BASED ON SIMS SOUND INTENSITY MEASUREMENT SYSTEM NOISE ANALYSIS OF LUXURIOUS BUSES AND HELICOPTERS

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ABSTRACT

This paper represents a flexible sound intensity measurement system known as SIMS. It has developed successfully and applied to noise measurement and analysis in vehicular engineering. Comparison with these sound intensity instruments in commercial market, SIMS has two main strengths: (1) it is indeed inexpensive relative to the instruments mentioned above and (2) it is more flexible to adapt to the noise measurement and analysis of vehicles in motion. In the latter half of the paper, SIMS have been used to identify noise sources of luxurious buses and analyze the sound isolation behavior of the fuselage of helicopters. SIMS was found to be sufficient for tackling problems associated with the noise measurement and analysis in vehicular engineering.

1. INTRODUCTION

Sound intensity measurement is one of the advanced measurement techniques in the field of noise control engineering. The technique is of a great commercial value. Many sound intensity measurement systems corresponding to the technique have been developed and put on market. They have good performance and have been used in the areas concern. However, these systems are quite expensive to noise control in engineering. Sometimes they are inconvenient to be used to measure and analyze vehicular noise in line. This is why we developed a flexible sound intensity system, that is SIMS, based on a personal computer. It is a flexible system rather than that for a certain purpose. Its cost is relatively inexpensive, so that it is easy to apply it in engineering. The correct method by using software in the system enhance its performance.

SIMS has been used to analyze the noise of buses and helicopters. Their noise is one of the pollution sources in metropolises. The noise pollutes not only the environment on which persons depend for existence, but also damages the passengers in the vehicles. Therefore, in order to control the noise it is very necessary to measure and analyze it.

2. SIMS

SIMS is mathematically and technically based the two-pressure microphone method[1]. The correction of phase mismatch between two channels by using SIMS software has also been employed. Figure 1 shows these components consisting of SIMS. They are, respectively, a p-p probe, a multi-functional digital processor with a two-channel simultaneously sampling, a personal computer (PC) and peripheral equipments. The multi-functional digital processor is an integrated instrument as shown in figure 2. It mainly includes a two-channel amplifier, lowpass-filter and A/D converter. Once gained by the p-p probe, two sound pressure signals will be respectively processed by measurement amplifiers and anti-alias filters ,successively. Then the analogue signals processed are transformed into digital information through the A/D converter.

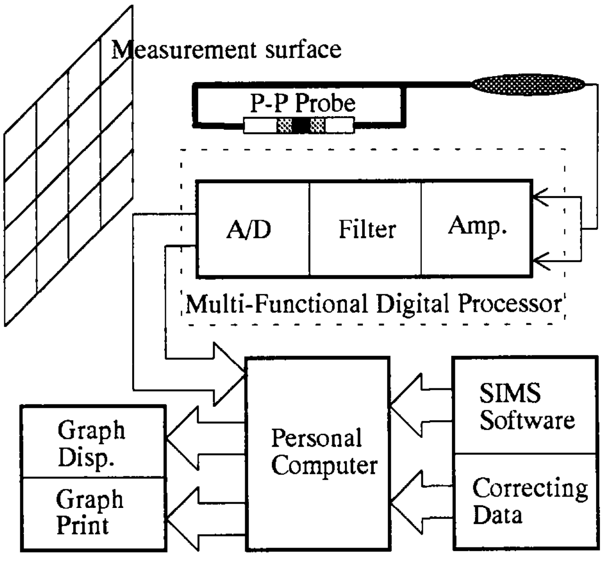

Fig. 1. Block diagram of SIMS

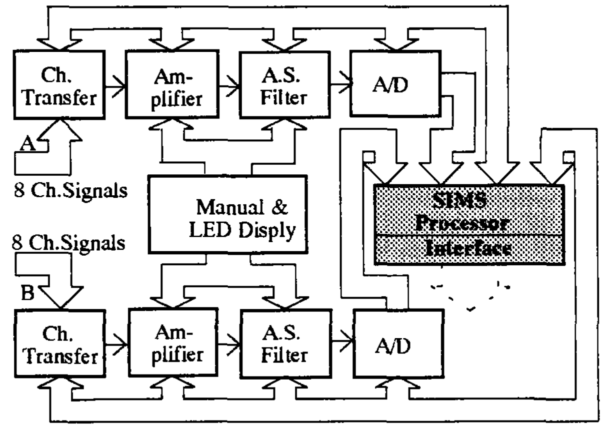

Fig. 2. Block diagram of the processor

In the sound intensity system SIMS software based on the mathematical principle of Fast Fourier Transformation (FFT) plays a role in sampling control, FFT, spectral analysis and the analysis of sound energy distribution from the surface of sound radiation. The data for correcting the phase mismatch between two channels is saved in the hard disk. They are able to be automatically read by the soft, so that it is not difficult to right the data in the sound intensity spectrum. As the result of the total error due to the phase mismatch is limited within 1 dB. The results obtained by SIMS can be given by means of the peripheral devices connected with PC.

