations on a given day, which is defined by

$$\overline{L_{EPN}} = 10\lg\left[\frac{1}{N}\sum_i \sum_j n_{ij} 10^{0.1 L_{EPNij}}\right]. \quad (2)$$

Where L_{EPNij} represents single event effective perceived noise level for aircraft category i in flight route j of a prediction point; n_{ij} is the total number of aircrafts per 24-h day for aircraft category i in flight route j; N is the total number of aircrafts per 24-h day, namely $N = N_1 + N_2 + N_3$.

2.1.2 The calculation model of L_{EPN}

Single flight event effective perceived noise level is defined as follows:

$$L_{EPN} = L_{Amax} + 10\lg T_d/20 + 13. \quad (3)$$

Where L_{Amax} is the maximum A-frequency weighted sound level of a single event; T_d is the time integration durations (the interval between the first and the last time that the A-weighted sound level is 10 dB less than the maximum A-weighted sound level). The meaning of t_1, t_2 shown in Fig.1.

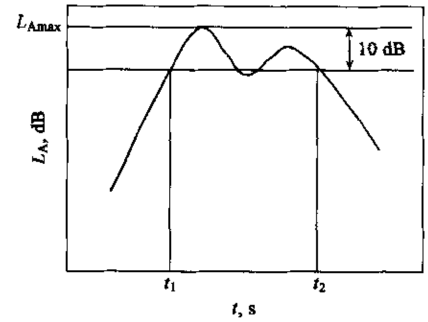

Fig.1 The time integration durations and sound level L_A of a flight event

Meanwhile, the magnitude of L_{EPN} correlates well with the bias distance D between the prediction point and the flight route, so the conventional noise-power-distance relationship curve can be obtained from a great deal of experimental data for any type of aircraft and its function expression can also be derived from multinomial simulation recurring to computer. Consulting relevant information domestic and abroad, we choose the simulation model as follows:

$$L_{EPN} = A + B \cdot \lg D + C \cdot (\lg D)^2. \quad (4)$$

Where A, B, C are coefficients obtained from simulation of noise-power-distance relationship curve for a certain type of aircraft; D is the bias distance between the prediction point and the flight route. The simulation functions are defined for take-off and landing respectively for each type of aircraft because of the significant differences of the noise characteristics when taking-off and landing.

2.1.3 Corrections for L_{EPN}

The aircraft noise data supplied by International Civil Aviation Organization or aircraft manufacturers is experimented under a certain circumstance. We need to do some necessary corrections to the data according to the actual conditions for the reason that the actual prediction conditions are not in accordance with the circumstances when the data is tested. Corrections are made up of the following aspects:

(1) Correction for thrust: Different noise levels under various thrusts can be derived from the following equations:

$$L_F = L_{Fi} + (L_{Fi+1} - L_{Fi}) \cdot (F - F_i)/(F_{i+1} - F_i). \quad (5)$$

Where L_F, L_{Fi}, L_{Fi+1} represent the noise level under the thrust F, F_i, F_{i+1} respectively of the same prediction point.

(2) Correction for velocity: Usually the aircraft noise data is obtained for a flight velocity of 160 kt, therefore we should make correction according to the actual airspeed of aircraft when calculating the sound exposure level. The corrections to L_{EPN} for variations of flight velocity V are equal to the ICAO recommendation:

$$\Delta V = 10\lg(V_r/V). \quad (6)$$

Where V_r is the reference flight velocity and V is the velocity on the ground of concerned moment.

(3) Corrections for atmospheric temperature and humidity: Atmospheric adsorption attenuation is experimented for atmospheric temperature of 15℃ and humidity of 70%. The influence of atmospheric temperature and humidity on aircraft noise impact must be taken into considerations when the conditions are notably inconsistent with that we referred above.

