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A new numerical tool for the Evaluation of Noise Impact Generated by Helicopters

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1.0 Introduction

This method estimates noise for both single and tandem main rotor helicopters except for approach where it applies to single rotor designs only. It does not apply to coaxial rotor designs. Application is limited to helicopters powered by turbo-shaft engines and does not apply to helicopters powered by reciprocating engine, tip jets or other types of power plants. It provides noise information using basic operating and geometric information available in the open literature. To keep the method simple, it generates A-weighted sound levels, precluding the necessity for spectral details. The method prescribes estimates for typical helicopter operations; certain maneuvers may produce noise levels different from those estimated. Estimates are given for the maximum sound levels at 4 ft (1.2 m) height above the ground. For aircraft in forward flight, the estimate is given for an aircraft at an altitude of 500 ft (152 m) on a path directly over the observer. For an aircraft in hover the estimate is given for an aircraft hovering 10 ft above ground level at a distance of 500 ft (152 m) to the side of the observer.

2.0 General Background

As the use of helicopters increases, so does the need for helistops and heliports. Thus, communities will be considering provisions for these helicopter facilities in developing their land use plans. One aspect of such planning requires forecasts of potential noise exposure before helicopter type specific data become available [6]. Such forecasts can also be used to estimate noise for known models. Therefore, a need exists for a noise estimation capability which is not dependent on detailed helicopter design information. The procedure described in this work is based on one study was developed by the Italian Aerospace Research Center. The data used to validate the method were provided by several other manufacturers and sources.

2.1 Nomenclature:

$C1, C_2$ = Constants in the regression equation

LAMAX = Maximum A-weighted Sound Level (dBA) for the conditions and distances for each flight condition as described in 5.2.

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MT = Rotational Flight Mach Number which can be determined by using Fig. 1

MF = Forward Flight Mach Number which can be determined by using Fig. 2

P = Independent parameter used in regression equation to describe helicopter characteristics. Defined in Section 2.2

R = Rotor radius in feet

w = Helicopter gross weight in pounds

π = 3.14

2.2 Selection of the Independent Parameter

The independent parameter was selected based on examination of mathematlcal correlation with measured data; intuitively, it includes the most important design variable as follows:

Main rotor disk load $W/\pi R^2$ is the obvious initial parameter because a more lightly loaded rotor will generate less noise than a heavily loaded one. In general, disk loading varies from about 3 psf (144 N/m2) for small helicopters up to about 10 psf (480 Nm^2) for large ones [2].

The term R non-dimensionalizes the prediction distance, 500 ft (152 m), to the number of rotor radii.

The Mach number function, $M_T/1-(M_T+M_F)$ reflects the importance of tip speed on rotor noise and provides a rapid growth in predicted level as the advancing tip Mach number (M_T+M_F) approaches 1.0. Mach number is the ratio of the actual speed to the speed of sound. [7]

Although the term $M_T/1-(M_T+M_F)$ obviously has a divergent simgularity at the value (M_T+M_F) = 1, this condition is not encountered in actual helicopter design due to the rapid buildup in nolse, vibration, and loads which are encountered [2]. See Section 5 on Accuracy and Limitations.

These design variables combine to give the following parameter:

$$P = \left(\frac{W}{\pi R^2}\right)\left(\frac{R}{500}\right)\left(\frac{M_T}{1-(M_T+M_F)}\right)$$

3.0 <u>Sound levels measures:</u>

Maximum A-Weighted Sound Levels provide noise estimates in units most common to community noise evaluation. It is planned that the method will be extended to provide Sound Exposure Level and directivity information as described in reference [1].

4.0 CALCULATION PROCEDURE:

4.1 ***General Procedures:***

The procedure is based on the fit of data to log *(P)*. The resulting regression equations are of the form [4]:

$$\text{LAMAX} = C_1 + C_2 \log_{10}(P)$$

where C_1 and C_2 are constants from the regression analysis.

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All estimates are for a measurement height of approximately 4 ft (1.2 m) above ground level and a measurement distance of 500 ft. Therefore, this procedure includes ground reflection effects in the estimates.

Predictions for other distances are described in reference [5].

Hover:

The equation for hover when the helicopter is near the ground is [4]:

$$LAMAX = 80 + 15 \log_{10} (P)$$

The level predicted is the spatial and time averaged sound level of the helicopter at 500 ft (152 m) radius with the wheels approximately 10 ft (3.05 m) from the ground. The sound levels were averaged because gusts and control inputs cause substantial variation to the noise produced by a hovering helicopter. Maximum sound pressure levels at a particular azimuth may exceed the averaged value by 3-5 dB. Fig. 3 shows the data on which this equation is based.

4.3 Take-off.

The equation for Take-off is [4]:

$$LAMAX = 81 + 11 \log10 (P)$$

The level predicted is the maximum directly under the flight path when the aircraft is 500 ft (152 m) above ground level. (Take-off climb angle is typically 10 - 12 deg). Fig. 4 shows the data on which this equation is based.