3. IDENTIFICATION OF NOISE SOURCES OF LUXURIOUS BUSES

The luxurious bus as shown in Figure 3 is about 12m, long and 2.8m wide. A 6-cylinder diesel engine is mounted in the rear of the vehicle.

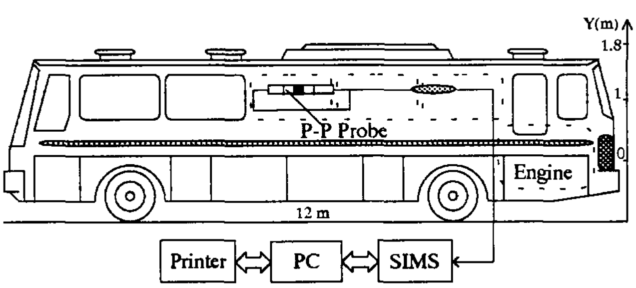

Fig. 3. Measurement of noise of luxurious bus

The sound pressure levels (SPL) of the acceleration noise of the buses come at 91 dB(A). The measurement point is as far as 7.5m from the center line of road. Inside the bus SPL is 78 dB(A) high when it travels at uniform speed. The measuring point arrays for sound intensity measurement are respectively placed on the left, right and rear surfaces outside the vehicle. Inside it the measurement surfaces are placed on left, its right, rear, ceiling and floor. To prevent the circulatory intensity flow from the vicinity of the vehicular body surface, These measuring surfaces are about 150mm from the body surfaces. Because the engine is in the rear of the vehicle, these points on front, left-front and right-front measuring surfaces are relatively less than that of rear, left-rear and right-rear measurement surfaces. The rear axle of the vehicle is supported slightly apart from the ground and the rear wheels are hung in the air. The vehicle operates at the normal speed but motion.

As soon as the sound information at a certain measurement point is measured, spectrum, the distribution graphs and contour maps of the sound intensity are simultaneously obtained. As shown in Figure 4, the distribution of noise energy on the rear surface outside the vehicle is clearly illustrated. In the figure, X and Y coordinates represent respectively the wide and long of the vehicle as shown respectively in Fig.3 and Fig.6. It is clear that the main noise sources are, in largely order, cooling fan exhaust, the cooling fan below and the exhaust noise.

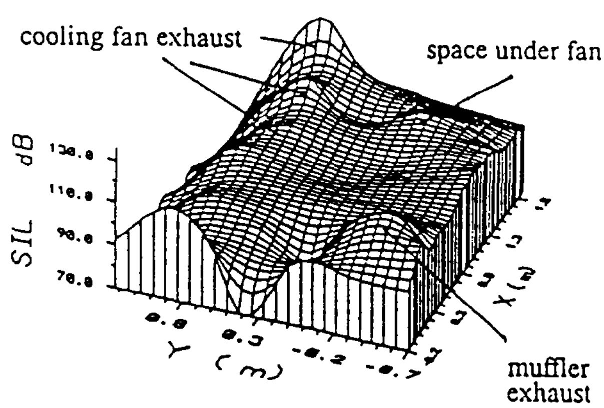

Fig. 4. Distribution of sound intensity on rear surface outside luxurious buses

The cooling fan may be one of main noise sources. This is also seen clearly in the its sound intensity spectrum as shown in Fig. 5.

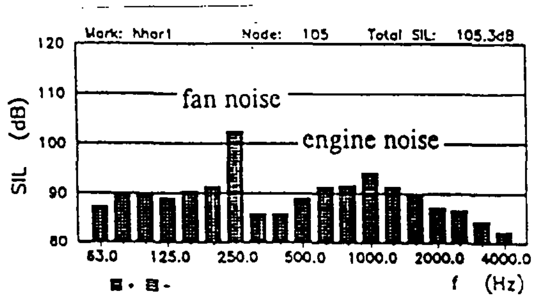

Fig. 5. 1/3 Oct spectrum of sound intensity of fan noise

It is found that the engine inlet duct, which passes through the passenger compartment at the rear-left corner, is the vibration source producing noise, and the sound leakage at the connections between plates of the rear floor is also a main noise source as shown in Fig. 6.

