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Effect of Resonator on Transmission Loss and Sound Pressure Level of an Air Intake System

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Abstract— ***This paper emphasizes the role of resonator on transmission loss in air intake system and its sound pressure level reduction. The intake noise of an automobile induced by firing of an engine accompanies acoustic resonance of ducts of an intake system. Conventionally, the adoption of an integrated type resonator was one of possible ways to eliminate the booming noise due to acoustic resonances of air ducts. Although the Helmholtz type resonator is convenient to attenuate the intake noise of an automobile, the usage of the Helmholtz type resonator requires cost increase or big engine room space.***

Index Terms— ***Air intake system, Resonator, Acoustics Simulation***

I. INTRODUCTION

The intake system of an engine has three main functions. Its first and most identifiable function is to provide a method of filtering the air to ensure that the engine receives clean air free of debris. Two other characteristics that are of importance to the engineers designing the intake system are its flow and acoustic performance. The flow efficiency of the intake system has a direct impact on the power of the engine is able to deliver. The acoustic performance is important because Government regulations dictate the maximum noise level that vehicles can make during a pass-by noise test. The speed of air generated by the intake system can be a significant contributor to this pass-by noise and separated flow. A resonator simply works by oscillating some frequencies and in turn generating waves of precise frequencies. Resonators are commonly used in 'muffing' the sound from exhausts of vehicles. The oscillations made by the resonator are called resonant frequencies.

The intake resonator chamber is located inside the passenger side fender-well. The resonator chamber is basically a muffler designed to reduce the intake noise by reducing the sound pressure level. However, it also restricts intake airflow. Recent advances in modeling and accurate performance prediction has led to the use of simulation methods for resonator calculation in commercial design. Resonator design needs simple, fast and accurate modeling tools, especially in the preliminary design evaluation stages. A resonator can be an effective acoustic attenuation device at low frequencies.

II. SCOPE

The main purpose of the work is to check the performance of the air filter system with resonator and its positive effect on sound pressure level reduction.

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In general, intake noise includes all patterns such as noise radiated from the snorkel opening and noise transmitted through pipe and air cleaner box, the noise generated from the on-off motion of inlet valves of an engine propagates through the intake system and it is eventually radiated from the snorkel opening.

During propagation inside the intake system, noise is affected by various compartments of the intake system that comprises the circular ducts with different lengths, areas, and materials, the manifold, the resonators and the air cleaner box. So need to define the systematic approach to reduce the SPL at air cleaner box.

III. ACOUSTICS SIMULATION

In acoustics simulation phase, first 3D CAD model is converted in to the 1D model by using pre processor software and 1D model is prepared for the simulation.

Acoustics simulation has been done for the different order of the engines like 2nd and 4th order and as well for the low frequency and high frequency.

3D CAD model used for the simulation purpose is provided in the .stp format for the preparation of the 1D model and to build it for the execution.

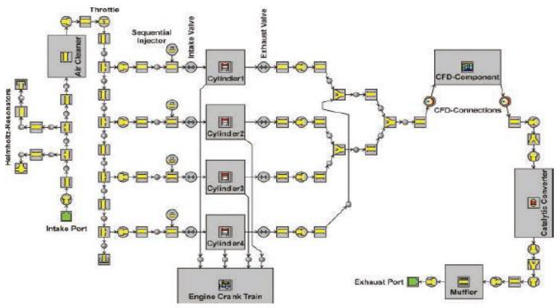

Fig. No. 1 Example 1D Model Prepared

IV. SIMULATION RESULT ANALYSIS

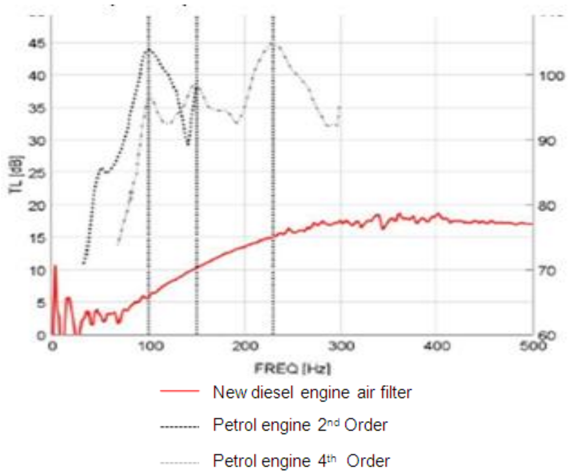

Fig. No. 2 Simulation Result

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After conducting the simulation for baseline, above shown results are achieved and in this Petrol vehicle 2nd and 4th order TL details show peaks at the frequency of 100Hz and 230 Hz

There is no transmission loss in the air filter box to reduce the sound pressure level so need further design modifications to increase the transmission loss (TL)

V. HELMHOLTZ RESONATOR CONCEPT

The intake noise is normally induced by firing of engine. Especially, the intake noise is enlarged by acoustic resonance at certain frequencies due to the length of intake system. To attenuate the acoustic resonance of the intake system at certain frequency, adoption of Helmholtz type resonator is popular.

The Helmholtz resonator is a simple acoustic system consisting of a rigid-walled cavity of volume V, filled with air and a neck of section S and the length L by which the cavity communicates with the exterior. This phenomenon has been exploited for thousands of years in making musical instruments.

Recently it has been used on noise control applications in automotive industry, for mufflers design and at the acoustic of habitable, subwoofers, concert halls acoustics or sport halls for enhancement the sound absorption at low frequencies.

Below shown is the model of the Helmholtz resonator where the volume of the first model is represented as a spring model in the second.

