EXAMINATIONS OF METHOD FOR CALCULATING L_{AE} OF HELICOPTER NOISE

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ABSTRACT The paper presents a simple method for calculating the sound exposure level (L_{AE}) of helicopter noise. It is assumed that a helicopter is a nondirective point source and that A-weighted sound pressure level at an observation point can be expressed by an A-weighted power level and a simple function of the distance from the helicopter. We derived a formula for L_{AE} by integrating the sound energy along a finite or an infinite flight segment. The values calculated from the formula agree well with the results of test flights in which three types of helicopters each were operated in three moving modes of approach, takeoff and level flyover.

1. INTRODUCTION

In Japan, the standard for estimating aircraft noise is defined using WECPNL or L_{den} (day-evening-night sound level). The index L_{den} is selected for estimating the noise around a small scale airport like a heliport. To predict the L_{den}, it is necessary to calculate the sound exposure level (L_{AE}) of each helicopter.

Heliport Noise Model (HNM)[1] has been reported from FAA (Federal Aviation Administration) to predict helicopter noise. HNM has the database[2] including the values of L_{AE}, which are prepared for various helicopter types, three moving operational modes, eight distances from a flight path, and three angles of elevation from an observation point to a point on a flight path. In this study we derived a simple formula for estimating L_{AE} using the HNM database. The accuracy of the derived formula was examined comparing with the test flight data[3].

2. FORMULA FOR CALCULATING L_{AE}

In this section, three kinds of formula are derived for calculating L_{AE} of helicopter noise assuming that a helicopter is a nondirective point source and that A-weighted sound pressure level at an observation point can be expressed in a simple function of the distance

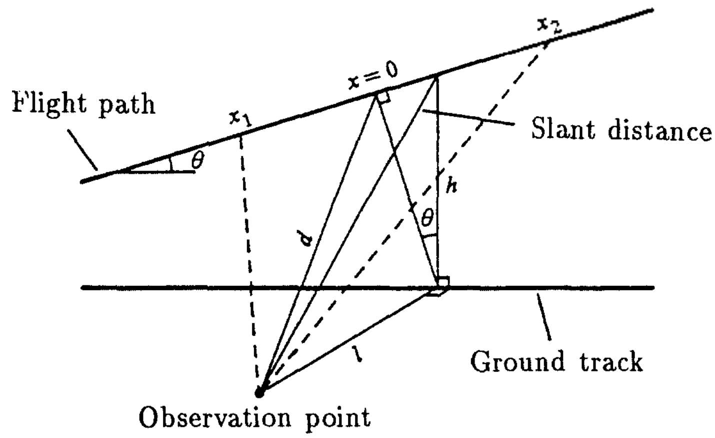


Fig. 1 Flight path and observation point. Distances and angle used for calculation are illustrated.

from an observation point to a sound source.

In Fig. 1, a straight flight path and an observation point are illustrated with symbols for distances and angle. The perpendicular distance, d (m), from an observation point to the flight path is given by:

$$d = \sqrt{l^2 + h^2\cos^2\theta} \tag{1}$$

where l (m) is the perpendicular distance from the observation point to the ground track, h (m) is the helicopter height as it flies over the intersection of the perpendicular to the ground track, and θ is the climb angle of the flight path. The position of the helicopter is described by x (m) taking the x-axis along the flight path.

First, we assumed that the A-weighted sound pressure level, L_A, at the observation point is expressed by the following formula:

$$L_A = L_W + 10\log_{10}\left[\frac{1}{4\pi(d^2 + x^2)}\right] \tag{2}$$

where L_W is the A-weighted power level of the helicopter. This formula is based on what is called "inverse square law". If the helicopter flies straight at an uniform velocity v (m/s), the sound exposure level is given by:

$$\begin{aligned} L_{AE} &= L_W + 10\log_{10}\left[\int_{-\infty}^{\infty}\frac{1}{v}\frac{dx}{(d^2 + x^2)}\right] \\ &= L_W + 10\log_{10}\left[\frac{\pi}{vd}\right]. \end{aligned} \tag{3}$$

Secondly, we assumed that the sound pressure level can be written in the form:

$$L_A = L_W + 10\log_{10}\left[\frac{1}{4\pi\{(d^2 + x^2) + a(d^2 + x^2)^{\frac{3}{2}}\}}\right] \tag{4}$$

where a is a positive constant. Then,

$$L_{\mathrm{AE}} = L_W + 10\log_{10}\left[\int_{-\infty}^{\infty} \frac{1}{4\pi v}\cdot\frac{\mathrm{d}x}{(d^2+x^2)+a(d^2+x^2)^{\frac{3}{2}}}\right]$$

$$= \begin{cases} L_W + 10\log_{10}\left[\dfrac{1}{4\pi v d}\left(\pi - \dfrac{2ad}{\sqrt{1-(ad)^2}}\ln\dfrac{\sqrt{1-(ad)^2}+1}{ad}\right)\right] & (ad < 1) \\ L_W + 10\log_{10}\left[\dfrac{\pi-2}{4\pi v d}\right] & (ad = 1) \\ L_W + 10\log_{10}\left[\dfrac{1}{4\pi v d}\left(\pi - \dfrac{4ad}{\sqrt{(ad)^2-1}}\tan^{-1}\dfrac{ad-1}{\sqrt{(ad)^2-1}}\right)\right] & (ad > 1) \end{cases} \quad (5)$$

