inter•noise 96
25th Anniversary Congress – Liverpool

INCE: 13

A THEORETICAL AND EXPERIMENTAL STUDY OF THE INTAKE NOISE OF A PASSENGER CAR

O Kwon & J Song

Kia Motors Corporation, 992-28 Shiheung-Dong, Kumcheon-Gu, Seoul, Republic of Korea

1. INTRODUCTION

Intake noise is one of the major noise sources in the vehicle. Other sources, such as exhaust noise, engine noise, etc., have been studied for a long time and the methods which decrease noise levels of them are matter of universal knowledge, relatively. However, the study of intake noise is somewhat limited to a trial-and-error method. Therefore, the study related to an intake noise as sound propagation, attenuation and radiation of the intake system, is highly necessary.

The whole intake system can be treated as a duct system, consisting of sudden area expansions, contractions and additional Helmholtz resonators. In this case, the conventional acoustic 4-pole parameter method has been used to predict noise reduction performance. However, the method gives an inaccurate solution frequently because of its basic assumption of a plain wave especially in an air cleaner[1]. This problem can be solved by using Boundary Element Method(BEM) to extract the 4-pole parameter matrix of air cleaner.

Changing the basic components have limitations to improve the noise level because of restricted space in vehicles. So a number of practical modifications in intake system are usage of the Helmholtz resonator. There are two aspects in relation to the resonator. One is to predict the accurate resonance frequency and effective noise reduction bandwidth of the resonator, and the other is to find the optimal location of it on the whole intake system.

It is obvious that the classical approach in modeling the Helmholtz resonator, which is to assume an equivalent spring-mass system where mass of air in the neck is driven by an external force and the volume acts as a spring, is unreliable to produce the accurate resonance frequency. This problem, however, can be overcome by using the multi-dimensional analysis such as Finite Element Method(FEM) or BEM[2]. If the resonator were installed at the improper position, a large amount of noise reduction would not occur no matter how good performance the Helmholtz resonator has. So the location of the resonator is more important than its innate performance. The best position of the resonator is described to the location where the highest Sound Pressure Level(SPL) exists, and it can be found by calculating sound pressure distribution inside the whole intake system.

2. THE EFFECT OF AN AIR CLEANER AND BOTH SIDES OF DUCT

An air cleaner consists of an arbitrary shaped box including filter elements, and is connected with 2 ducts. Acoustically, an air cleaner itself can be compared to a simple muffler because sound energy is not transmitted owing to impedance mismatch through it. The element is regarded as an acoustic absorption material, then it is not easy to model its characteristics precisely in a numerical simulation. Fortunately, being considered the relation between booming noise inside a passenger room and intake noise, main concerned frequency of intake noise is confined to low frequency range, which is mostly below 500 Hz. So element can be excluded from the simulation in that point of view, and it is proven experimentally(Fig. 1).

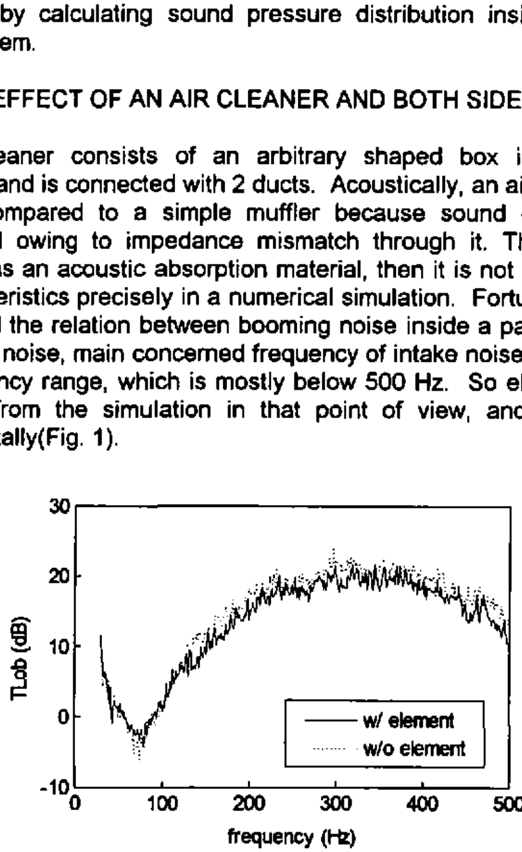

Fig. 1 Effect of an element in an air cleaner

As for simple expansion chamber like an air cleaner, classical acoustic theory tells that the amount of noise reduction results from the ratio of the expansion and contraction area between a chamber and a attached duct. However, it is not clear to assume the same theory can be applied to the case of an air cleaner, because the longitudinal length is not long enough compared to lateral length for plain wave to be developed in full scale. In general, the acoustical performance of an air cleaner is explained just by the volume of it(Fig. 2). When the size and shape of an air cleaner and the position of a duct remain identical, the smaller the cross section area of a duct is, the larger noise reduction is accomplished.

