IN-CABIN NOISE LEVELS DURING COMMERCIAL AIRCRAFT FLIGHTS

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ABSTRACT

Air transport is one of the most commonly used mode of transportation and hence passenger comfort is highly desirable. Aircraft interior noise is important, especially in long-term flights, concerning the health, comfort, and psychological wellness of both passengers and flight crew. Noise levels, which changes according to different motions of aircraft, can be defined as the noise during takeoff and landing and during level flight (cruise). There are also non-aircraft-originating noise sources in the cabin. These can be classified into those caused by passenger activities such as conversations and luggage-related rearrangements as well as those caused by flight-crew such as flight attendant-related speaking activities, announcements from pilot and flight attendants, mechanical noises during food/beverage services and flight security demonstrations, and other announcement signals. In this study, in-cabin noise levels were measured during all flight activities in a commercial jet passenger plane. These noise levels consist of both continuous and discontinuous types. As a general tendency, continuous noise levels were seen to be 60-65 dB(A) prior to takeoff, and 80-85 dB(A) and 75-80 dB(A) during flight and landing, respectively. Discontinuous in-cabin noise levels were observed to reach levels as high as 81-88 dB(A) range. This study shows that it can be possible to control and reduce in-cabin noise levels, especially due to human activities and a few recommendations are suggested.

SOMMAIRE

La transportation aérienne est l'une des modalités de transportation la plus générale et de cela, le confort de passagers est hautement désirable. Le bruit intérieur de l'avion est important, particulièrement á des longues distances, concernant la santé, le confort et la vaccination psychologique de ces passagers et équipes de vole. Les aptitudes du bruit changes selon les motions différents de l'avion peuvent être définies comme le bruit durant le décollage et atterrissage et, durant le vole du niveau (excursion). Il y a aussi dans la cabine, des sources du bruit se produisant spontanément non pas par l'avion. Ces sources du bruit peuvent être classifiées dans celles-ci causées par des activités de passager telles que conversation et des réarrangements en relation avec bagage ainsi que celles-la causées par des équipes de vole telles que les activités d'expression en relation avec les gens attentant leur vole, les annonces faites par un pilot et les voles attendant á se réaliser, les bruits mécaniques durant les services de nourriture / breuvage et les démonstrations de sécurité au vole , et d'autres signales d'annonces. Dans cet étude, les niveaux du bruit ont été mesurés dans la cabine durant toutes les activités de vole réalisées dans une avion de passager commerciale. Ces niveaux du bruit consistent de tous ces types continues et discontinues. Comme une tendance générale, les niveaux du bruit continuels avaient été vus être 60 á 62 dB (A) avant le décollage et, respectivement 80 á 85 dB(A) et 75 á 80 dB(A) durant vole et atterrissage .Il a été observé que les nivéaux du bruit discontinues dans la cabine sont arrivées aux nivéaux aussi hauts que la gamme de 81 á 88 dB(A). Cet étude manifeste que il peut être possible de contrôler et réduire les niveaux du bruits dans cabine particulièrement due á des activités humaines et , quelques recommandations sont suggérées.

INTRODUCTION

Undesirable sound waves in an environment are defined as noise. The importance of noise pollution increases every day, due to its human-related hazards in modern world. Noise have both physiologically and psychologically negative effects on human health such as influencing temporary hearing losses like elevation of noise hearing threshold and continuous hearing losses like acoustic trauma (Karpuzcu, 1999). These problems can be influenced by both exposure time and/or level of noise. There are several effects of noise on human psychology such as fatigue, nervousness, stress, insomnia, decrease of concentration and labor yield, and changes in both memory and social behaviors (Ingle et al., 2005). Although personal and public differences exist, it is generally accepted that sleeping and other activities are seriously disturbed and humans become irritated from noise, when sound level is above 65 dB(A) (Karabiber, 1999).

Air transport is currently the most preferred mode of transportation.. Interior noise of a plane in operation affects health conditions of passengers and flight crew, as well as their comfort and psychological well-being. The active control of noise in aircraft and automobile interiors is a problem that has received considerable attention in the recent past (Bullmore et al., 1990; Tichy, 1991; Sun et al., 1996). Active strategies for aircraft interior noise suppression are generally applied at low frequencies (100-400 Hz), where passive techniques become ineffective (Jayachandran et al., 1999).

