AIRPORT ACOUSTICS: AIRCRAFT NOISE DISTRIBUTION AND MODELLING OF SOME AIRCRAFT PARAMETERS

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Abstract

An acoustical survey that comprised enumerating aircraft noise events and parameters and measurements of associated noise levels has been conducted. Results show the contribution of aircraft noise to the environmental noise climate in some Nigerian cities. One of the models developed for an operating aircraft engine and some aircraft parameters suggests that the former behaves like a pulsating balloon that radiates noise. Results have further shown that the difference between the maximum noise levels emitted at take-off and landing is 16-20 dB. The models will be useful to aircraft engineers in the quest to 'design-out' noise.

Keywords :Aircraft noise, aircraft parameters and environmental noise climate.

1. Introduction

Since the early 1950s, the number of transportation aircraft has increased tremendously (EPA, 1971). The increase, especially of general aviation aircraft, jet aircraft and helicopters, has had significant impart on our environment, particularly on those communities bordering on airports. Infant, it is known that extremely intense aircraft noise occasionally exceeding 120 dB occurs in the area of the residences. As a consequence, aircraft noise around most airports has been expressed "murderous" or "lethal"; and residents have been found to suffer from various kinds of damages due to the noise exposure. The effects are now known to range from interference with speech/conversation and sleep, disruption of classes, jamming of TV/radio broadcasts to causing physical and mental strains such as loss of hearing, fatigue and neurosis. There has, therefore, been a wide range reaction against aircraft noise in particular by community residents living close to the airports. Research has, thus, been mainly on effect of aircraft noise particularly and environmental noise and community reactions in general with a catalogue of well over 521 social surveys of residents' reactions to environmental noise between 1943 and 2000 (Fields, 2001).

Little attention has really been paid to the parameters of the aircraft that cause the high noise levels. Council Directive 89/629/EEC (1989) has expressed the need to further reduce aeroplane noise by taking into account technical feasibility, among others. This Directive applies to aeroplanes with a take-off mass greater than 34,000kg and a capacity of more than 19 seats. Computer-based models that provide a better understanding of how noise is produced during flight have been developed. These involve computationally efficient calculations of the noise made by helicopter blades moving at high subsonic speeds. There is also a project involving into jet engines in order to reduce noise at take-off (Dowling, 2004). This project involves developing a computer model capable of predicting jet noise, improving understanding of noise source mechanisms, and identifying potential ways of modifying these mechanisms. This silent aircraft initiative (SAI), as it is called, is aimed to have impact on the aerospace industry, and people living near airports by developing designs and operational producers for a radically different type of aircraft. This will be a right step in the right direction in the war against noise, a major aviation issue, that will become even more pressing in future, with a 300% increase in air traffic forecast by 2020 (Dowling, 2004).

The objectives of this paper are therefore mainly to consider some variables of the aircraft that constitute aircraft noise and develop models for them. The results obtained will lead to a better understanding of airport acoustics and will also be useful to aircraft designers and engineers in the quest to "design- out" noise.

2. Survey and Measurements

The survey was conducted in 17 Nigerian airports in 2002. The number of air traffic in each of the airports in one day was taken. This was made up of the number of flights from 12 midnight to 7 p.m.; that from 7 a.m. to 7 p.m.; that from 7 p.m. 10 p.m. and that from 10 p.m. to 12 midnight (Yamamoto at al., 2000). The engine capacity of each aircraft and the maximum number of passengers it could carry were also recorded. The maximum noise levels, $L_{Amax.}$, at landing and take-off were measured using a precision sound level meter (B & K Type 2203) with the microphone position at about 100 m from the aircraft. All measurements were made in the open area.

3. Results and Discussion

3.1 Statistics and distribution of air traffic at Nigerian airports

Figure 1 shows statistics and distribution of air traffic at the 17 Nigerian airports during the first quarter of 2002. The percentage traffic volume shows 54 for Lagos, 24 for Abuja and 6 for Port-Harcourt. Others are Kano (4%), Kaduna (2.4%), Calabar (1.2%), Maduguri (1.1%), Sokoto (1%), Jos (0.6%), Yola (0.6%) and others (5.1%).