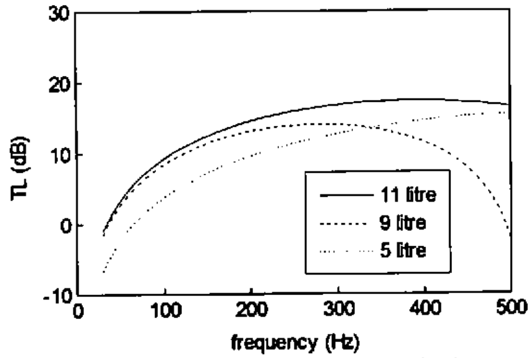

Fig. 2 Transmission loss of several air cleaners

The existence of duct alters the noise reduction performance; it strengthens or weakens the performance by the variation of frequency(Fig. 3).

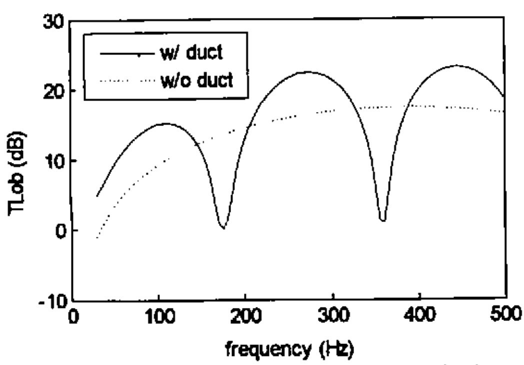

Fig. 3 Effect of the duct attached to an air cleaner

This change cannot be expressed in terms of Transmission Loss(TL) because TL, speaking rigorously, is defined as the ratio of incident acoustic energy to transmitted acoustic energy on the assumption of anechoic termination at the final port. In this case, observed TL, which substitutes for TL to consider the reflection of acoustic wave at the final port, is used. Using observed TL and Radiated Sound Pressure Level(RSPL), we can recognize the frequency range in which loud noise

takes place. Then if above frequency range coincides with other noise components, the adjustment of duct length would be required.
There must be an inflow of air and the temperature variation all through the intake system. In fact, those factors do not affect the performance too much, it can be neglected in most cases.

3. HELMHOLTZ RESONATOR

Designing Helmholtz resonator has several stages. At first, the target frequency should be defined. Then the sound pressure distribution inside the whole intake system including an air cleaner and ducts should be predicted before designing resonator. This process prevents the resonator from being located at inadequate position. After these procedures, the limited space of engine room is considered to find out the restraints of dimension of the resonator. Among the infinite number of the trial resonator being satisfied with restraint condition, several cases can be chosen and compared in terms of TL curve. Here in order to describe the acoustic performance of the resonator more precisely, the effective noise reduction band is defined as a bandwidth where TL is over a certain standard value like 10 dB, 20 dB, etc. If the bandwidth is satisfactory, then finally a little modification to tune it exactly in the target frequency is the last work.
In general, every resonator has to have enough volume to guarantee sufficient noise reduction, and the lower frequency target there is, the larger volume resonator should have. An extraordinary design for the resonator dimension, for instance, exceedingly short neck or thin volume, etc., could result in the failure in controlling unwanted noise.

4. CONCLUSION

This paper demonstrated the design information that can be applied to the low noise intake systems as follows. The various aspects of intake systems were studied. Using the various methods on noise prediction, the acoustic performance could be evaluated and compared to one another. Finally, the effective design method to design a Helmholtz resonator was suggested.

REFERENCE

[1] C. M. Lee and O. Kwon, KSAE 953708, 89, 1995
[2] A. Selamet and P. M. Radavich, SAE 951263, 227, 1995