Noise levels change depending upon the different operations of aircraft, and they can be defined as the total noise during takeoff and landing and level flight (cruise). The main sources of aircraft interior noise are the power plant (propeller and engine-reciprocating or turbine) and the turbulent boundary layer.(Wilby, 1996) High speed turbulent flow over an aircraft fuselage is responsible for a substantial component of the interior noise, and is probably the most important source of cabin noise for jet powered passenger aircraft in steady cruise. (Wilbiy, 1996; Howe, 1998). The ground operations of aircraft include aircraft engine tests, takeoff preparation, and braking after landing (Large, 1981). If noise effect is related to its duration, then it can be seen that cruise flight of the aircraft tis the most important noise type, affecting health of passengers and flight crew. Minor noise sources are air conditioner humming and air friction.

There are also noise sources that are not aircraft-related. These are non-special noises, such as conversations and noises during placing of hand-luggage into overhead compartments. Noise sources due to flight crew are flight attendant conversations, loudspeaker announcements by pilots and attendants, mechanical noises during food and beverage service and flight safety demonstrations, and announcements.

Although noise is a factor which can generally cause hearing losses, both commercial and business jet airplanes are manufactured under international standards, producing noise levels below hearing threshold limits. However, during flights at night, noise can really be a disturbing factor affecting passengers' sleep. This can cause physiological and psychological problems. The threshold level of a noise which will cause arousal from sleep depends on sleep stage and the age of the subject, among other things. Noise levels which can cause sleep disturbance cover a wide range. For sleeping environments, the maximum acceptable intrusive level is 55 dB(A) (U.S. Department of Commerce, 1985). This factor must be taken into account while investigating in-cabin noise levels.

THE EXPERIMENT

In-cabin noise measurements were performed in two Airbus A321 commercial passenger planes. A Testo 816 sound level meter (defined as Type 2 as per IEC standards) was used in noise measurements, and noises were expressed as dB(A) units. Noise values were obtained as continuous and instantaneous signatures. Noise measurements were continuously performed and significant noise changes manually recorded.

Noise measurements were conducted in the cabins of two similar single-aisle Airbus A321 jet passenger aircrafts. Figure 1 shows the measurement point at passenger seat and general layout of the cabin. Noises during parking, taxiing, takeoff, climbing, cruise, approach, landing, and parking again, were measured at this point. During cruise (straight flight), indicative noise measurements were done at different passenger seats, in the corridor, and front and rear sides of the aircraft. The measurements included two different domestic line flights about 1,000 km long along the same flight route, over a 1 hour and 45 minutes flight duration. There are two jet engines mounted on the wings of Airbus A321. The salient aircraft details are shown in Table 1 (Onurair Transport Co., 2005). There were 219 passengers in the first (Flight No. 1) and 212 in the second (Flight No. 2) flight, and both flights used 2 pilots and 5 flight attendants. Cruise altitude in both flights was about 9,000 m.

RESULTS

A total of 103 noise measurements were made, 54 in the first and 49 in the second flight. In these measurements, it was observed that aircraft interior noise levels were in the range of 58 to 85.5 dB(A). A summary of the measurement results are presented in Table 2.

Table 2 shows that average values for continuous noises in a 1,000-km flight are 64.0 dB(A), 64.0 dB(A), 78.4 dB(A), 78.7 dB(A), 76.0 dB(A), 63.6 dB(A), and 58.5 dB(A) during parking, taxiing, takeoff and climbing, cruise, approach and landing, taxiing, and parking, respectively.

In the ground measurements prior to takeoff, it was seen that continuous aircraft interior noise levels were 60.9 dB(A), 63.0 dB(A), and 64.7 dB(A) for before passenger entry, during passenger entry (with no music broadcast), and during passenger entry (with short-time music broadcast), respectively. Music broadcast was intentionally maintained for one minute and all other measurements were collected without music broadcast in the cabin.

In both flights, demonstration announcements were performed by flight attendants while parked. Demonstrations

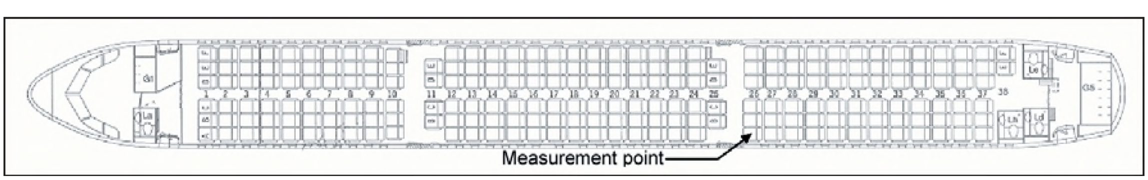

Figure 1. Airbus A321 cabin layout

Manufacturer	Airbus
Wing span	34.09 m
Overall Length	44.51 m
Cabin Length	34.44 m
Max. cabin width	3.70 m
Height	12.09 m
Fuselage diameter	3.96 m
Total volume (LD3+Bulk)	41.85m^3
Max. Operating Mach n° (Mmo)	0.82 Mc
Max. flight height	11900 m
Power plant (wing mounted)	Two PWD JT V2530-A5
Passenger capacity	220