(4) Lateral ground attenuation: The lateral ground attenuation is caused by propagation when an aircraft is opposite a receiver or climbing out with a low elevation angle, which is derived as the following formulas:

When the aircraft is on the ground:

$$\Delta(L) = 15.09(1 - e^{-0.00274L}), \quad 0 < L < 914 \text{ m}, \quad (7)$$

$$\Delta(L) = 13.86, L \geqslant 914 \text{ m}. \quad (8)$$

Where $\Delta(L)$ is the lateral ground attenuation; L is the distance from the prediction point to the horizontal cast of flight route.

When the aircraft is in air:

$$\Delta(\beta) = 3.96 - 0.066\beta + 9.9e^{-0.13\beta}, \quad L > 914 \text{ m}, 0° \leqslant \beta \leqslant 60°, \quad (9)$$

$$\Delta(\beta) = 0, \beta > 60°. \quad (10)$$

Where, $\beta = \cos^{-1}(L/D)$, β is the angle between the bias distance D and L; $\Delta(\beta)$ is the lateral ground attenuation; D is the bias distance between the prediction point and the flight route.

$$\Delta(\beta, L) = (\Delta L) \cdot (\Delta\beta)/13.86, \; 0 < L \leqslant 914 \text{ m}. \quad (11)$$

Where $\Delta(\beta, L)$ is the lateral ground attenuation.

2.1.4 The definition of the bias distance D

(1) When the aircraft is in air: The Descartes reference frame is set up with the definition that the take-off or landing point is the origin, the central line of runway is coincident with x-axis. If the ordinate value of the prediction point is (x, y) and the take-off or landing angle is θ, then

$$D = \sqrt{y^2 + (x \cdot \tan\theta \cdot \cos\theta)^2}. \quad (12)$$

If the flight track deflects or the flying angle varies after taking off, we should calculate D according to the actual conditions.

(2) When the aircraft is running in the runway, $D = |y|$.

2.2 The procedure of drawing airport noise contours

The procedure of drawing airport noise contours mainly consists two parts: (1) calculate the L_{WECPN} of each prediction point and generate the result file in visual C++ code; (2) grid the result data with the GRID module and draw noise contours in Surfer. The whole procedure of the prediction program is shown in Fig.2.

2.3 The design of the procedure on drawing airport noise contours

(1) The Descartes reference frame is set up with the definition that one endpoint of the runway is the origin, the central line of runway is coincident with x-axis. Prediction points are fixed up with the gridding method in which the steps of x, y directions are 200 m and 100 m.

(2) Calculate the L_{WECPN} of each prediction point according to the prediction model of L_{WECPN} and generate the result file in visual C++ code.

(3) Choose the interpolation model through calling Surfer in the program and grid the result data with the GRID module.

(4) Control the smoothing parameters of contours in Surfer and generate the noise contours including 70 dB, 75 dB, 80 dB, 85 dB and 90 dB with the TOPO module;

(5) Combine the local map around the airport with the contours in Surfer;

(6) With synthetically processing get the final airport noise contour map.