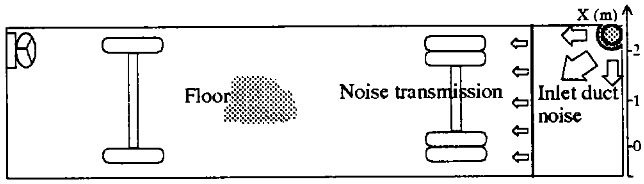

Fig. 6. Inlet duct noise inside buses

As shown in Figure 7, We have noticed the negative sound intensity in the front of the middle port occurs once the air condition system works. This means the noise of the diesel of air conditioning system is stronger than that of the engine.

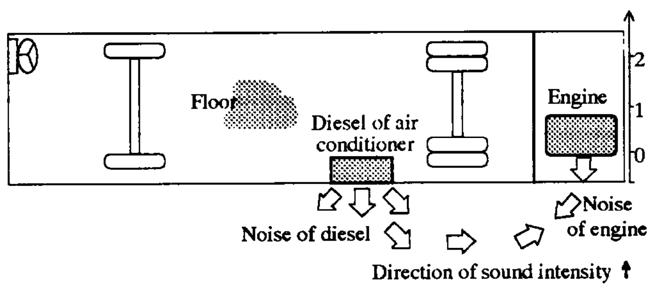

Fig. 7 Sound intensity characteristics of the air conditioning system

According to the results obtained by using SIMS, some practical and effective treatments of attenuating the noise of the vehicle have been made. They associate with the wire mesh structure being changed into the plate structure or the shutter structure at the rear parts of the body; the engine inlet duct in the passenger compartment being redesigned by means of the techniques of sound absorption and vibration isolation, the gap between connections of the floor in the passenger compartment being sealed and a design of to the silent engine room being considered. This represents that the SPL outside and inside the vehicle is respectively reduced to 88dB(A) and 70dB(A) by using the same measurement method as described in section 2 above.

4. ANALYSIS OF SOUND ISOLATION BEHAVIOR OF THE FUSELAGE OF HELICOPTER

The SPL of exterior and interior the helicopter, which remains on ground and only its turboshaft and rotary-wing operate under its rated speed of 85% and 95%, is respectively 91.2 dB(A) and 82.6 dB(A) high. The analysis of sound isolation behavior of fuselage of helicopters is a sub project of noise control of helicopters. The project focus on determining the behavior of the fuselage and the influence of exterior noise on the interior noise. It tries to find out the acoustic vulnerable areas of the fuselage. Therefore, it is of the significant to control the noise of helicopters. The idea of measuring sound isolation behavior of the fuselage can be explained by Fig. 8. It is known as "Doule-Rotorcraft Measurement Method" (DRMM)and is more conformable with the actual situation concerned with helicopters and convenient than the sound isolation measurement in laboratory.

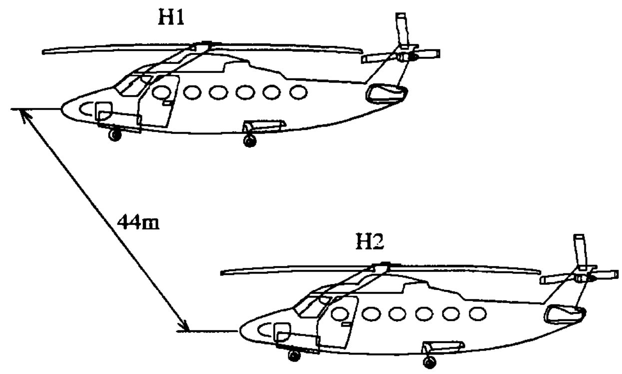

Fig. 8 Diagram of DRMM

In Fig.8 H1 and H2 are two helicopters with the same type. They are separated on ground as far as 44 meters . Though they are started at different time, they operate with the same speed of turboshaft and rotary-wing. The measurement system is shown in Fig.9.

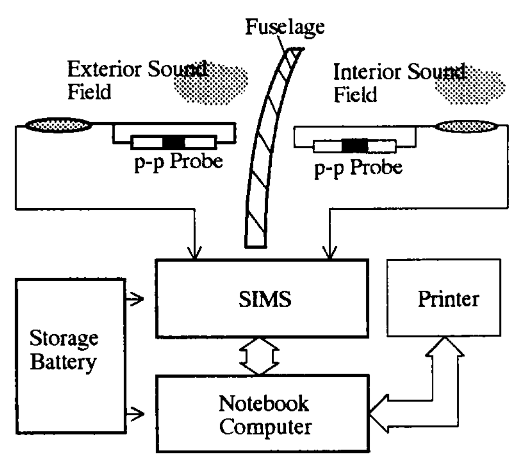

Fig. 9 Diagram of Measurement system of sound isolation behavior of fuselage

The measurement procedure can be divided into two steps. In the first, in Fig. 8 the helicopter H1 is started but helicopter H2, the sound intensity near the outer surface of the fuselage of H2 is measured by SIMS. In this case sound isolation of the fuselage of H2 is the result only sound generated by H1. Secondly, H2 is only started at the speed of turboshaft with rotary-wing with the same as that of H1, to measure the sound intensity near the fuselage outside and inside H2. The sound intensity, generated by H1, near outer surface of fuselage H2 is exactly equal to the sum of result obtained in the first step and the attenuation of sound intensity due to the sound transmission from H1 to H2. In the second step the sound isolation of fuselage of H2 is the hybrid result of sound and vibration generated by H2. With the help of SIMS, the measuring error of the sound reflection produced by H1 and H2 will be decreased greatly.