Table 1. Some technical details of Airbus A321 commercial aircraft.

were repeated two times in native language (live) and in English (tape). In the demonstrations, continuous noise levels were 68 dB(A) and 56.3 dB(A) during live and taped announcements, respectively

Instantaneous aircraft interior noises and noise sources are shown in Table 3. Time histories of continuous and instantaneous noise values are presented in Figures 2 and 3, respectively. It can be seen from Figures 2 and 3 that noise levels show significant differences in takeoff and landing. Instantaneous noise levels were found to be concentrated before takeoff and after landing. The principal causes of instantaneous noises, before takeoff and after landing, were found to be generated by in-cabin announcements and passengers (Please refer to Table 3).

Figure 4 was generated to determine the general tendency of flight-time-noises, by merging the takeoff moments of the two flights into one graph. Figure 4 shows, in general, there is similarity in the two flights. This similarity can then be summarized for continuous noise levels to be 60-65 dB(A) before takeoff, 80-85 dB(A) during takeoff, 75-80 dB(A) in cruise, and slightly lower than these during landing. In Flight No. 2, there was a slight turbulence at 22:16 during cruise, and this caused the continuous noise levels to be 79-80 dB(A)

Flight stage	No. of measurements		Max. dB(A)		Min. dB(A)		Avg. dB(A)	
Flight no.	1	2	1	2	1	2	1	2
Parking	12	7	68	68	58	56.3	65	63.1
Taxiing	6	4	68	67	60	62	64.3	63.8
Takeoff and climb	6	4	85.5	83	77	69	79.4	77.4
Cruise	10	16	82	82	74	75	79.4	78.1
Approach and landing	14	11	85	82	73	70	76.1	76
Taxiing	2	3	67	64	63	60	65	62.3
Parking	4	4	60	60	57	58	58.4	58.7

Table 2. Continuous noise data of aircraft interior environment

Flight No. 1			Flight No. 2		
Flight stage	**Instant noise dB(A)**	**Noise source**	**Flight stage**	**Instant noise dB(A)**	**Noise source**
Parking	70	Overhead stowage cover	**Parking**	75	Overhead stowage cover
	62, 62, 68	Passenger conversation			
	80, 81, 83	Announcement			
Taxiing	69	Mechanic	**Taxiing**	82	Announcement
Takeoff and Climb	-	-	**Takeoff and Climb**	89	Mechanic
Cruise	-	-	**Cruise**	88	Warning signal
				82	Pilot's Announcement
Approach and Landing	81, 85	Announcement	**Approach and Landing**	85, 88	Announcement
				87	Brakes
Taxiing	-	-	**Taxiing**	88	Announcement
Parking	-	-	**Parking**	81	Announcement

Table 3. Instantaneous noise data and noise sources of cabin interior environment

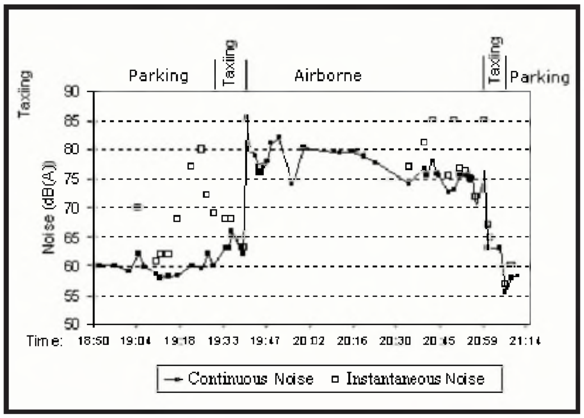

Figure 2. Changes of continuous and instantaneous noise measurements for Flight No. 1

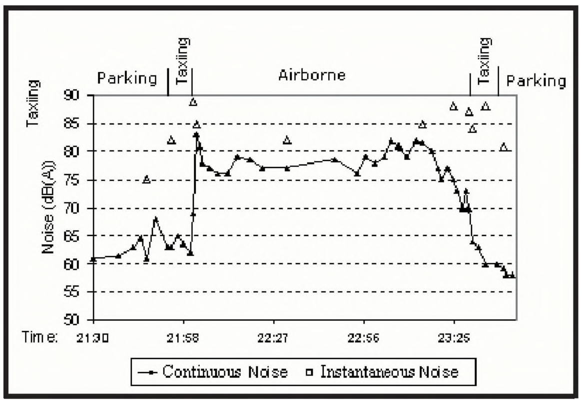

Figure 3. Changes of continuous and instantaneous noise measurements for Flight No. 2

for around four minutes. The continuous noise level before turbulence was 76 dB(A).