4.4 Approach:

The equation for approach is [4]:

$$LAMAX = 84 + 13 \log_{10} (P)$$

The level predicted is the maximum directly under the approach path when the aircraft is 500 ft (152 m) above the ground and descending along a 6 degrees slope. (This corresponds to a 4757 ft (1450 m) distance from the touchdown point.) The approach equation is only applicable to single main rotor helicopters.
Fig. 5 shows the data on which this equation is based.

4.5 Flyover:

The equation for flyover is [4]:

$$LAMAX = 81 + 12 \log10 (P)$$

The level predicted is the maximum directly under an unaccelerated level flyover at a height of 500 ft (152 m). Fig. 6 shows the data on which this equation is based.

4.6 Combined Equation:

The similarity of equations described above indicates that little accuracy would be lost if the data for all flight conditions were combined to form a single data set with a

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single slope and a constant of 81 dB for hover, take-off, and flyover and a constant of 84 dB for approach. The combined equation for all flight conditions is:

$$LAMAX = C_1 + 11 \log10 (P)$$

where

C_1 = 81 for hover, take-off, and flyover
C_1 = 84 for approach

Fig. 7 shows the data on which this equation is based.

4.7 Adjustment for Other Distances

The sound pressure levels predicted by the equations in Sections 5.2 - 5.5 have all been normalized to a distance from the microphone of 500 ft (152 m). Reasonable estimates of levels at other aircraft altitudes may be made by [7]:

$$LA = LA (500) - 24 \log D/ 500$$

where:

LA = A-weighted SPL at D ft
LA(500) = A-weighted SPL at a distance of 500 ft (152 m) from microphone
D = Distance from helicopter to microphone, ft

This approximation is for far field noise only and should not be used for distances less than 100 ft (30.5 m) or greater than 3000 ft (914 m) since it is based on measured data including ground effects [3].

5. Accuracy and limitations:

The 90%. confidence limits of the data point with respect to the regression lines range from 3.5 to 5 dB. The data scatter may be due to several factors: accuracy of aircraft location, accuracy of operating parameter identification, atmospheric propagation effects [5], as well as effects of design which are not accounted for such as rotor blade airfoils and tip shapes. As more data taken under carefully controlled conditions become avalaible, the confidence limits may reduce.

The use of these methods should be limited to helicopters which fall generally within the parameters of the helicopter which comprised the data base as follows:

Gross Weight:

2000 lb - 50 000 lb

(907 kg - 22 680 kg)

Disc Loading,

3 psf - 15 psf

(144 N/m^2 - 718 N/m^2)

Hover Tlp Speed:

600 fps - 800 fp

(183 m/s - 244 m/s)

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Advancing Tip Mach Number:

<.9

Location:

Under Flight Path

6 EXAMPLE:

Assume a helicopter with the following design parameters:

Gross Weight = 10.000
Rotor Radius = 25 ft
Rotor Speed = 250 RPM
Temperature = 60^0F

Predict LAMAX for the following:

a. Hover at a distance of 500 ft
b. Take-off passing over the microphone at a height of 400 ft at a speed of 80 knots

STEP 1: Calculated Disk Load

Disk Load =

$$\frac{W}{\pi R^2} = \frac{10000}{\pi * 25^2} = 5.09 psf$$

STEP 2

Calculated Rotational Tip Mach Number

Rotational Tip Speed =

$$\frac{2\pi(RPM)(RADIUS)}{60} = \frac{2\pi(250)(25)}{60} = 654 ft/s$$

From fig. 1, at 60 F. degrees

M(T) = 0.582

STEP 3 Hover at 500 ft Distance

$$P = (5.09)\left(\frac{25}{500}\right)\left(\frac{0.582}{1-0.582}\right) = 0.354$$

From 5.2

La = 80 + 15 log 0.354 = 73.2 dB

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STEP 4

Take-off at 80 knots and a height of 400 ft :

Mz = 0.582

From Fig. 2: MF = 0.12

At 500 ft Distance

From 5.3 (or Fig. 4)

$LAMAX_{500} = 81 + 11 \log 0.497$

LAMAX = + 77.7 dB

From 5.7 [8]

At 400 ft :

LAMAX = 77.7 - 24 log 400/500 = 80.0 dB

$$P = (5.09)\left(\frac{25}{500}\right)\left(\frac{0.582}{1-(0.582+12)}\right) = 0.497$$

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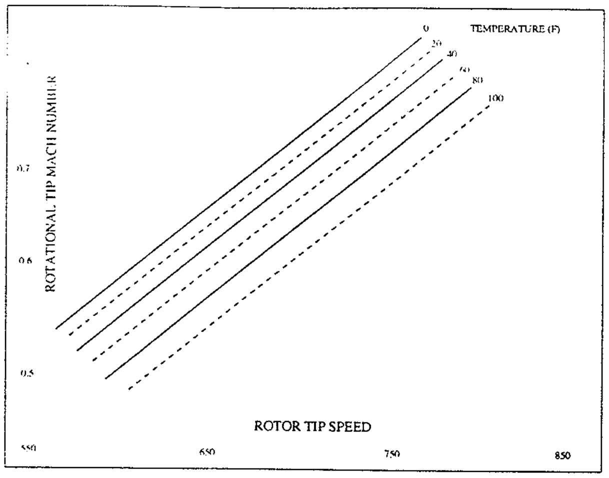