Thirdly, assuming that the sound pressure level is expressed by:

$$L_{\mathrm{A}} = L_W + 10\log_{10}\left[\frac{1}{4\pi\{(d^2+x^2)+a(d^2+x^2)^2\}}\right], \quad (6)$$

where a is a positive constant, we obtained the following formula:

$$L_{\mathrm{AE}} = L_W + 10\log_{10}\left[\int_{-\infty}^{\infty}\frac{1}{4\pi v}\cdot\frac{\mathrm{d}x}{(d^2+x^2)+a(d^2+x^2)^2}\right]$$

$$= L_W + 10\log_{10}\left[\frac{1}{4vd}\cdot\left(1-\sqrt{\frac{ad^2}{ad^2+1}}\right)\right]. \quad (7)$$

The relation between L_{AE} and the distance from an observation point to the flight path changes according to the value of the constant a in Eq. (5) and Eq. (7). Fig. 2 shows the comparison of Eq. (3), (5), (7) with the data in the HNM database. The HNM data in this figure are for a moving operation of approach with an elevation angle of 90° from an observation point to a flight path. We have chosen these data, since the data mostly show higher level than other data in the HNM database.

The line calculated from Eq. (7) with $a = 3 \times 10^{-7}$ agrees better with the mean value of the data in the HNM database than other lines. In addition to this, Eq. (7) is simpler in form than Eq. (5). We have selected Eq. (7) with $a = 3 \times 10^{-7}$ as the formula for calculating L_{AE} of helicopter noise in a moving operation.

When a flight path is not straight, it is divided into some finite straight segments. The value of L_{AE} is obtained by summation of integrations along the finite segments. If a helicopter flies along a finite segment from x_1 to x_2 ($x_1 < x_2$) as in Fig. 1, Eq. (7) becomes:

$$L_{\mathrm{AE}} = L_W + 10\log_{10}\left[\int_{x_1}^{x_2}\frac{1}{4\pi v}\cdot\frac{\mathrm{d}x}{(d^2+x^2)+a(d^2+x^2)^2}\right]$$

$$= L_W + 10\log_{10}\left[\frac{1}{4\pi v d}\left\{\tan^{-1}\frac{x_2}{d} - \tan^{-1}\frac{x_1}{d} - b\left(\tan^{-1}\frac{bx_2}{d} - \tan^{-1}\frac{bx_1}{d}\right)\right\}\right] \quad (8)$$

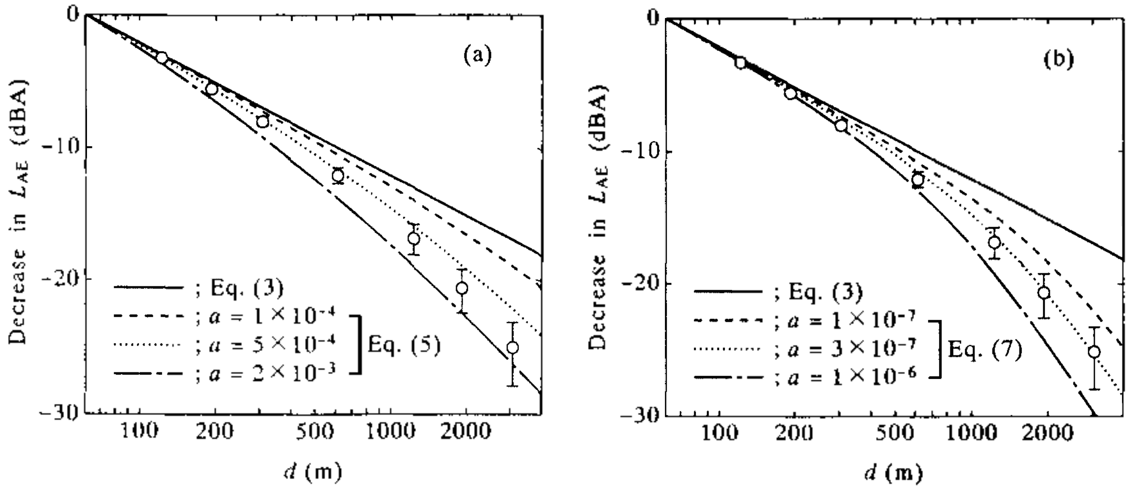


Fig. 2 Relation between Eq. (3), (5), (7) and perpendicular distance from the flight path. The sound exposure level relative to the level at 200 ft is plotted in the ordinate. The lines are calculated from the derived formulas with the several values for the constant a. The circles show the mean values of the data in the HNM database, and upper and lower lines show the maximum and the minimum values of them.