Noise exposure times, in both flights, 5 to 8 minutes for takeoff and climb, 45 to 63 minutes for cruise, and 20 to 25 minutes for approach and landing. Takeoff and landing times were each shorter than 1 minute. For operations on ground, total noise exposure times were 30-35 minutes for parking, and 15-16 minutes for taxiing. Flight crews were on board for at least 10 minutes more than the passengers.

In addition to the measurements at seat 26A, which included the continuous noise measurements during flight, short-timed-measurements over one-minute periods were collected at several places in the cabin. Continuous noise values obtained at these places were - 76 dB(A) in the front section, 75 dB(A) in the middle part, and 78,5 dB(A) in the rear section. Continuous noise values at passenger seats were - 82 dB(A) for window side, 78 dB(A) for middle seats, and 78 dB(A) for aisle side.

DISCUSSION

Aircraft interior noise levels in two domestic flights were measured for 1,000 km-long cruise in a commercial jet passenger aircraft. In both flights, averaged noise levels were 77.4-79.4 dB(A) for takeoff and climb, 78.1-79.4 dB(A) for cruise (level flight), and 76.0-76.1 dB(A) for approach and landing. These values were higher than the hazardous threshold limit for human health of 65 dB(A). In addition, for operations on ground, average noise levels were measured to be 58.4-65 dB(A) for parking, and 62.3-65 dB(A) for taxiing.

In-cabin noise levels were in the range of 81 to 88 dB(A), including mechanical noises for takeoff and climb, cruise, approach and landing, and miscellaneous noises during warning signal, announcements from pilot and flight attendants, and brakes. In ground stages (parking and taxiing), instantaneous noises ranging from 62 to 83 dB(A) were due to closing of overhead luggage compartments, passenger conversations, and to announcements. It was foundd that during flight, instantaneous noises were mainly of flight crew-origin, while noises on the ground were mainly passenger-generated.

During level flight, continuous in-cabin noise levels did not vary too much. Continuous noise levels, within the same minute, were75 dB(A), 76 dB(A) and 78.5 dB(A) in the middle part of cabin, front and rear sides respectively. The position of passenger seats was important regarding the aircraft interior noise levels during flight. Window-side-seats showed 4 dB(A) more noise exposure than the middle and aisle-side seats. This shows that the real sources for continuous noise are airborne friction on aircraft fuselage and engine noises, and that it is necessary to develop the isolation of the cabin with better noise-absorbing materials to lower the continuous noise levels inside the cabin. Noise isolation must be far more efficient in the rear side, and the auxilary power unit must be operated more quietly.

It was seen that the effective instantaneous in-cabin noise source was primarily the live announcements by flight crew. Such public announcements, therefore, can be substituted by taped ones and the noise levels can be reduce by 12 dB(A) to 56 dB(A) or less. The 56 dBA level is near the waking threshold of 55 dB(A). Moreover, live announcements can be less controlled and high-pitched, and hence during cruise,

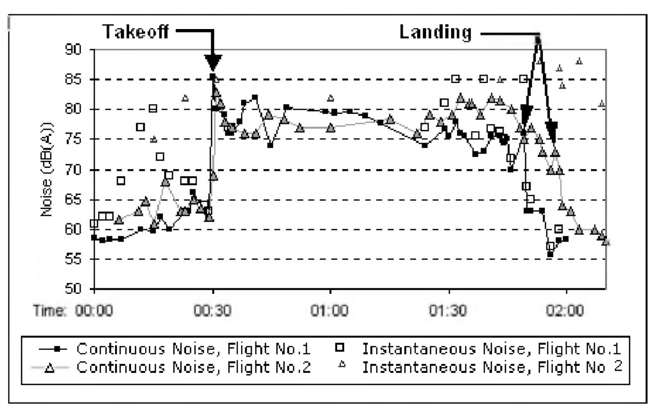

Figure 4. Fitted presentation of noise levels for both flights, referenced to takeoff stage

more disturbing. If they can be provided as taped substitutes, these announcements will more controlled and less disturbing. Therefore, it is be possible to minimize the human-originating portion of aircraft interior noise. This rearrangement about announcements will be useful in reducing both continuous noise levels during demonstrations as well during food and beverage services by the flight crew.

During ground operations, there are principally mechanical noises. The "mild" (low volume) music broadcast will increase the continuous noise level by 1.7 dB(A), however, this broadcast is still useful, since it masks both continuous and instantaneous noises. Mild music broadcast was observed to have a positive effect in masking noises of passenger conversations and overhead compartment arrangements, and thus providing a relaxed ambience.

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