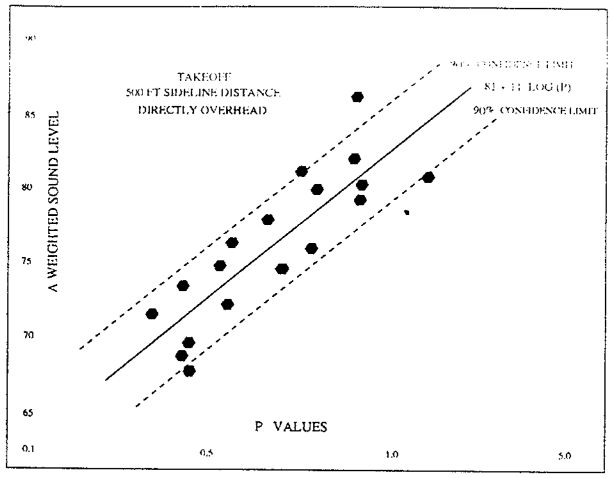

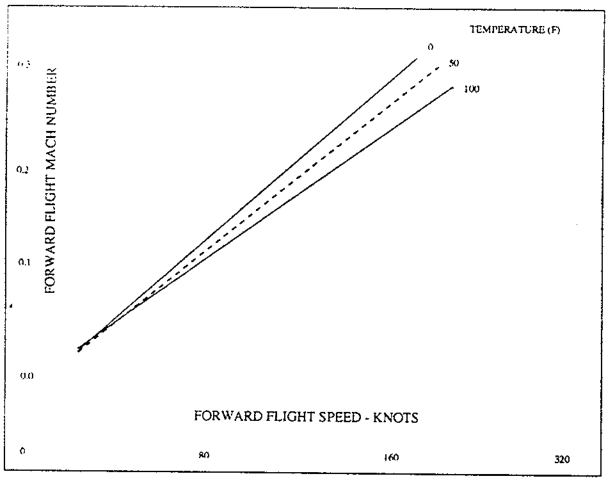

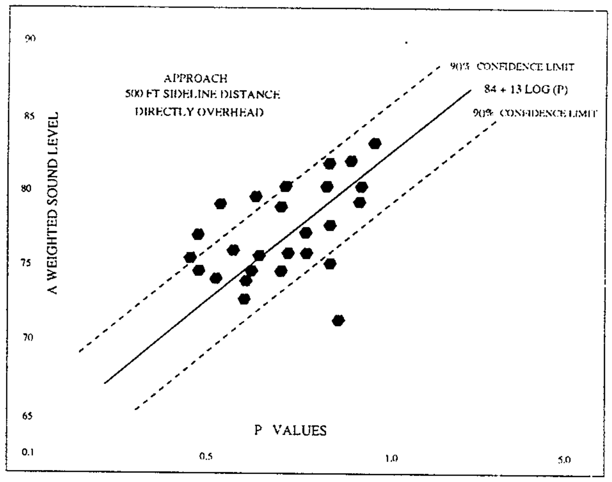

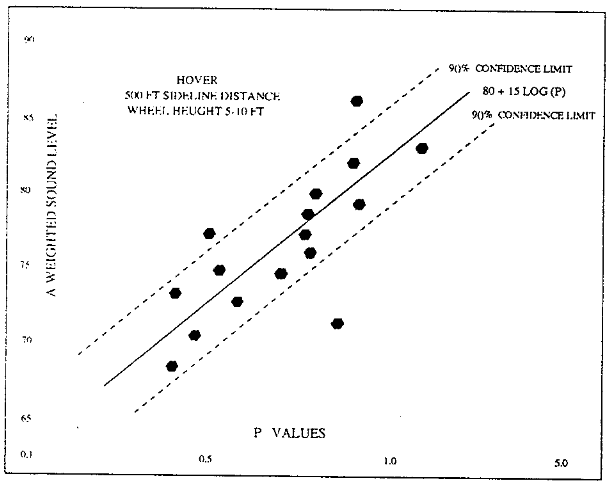

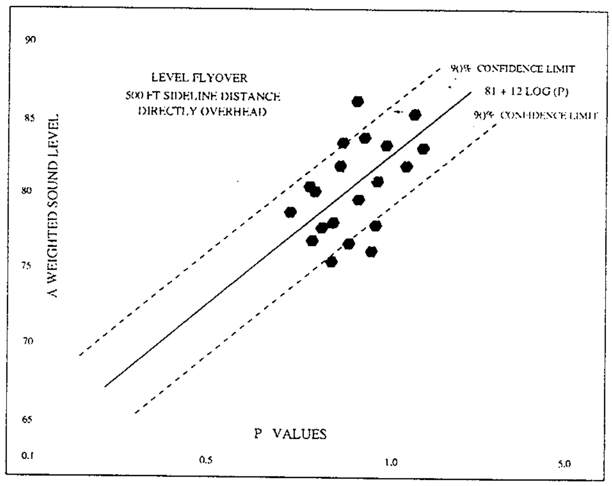

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