Based on DRMM the sound isolation of the fuselage are respectively are listed in table 1, 2 and 3 below.

Table 1. Result of Sound isolation of the fuselage only when H1 is started

	SPL (dB)	EP	IP	D(SPL)
	SPL (L)	102.0	95.5	6.5
Case1	SPL (A)	91.2	82.6	8.6
	SPL (L)-SPL (A)	10.8	12.9	
	SPL (L)	95.0	86.0	9.0
Case 2	SPL (A)	88.4	75.0	13.4
	SPL (L)-SPL (A)	6.6	11.0	

Table 2. Result of Sound isolation of the fuselage only when H2 is started

	SPL (dB)	EP	IP	D(SPL)
	SPL (L)	114.0	108.7	5.3
Case 1	SPL (A)	103.2	102.0	1.2
	SPL (L)-SPL (A)	10.8	6.7	
	SPL (L)	107.0	107.5	-0.5
Case 2	SPL (A)	100.4	98.9	1.5
	SPL (L)-SPL (A)	6.6	8.6	

Note: **Case 1** : the speed of turboshaft and roatry-wing are respectively 85% and 95%. **Case 2**: the speed of turboshaft and roatry-wing are respectively 76% and 68%. **EP** and **IP**: measurement points placed on near surfaces of outside and inside of H2. **SPL (A)**: sound pressure level weighted by A class. **SPL (L)**: liner sound pressure level. **D (SPL)**: difference between SPL (L) and SPL (A).

Table 3. Comparison of sound isolation of the fuselage between when H1 is started or H2 is done

	SPL (dB)	IS (H1)	IS (H2)	D(SPL)
Case 1	SPL (L)	6.5	5.3	1.2
	SPL (A)	8.6	1.2	7.4
Case 2	SPL (L)	9.0	-0.5	9.5
	SPL (A)	13.4	1.5	11.9

Note: **IS (H1)**: SPL is isolated by the fuselage only when H1 is started.
IS (H2): SPL is isolated by the fuselage only when H2 is started.
D (SPL): difference between IS (H1) and IS (H2).

In table 1 it is seen that in case 1 the sound isolation of the fuselage is quantified by 6.5 dB (L) or 8.6 dB (A). This indicates that the isolating ability of the fuselage at high frequency is higher than that at low frequency. From the SPL in the 3th line in table 1 we are also able to know the noise at low frequency inside the cabin is more stronger than that outside the cabin. It is demonstrated in the spectrum as shown in Fig.10. In case 2, the sound isolation characteristic is similar to that in case 1.

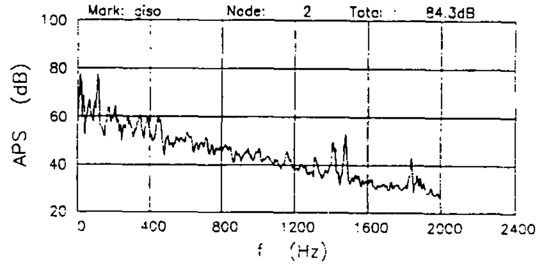

Fig. 10 Noise spectrum due to H1's starting

As shown in table 2, the SPL, generated only by H2's starting, of sound isolation of the fuselage is 5.3 dB(L) (1.2 dB(A)) and less than that only by H1's starting. This is that the noise generated by the vibration of H2 contributes also to the sound field inside H2.

Comparison between the SPL in column 1 and 2 of table 3, in both of case 1 and case 2, the differences between IS (H1) and IS (H2) come respectively at 7.4 dB and 11.9 dB. This indicates that the noise inside the cabin is not only due to the sound excitation, but also due to the result the structural vibration.

5. CONCLUSIONS

SIMS, a flexible sound intensity measurement system, is enough to analyze the noise problems in vehicular engineering.

Based on SIMS the noise sources of luxurious buses are accurately identified. This results in an effective suppression to the vehicular noise.

With the help of SIMS the measurement of sound isolation behavior of the fuselage of helicopters is completed. The result is a key for the further noise control of helicopters.

REFERENCE

[1] F.J.Fahy, Sound Intensity (Elsevier Applied Science, London and New York, 1989)