where

$$b = \sqrt{\frac{ad^2}{ad^2 + 1}}. \tag{9}$$

3. POWER LEVEL OF VARIOUS KINDS OF HELICOPTERS

The value of A-weighted power level, L_W, is necessary to calculate Eq. (7) or (8). We have classified the values of power level into three groups according to the maximum takeoff weight of the helicopters. Fig. 3 shows the relation between the maximum takeoff weight and the power level which is obtained by the reverse calculation using Eq. (7) and the data in the HNM database. The values of power level are classified according to the maximum takeoff weight as follows:

large	(over 10 ton)	140 dBA
medium	(2 ~ 10 ton)	135 dBA
small	(under 2 ton)	130 dBA

4. COMPARISON WITH THE TEST FLIGHT DATA

Field measurement[3] was carried out in Osaka using three kinds of helicopters (AEROSPATIALE SA316B, AEROSPATIALE SA365N, BELL 206B). Each helicopter was operated in the three moving modes of takeoff, approach and level flyover. The observation

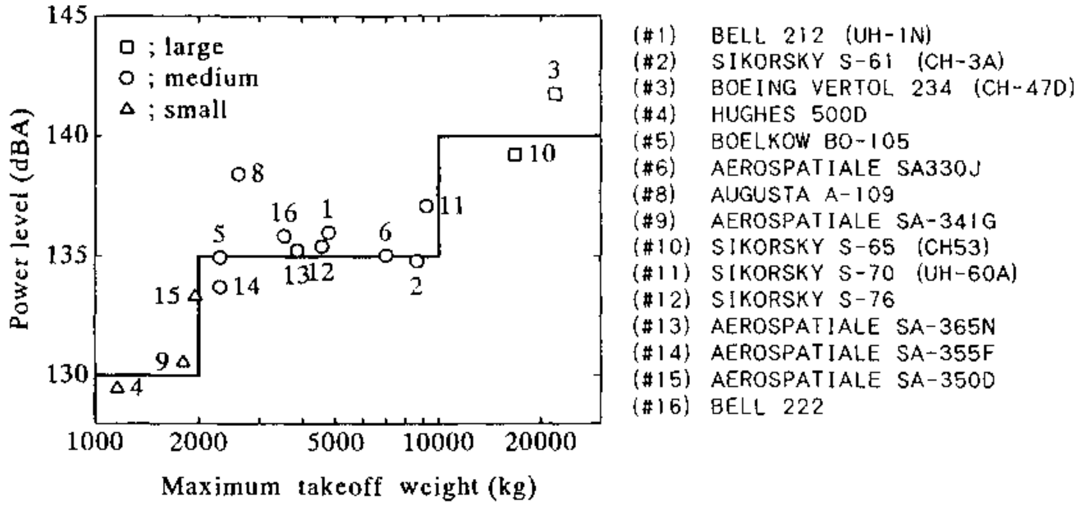
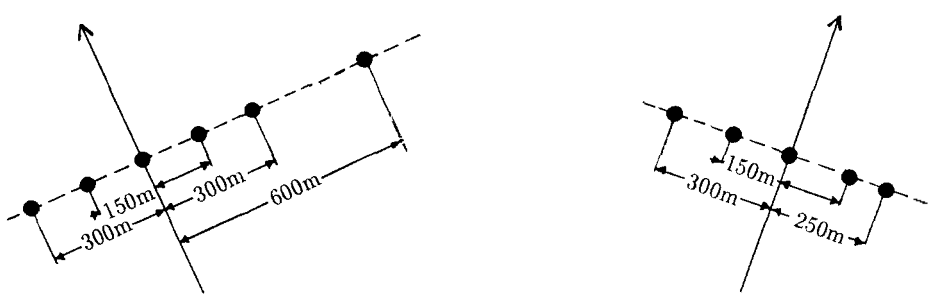


Fig. 3 Relation between the maximum takeoff weight and the power level. The solid line indicates the value of power level classified into three groups.



(a) SA316B, SA365N

(b) BELL 206B

Fig. 4 The observation points in the test flights.

points in the test flights are illustrated in Fig. 4. The range of flight height was 20~151 m and that of helicopter speed is 51.1~150.6 knot. Fig. 5 shows the correlation between the calculated values and the observed values.