3 Case study

The automation level and efficiency in environmental

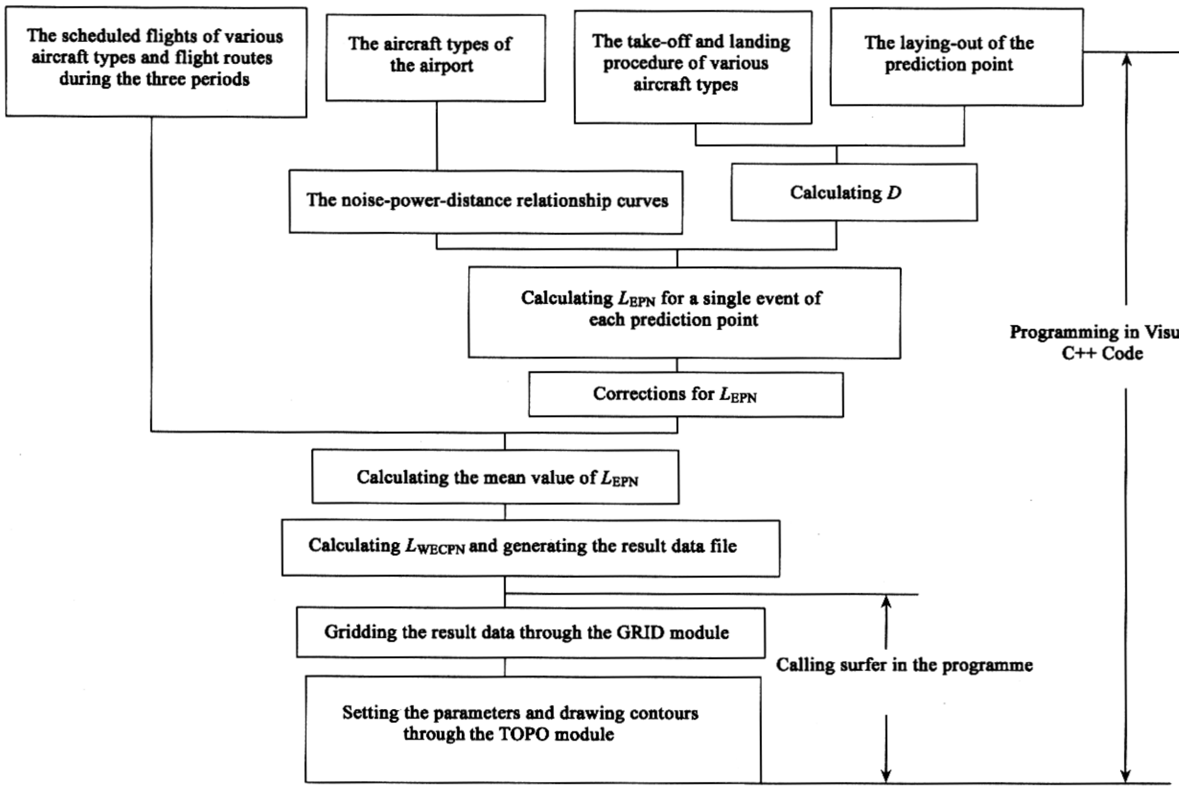

Fig.2 The procedure of drawing airport noise contours

research and management can be improved if airport noise contours drawing and analysis are carried out on a computer. In this paper a soft for drawing airport noise contours based on the method referred above is established. The example of its use for drawing noise contours of a certain airport in Zhejiang Province is proposed.

3.1 The prediction of airport noise

The prediction model referred above is adopted to calculate the L_{WECPN} of the airport. Suppose the aircraft category in the certain airport consists of B737, A320, B757 and DHC-8, the east-west runway is 3600 m long and the flight operations on a given day are given in Table 1 and Table 2.

Table 1 The flight operations on the measurement day

Item	Total number of aircraft operations on the day	Taking-off eastward	Landing eastward	N_1	N_2	N_3
Flights	86	43	43	70	13	3

Table 2 The directions of flight operations on the measurement day

Aircraft type	B737	B757	A320	DHC-8	A300	B767	B777	MD82
Taking-off eastward	12	7	11	6	2	2	1	2
Landing eastward	2	7	11	6	2	2	1	2

Set the parameters of the airport and aircrafts appropriately in the program and calculate the noise level of the prediction points. The predicted noise level and measured value of these points are given in Table 3. It shows that the predicted value agrees with measured value well with an error between 1.6 dB to 3.1 dB. So the noise contours based on the result data derived from the program fit the actual condition well.

Table 3 The comparison between the predicted and measured noise level (L_{WECPN}) dB

Serial number of points	The measured value of L_{WECPN}	The predicted value of L_{WECPN}	Errors
1	77.8	79.4	1.6
2	72.6	75.0	2.4
3	68.3	71.2	2.9
4	65.0	68.1	3.1

3.2 Drawing noise contours through calling Surfer

Firstly, set the parameters of the airport and aircrafts appropriately in the program according to the flight schedules of the airport in 2010. Then draw noise contours through calling Surfer after the result file is generated. The calculating parameters are set as Fig.3 shows before drawing contours.