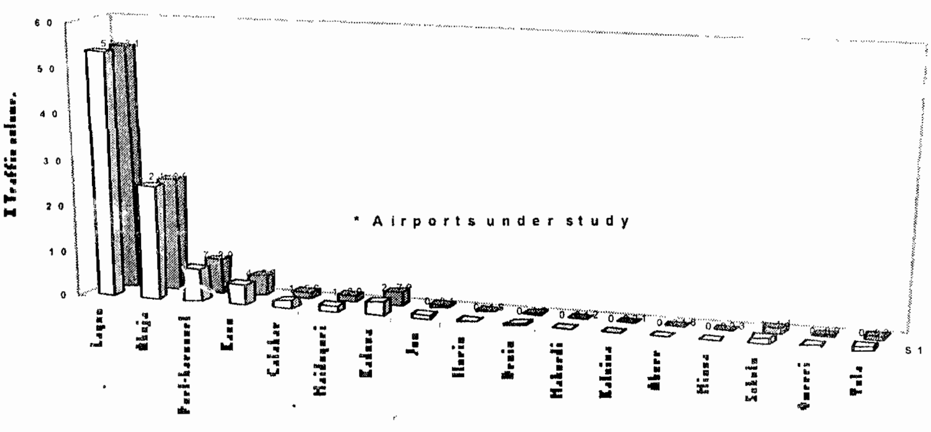

Fig.1: Statistics of air traffic at Nigerian airports for the first quarter of 2002

A smooth graph drawn to fit the histogram (not shown) is an exponential decay curve. From Figure 1, it is possible to know how developed a city could be in comparison with others; and the contribution of aircraft noise to the overall noise climate in a city with the number of noise events known (Dowling, 2004). Thus, the contribution of aircraft noise to the overall noise climate in Nigerian is highest in Lagos, followed by Abuja, Port-Harcourt, Kano, Kaduna, Calabar, Maduguri, and Sokoto in that order. Contribution in Jos and Yola should be equal while it should be the same for the rest of the cities.

3.2 Empirical Model

Maximum number of passengers versus engine capacity of aircraft is plotted in Fig. 2. A polynomial of the order 6 best describes the relation with the square of the correlation coefficient of 0.7725.The correlation coefficient of 0.8789 shows that the points fit the data well. From Fig. 2 it could be seen that the graph of maximum number of passengers plotted against engine capacity resembles that of a harmonic oscillator that was initially damped and then freed. This suggests that the operating engine of an aircraft as a point source assumed to be decreasingor increasing in capacity can be modelled as a pulsating balloon. As the spherical surface of the engine (which capacity decreases or increases)