5. CONCLUSION

We derived a simple formula (Eq. (7), (8)) for estimating L_{AE} of helicopter noise in a moving operation. The power level of a helicopter and the constant in the formula are determined using the data in the HNM database. The values of power level are classified into three groups according to the maximum takeoff weight of helicopters. The estimated values using the derived equation agree well with the observed values in the test flights.

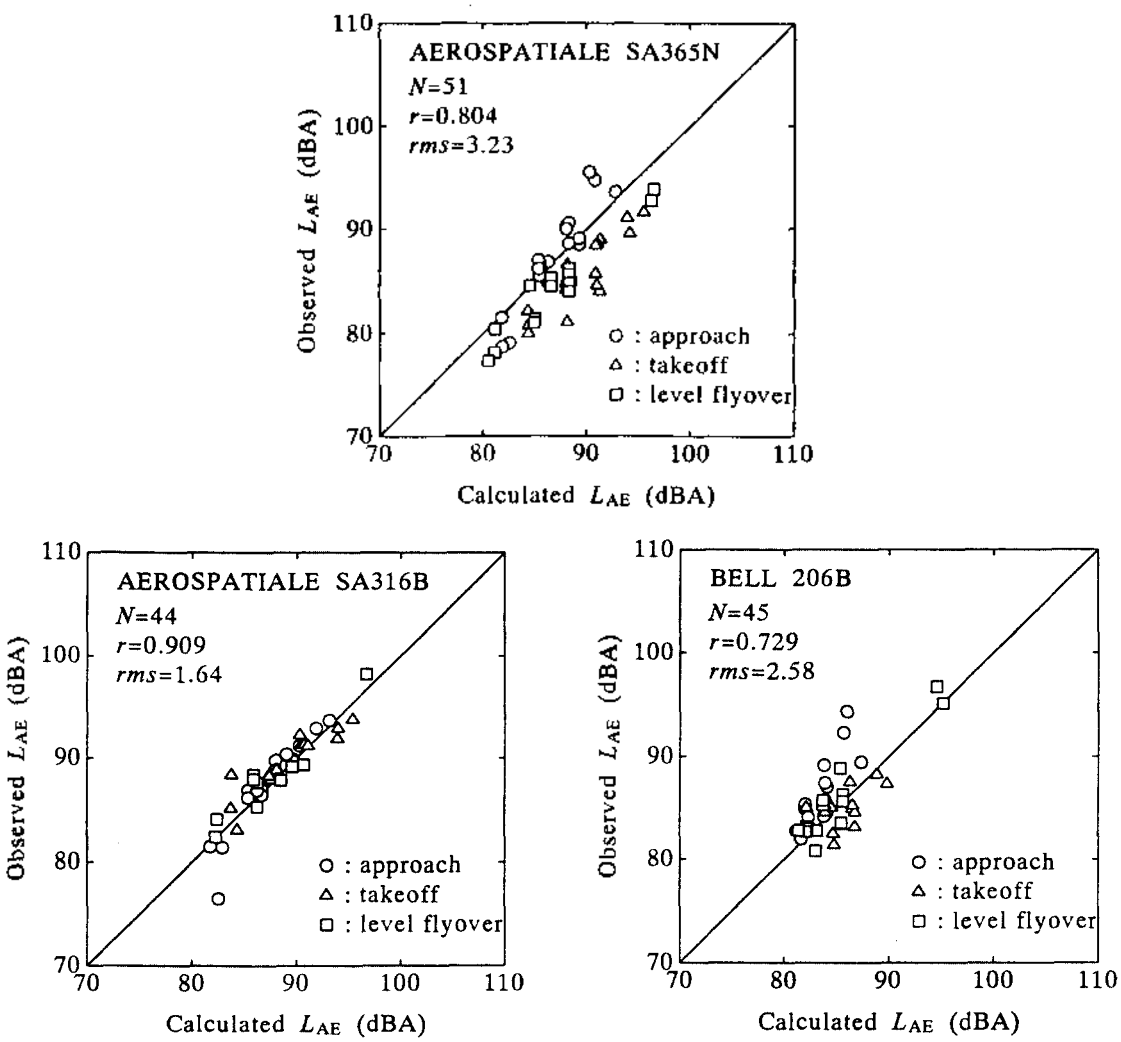


Fig. 5 Correlation between the calculated values and the observed values. The symbol *rms* is the root mean square of errors.

REFERENCES

1. T. Connor, D. Warren, "Federal Aviation Administration, Heliport Noise Model (HNM)," INTER-NOISE 88, 1-6(1988).
2. Federal Aviation Administration, Heliport Noise Model Version 1 User's Guide, Appendix A, (1988).
3. Osaka prefecture, Report on the method for environmental assessment around a heliport, (1991) (in Japanese).