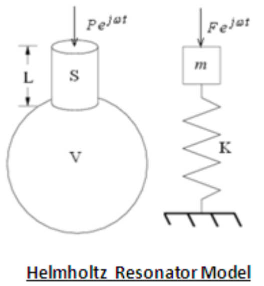

Fig. No. 3 Helmholtz Resonator Model

When air is forced into a cavity, the inside pressure increases. Once the external force that forces the air into the cavity disappears, the higher-pressure air inside will flow out. However, this surge of air flowing out will tend to over-compensate, due to the inertia of the air in the neck, and the cavity will be left at a pressure slightly lower than the outside, causing air to be drawn back in. This process repeats with the magnitude of the pressure changes decreasing each time.

This effect is akin to that of a bungee-jumper bouncing on the end of a bungee rope, or a mass attached to a spring. Air trapped in the chamber acts as a spring. Changes in the dimensions of the chamber adjust the properties of the spring: a larger chamber would make for a weaker spring, and vice-versa.

The air in the port (the neck of the chamber) is the mass. Since it is in motion, it possesses some momentum. A longer port would make for a larger mass, and vice-versa. The diameter of the port is related to the mass of air and the volume of the chamber. A port that is too small in area for the chamber volume will "choke" the flow while one that is too large in area for the chamber volume tends to reduce the momentum of the air in the port.

The frequency of a resonator can be calculated as below

$$\text{Frequency } f = (c/2\Pi).\sqrt{\ } (A/L.V)$$

Where,

c = the speed of SOUND. L = length of the neck, A = area of the neck, V = cavity volume of the resonator

As discussed above there are two frequencies 100Hz and 230 Hz to be considered for further acoustics analysis and TL optimization. With reference to this simulation has been done to calculate the resonator volume required at the desired frequencies.

Simulation is carried out and calculated the resonator volume for respective frequency and it is as below

Parameter	100 Hz Resonator	230 Hz Resonator
Dia. of Neck (Ø) mm	25	23
Length of neck (L) mm	260	98
Volume of the resonator (V) Ltr.	0.5	0.23

Acoustics simulation has calculated the resonator volume required for the targeted frequencies so subsequently CAD model of this calculated resonators are made and again this CAD model is again converted in to the 1D model for further simulation. Simulation software has calculated volume 0.5 liter for 100Hz frequency with the neck diameter of 25mm and length of the neck 260mm and for 230 Hz frequency calculated volume is 0.23 liter and diameter of neck is 23mm and length of the neck is 98mm

So for this new configuration again acoustics simulation is carried out and found the result as shown in below graph.

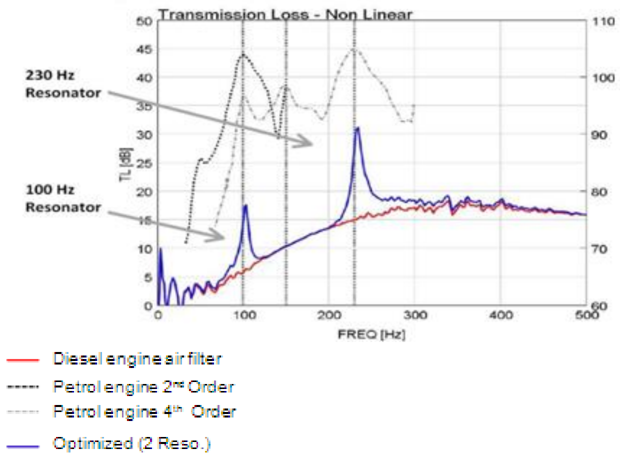

Fig. No. 4 Simulation Result with New configuration

Addition of the resonator has shown the drastically improvement in the transmission loss (TL) at the 100Hz and 230 Hz frequency and also shows the same trend as of the petrol vehicle test result.

But after considering this transmission loss, sound pressure level in dBA to be identified for the baseline and new configuration of the air filter box with the two resonators.

And it has to be check for the different operating conditions of the engine and hence in an acoustics simulation both configuration has been checked for the below mentioned conditions and the performance is compared.

Below graph shows significant effect of the resonator on the overall sound pressure level of an air intake system at following condition:

1. Total pulsation SPL,
2. 4th Harmonic dB (4 stroke, 2.0 order)
3. 8th Harmonic dB (4 stroke, 4.0 order)
4. 12th Harmonic dB (4 stroke,4.0 order)

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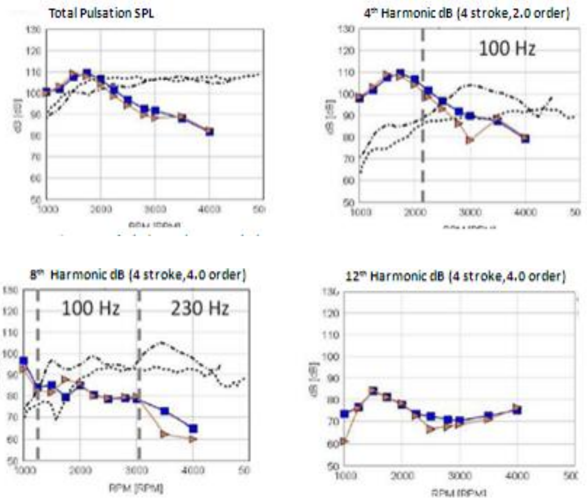

At different engine order overall SPL of the new concept is low than that of the concept1 and at low frequency performance of the concept 2 with the resonators is better than the existing configuration.

VI. CONCLUSION

Resonator is having a significant effect on the transmission loss inside an air intake system and increase in transmission loss will reduce the overall sound pressure level.
Also as observed resonator is playing a vital role in sound pressure level reduction but it should be designed for the desired certain frequency only. Volume, neck length and neck diameter of resonator can be tuned for the optimized result.
There are different ways to reduce the sound pressure level of an air intake system but simple way is to provide a resonator for increasing the transmission loss in an air filter box.

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