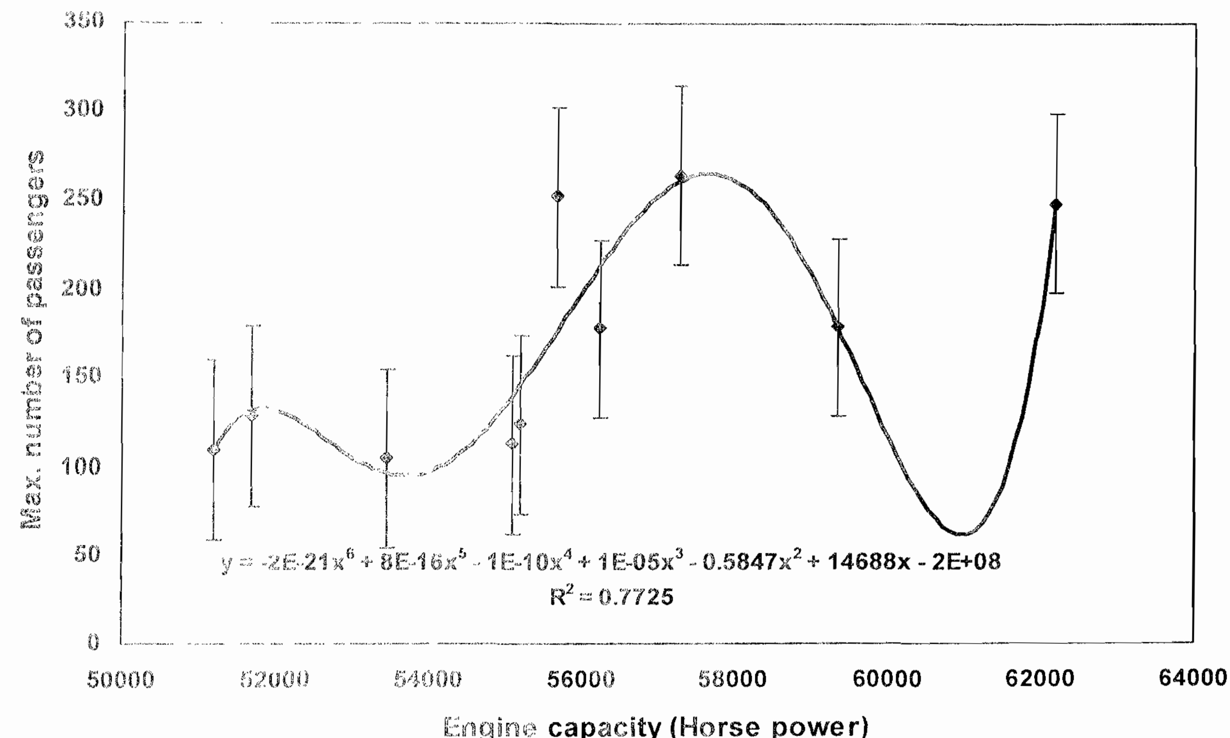

Fig.2: Max. number of passengers versus engine capacity of aircraft

decreases or increases it oscillates radially and sets adjacent air molecules into oscillation producing rarefactions and compressions. Thus, spherical waves are developed with sound pressure levels that constitute noise that depends on the capacity of the engine.

Table 1: Coefficients of x^n and the regression parameters.

S/No	**Parameters regressed on engine capacity**	**Coefficients of x^n**	**Correlation coefficient, r**
1.	N_{max} (passengers)	a_1 = -2E-21 for x^6, a_2 = 8E – 16 for x^5, a_3 = -1E-10 for x^4, a_4 = 1E -05 for x^3, a_5 =-0.5847 for x^2, a^6 = 14688 for x a^7 =- 2E + 08 for x^o,	0.08789
2.	L_{max} (landing)	b_1 = 0.0003, b_o = 73.217	0.8037
3.	L_{max} (take- off)	b_1 = 0.0007, b_o = 68.665	0.9894

* Regression equations are:

1. N_{max} (passengers) = $a_1x^6 + a_2x^5 - a_3x^4 + a_4x^3 - a_5x^2 + a_6x - a_7x^0$
2. L_{max} (landing) = 0.0003EC + 73.217
3. L_{max} (take-off) = 0.0007EC + 68.665

where EC = Engine capacity in horse power

The relationships between maximum noise levels, at landing and take-off, and engine capacity were also investigated (Table 1 and Fig. 3). A priori examination of the scatter diagrams suggests that linear regression models best describe the curves. The regression equations showing maximum noise levels at landing and take-off as functions of engine capacity are shown in Table 1; with respective correlation coefficients of 0.8037 and 0.9894,

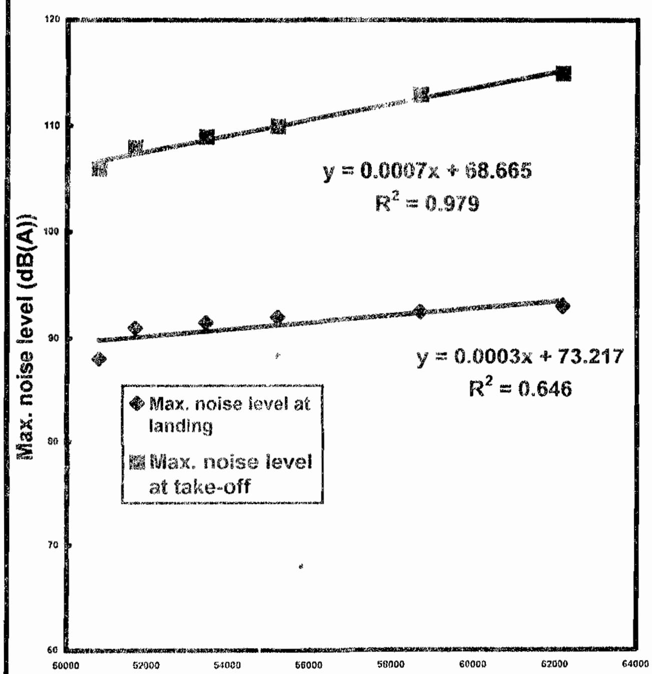

Fig.3: Max. noise level of aircraft versus engine capacity

which suggests a very strong correlation. The graphs (Fig. 3) show that, for a particular engine capacity of the aircraft, the maximum noise level at take-off is always higher than that at landing by 16-20 dB (A).

4. Conclusions

A distribution showing percentage air traffic volume for Nigeria airports, which will make it possible for the determination of the contribution of aircraft noise to the environmental noise climate in Nigeria, has been obtained for various airports. An operating aircraft engine has been modelled as a pulsating balloon. This, therefore, suggests that the smaller the size of an operating aircraft engine, the less the noise it radiates. Regression models have been developed for the following relations: maximum number of passengers and engine capacity of aircraft; and maximum number of noise levels (at landing and take-off) and engine capacity of aircraft. It is suggested that these models will be useful to aircraft engineer and designers in the quest to "design-out" noise.

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