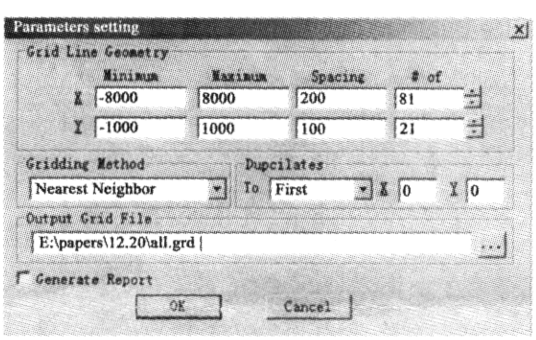

Fig.3 The window of setting contours drawing parameters

The mathematical models supplied by Surfer have their own parameters setting. We can get the contours presentation we expect exactly if choosing the suitable interpolation method and setting the parameters flexibly. Various effects can be expressed according to various mathematical models. The noise contours can fit the actual conditions well if a good gridding method is chosen. In respect that the interpolation models' requirements to the data source and actual conditions, authors think the "Nearest Neighbor" interpolation method can reflect the distribution of noise level around airport appropriately after repetitive practice. The reason is "Nearest Neighbor" interpolation method is preferred when the data is dispersed regularly. Therefore we choose "Nearest Neighbor" in the option of "Gridding Method" in the window of parameters setting which shown in Fig.3

The final noise contours is shown in Fig.4.

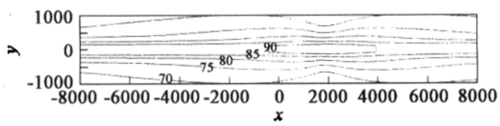

Fig.4 The noise contours around a certain airport in Zhejiang Province in 2010(dB)

4 Conclusions

This paper presents a new method to draw airport noise contours automatically through calling Surfer in Visual C++ and a practical case is proposed. In result, the predicted value agrees with measured value well and the approach improves the efficiency of drawing contours. It will have broad applied prospects in the research of pollutants dispersion and environmental measurements where contours need to be drawn.

References:

Bai S B, Chen Y, Wang J, 2002. An introduction to nine gridding methods and their application in Surfer version 7.0[J]. Computing Techniques for Geophysical and Geochemical Exploration, 24(2): 157—162.

Pereira F A J, Braaksma J P, Phelan J J, 1995. Interpreting airport noise contours[J]. Transportation Research Record, 1475: 66—69.

Sheng H Y, Liu J S, 2000a. Airport noise prediction model and case study[J]. Journal of Hebei Normal University(Natural Science), 24(1): 137—140.

Sheng H Y, 2000b. Program and method of noise environmental impact assessment from airport[J]. Chongqing Environmental Science, 22(4): 67—69.

SEPA(State Environment Protection Agency), 1988a. Measurement method of aircraft noise around airport (GB9661-88)[S].

SEPA(State Environment Protection Agency), 1988b. Standard of aircraft noise for environment around airport (GB9660 - 88)[S].

Tu R Y, 1993. Prediction of airport noise contours[J]. Technology of Shanghai Jiaotong University, 1: 25—32.

Wang X, Lin G H, Lin F, 1994. Noise impact assessment and control measurements of Sanming Shaxian Airport [J]. Control of Noise and Vibration, 10(5): 14—19.

Wei W F, 1993. The application of Surfer in environmental protection work[J]. Fujian Environment, 10(5): 26—27.

Zheng D R, Cai X L, 1991. Study on evaluation about aircraft noise around airport[J]. Acta Acustica, 16(3): 218—229.

(Received for review June 2, 2003. Accepted December 5, 2003)