

Air Intake System Optimization for Acoustic Advantage on Automotive Vehicles

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10/05/2010Shital Shah
Defiance TechnologiesShaiju M Belsus
Nissan Ashok Leyland Technologies

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ABSTRACT

Recently quietness has become an important quality parameter for automotive vehicles and as a result various improvements have been brought to reduce noise at system and vehicle level. Due to stringent noise emission norms on automotive vehicles and increasing desire of quieter in-cab performance by users, reduction of air intake noise tends to be an area of explanation. Air intake noise, which was relatively considered as a minor source of noise in the past, is now gaining importance.

To reduce air intake noise basically resonator and expansion chamber are used on automotive vehicles. Resonators are widely used for noise reduction of intake and exhaust systems, but due to increased number of components, its associated cost; complexity of the system increases. The next option that is an expansion chamber prevents the formation of large amplitude standing waves and dissipates sound energy, however use of such a device reduces engine torque at narrow range of engine speeds.

The objective of the paper is to propose a simple in construction, effective silencing device, which can achieve good results in minimizing the noise produced by air charge (drawn into the AIS) without drastically deviating the power ratings of engine. Air intake muffler (proposed) is used as noise reduction device in place of an intake pipe on the suction side of AIS. The proposed concept is able to submit an optimized design package on the vehicle and virtual simulations show significant improvement in the flow patterns of air charge that will enable good acoustic behavior by AIS. The project is considered for validation plan on real

time vehicle application to realize the objective of the design as future scope of work.

Key words

Acoustic Advantage, Silencing Device, AIS, Air Intake Muffler

1.0. INTRODUCTION

The function of AIS is to furnish an adequate supply of clean (filtered), dry air to engine within an acceptable temperature range. In general, a four cylinder engine generates a low frequency induction noise around 50 - 200 Hz (1500 to 6000 rpm), which is basically contributed by engine firing frequency (as a result of impact noise generated by pistons and valves) during engine operation. In addition, the induction noise being a complex signals with variations in terms of increase in sound levels and frequency for abrupt/non-uniform vehicle acceleration signal. It is noted that level of the induction noise under rapidly accelerated driving conditions of the vehicle is much higher than the level of the induction noise under normal driving conditions. In order to reduce the induction noise, one option is to concentrate on avoiding rapid acceleration during driving, however this remains as an uncontrolled parameter from designer standpoint.

What AIS designer could opt is either of the two methods i.e. active control or passive control. Active control uses phenomenon by which the sound from the secondary source interferes with sound from the primary source. Passive control applies methods which use sound absorbing materials or resonators or change in design parameters of the AIS resulting in optimization of acoustic performance.

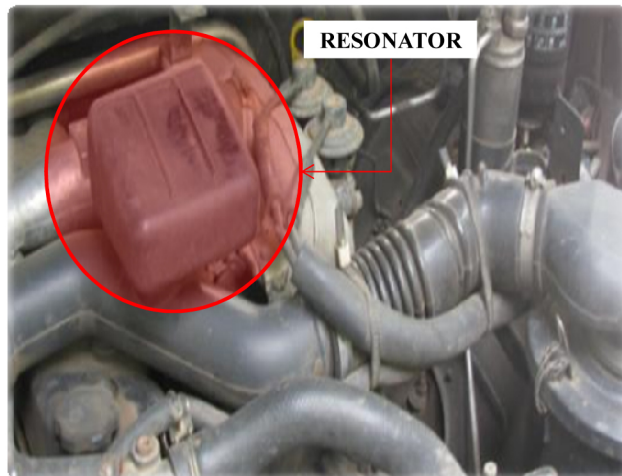


Figure 1.0. (a) Resonator on Clean Side piping of AIS (b) Air cleaner Assembly with Extended Air Cleaner Volume

One of the demerits of a passive control method is that the effect of noise reduction using the sound absorbing materials is poor at low frequency (below 500Hz range). There also exists a need to employ multiple resonators in order to reduce noise at various resonant frequencies and installation of these resonators becomes a critical concern for an optimal package design within the engine room. Such multiple resonator combination also leads to drop in engine output power and the increase in fuel consumption. [2]

Hence we foresee a need to provide a noise reduction device for AIS on automotive vehicles which would address the above contested problems innovatively. This need governs the work content of the paper.

2.0. BRIEF OVERVIEW OF EARLIER WORK

Researches on noise control applied to the air intake systems have not received much attention when compared research on exhaust systems. Tanaka and Nishio developed an actively controlled Helmholtz resonator by placing a speaker inside the cavity of the resonator located at a branch of the fresh air duct [1, 2]. According to the literature available so far on the intake noise reduction, the techniques currently used to reduce air induction noise include usage of expansion chambers, absorption or cancellation principle [3, 4, and 5]. Franc investigated the possibility of integrating an active noise cancellation system within the AIS. [7]

To reduce air intake noise, basically resonator (Figure 1.0 a) and expansion chambers (Figure 1.0 b) are used on automotive vehicles. Resonators are usually mounted as side branch volumes to the main air intake system, occupying additional packaging space. The “Helmholtz” resonators being limited to narrow range of engine speed in terms of its effectiveness are not preferred much.

The objective of our work is to introduce an effective silencing performance AIS to meet increasingly stringent noise emission legislative targets, without affecting much on engine performance, fuel economy and AIS layout of vehicle.

3.0. WHY THIS PAPER?

In future, requirements of acoustic behaviors of vehicle will continue to get more stringent. Generic passive or active acoustic measures will not be able to reach higher standards while maintaining reasonable cost and packaging specifications. For new engine developments with future legislative limits (in noise emission) and higher quality standards targeted, it will be necessary to develop noise reduction device in secondary noise source systems. The future breakthrough in noise optimization could be through concentration on research related noise control devices, which has the advantage of sound reduction below 500 Hz and can eliminate usage of multiple resonant frequencies attenuators and have minimum changes on the vehicle layout or the engine room space.

4.0. SCOPE OF THE WORK

We must understand that complexity of AIS design is in incorporating noise reduction device on AIS meeting the required (legislative) targets, without affecting engine performance, package protected to the available space and ultimately maintaining reasonable cost targets. This defines the scope of our work and the intent is to develop a noise reduction device which will have following advantages:

- More effective silencing and capable to attenuate noise frequencies without affecting engine or vehicle performance.
- Simple in construction and low cost design.
- No additional space requirement with respect to conventional AIS layout (package protected).

- Design capable of remove water particles, which affect noise performance of AIS.

CFD analysis of air intake muffler is also included in scope to verify flow restrictions and TL characteristics computed by virtual analysis for noise predictions. This work basically emphasis on design of air intake muffler for noise cancellation within the AIS.

5.0. CONCEPT PROPOSAL AND WORKING

Figure 2.0 is a schematic representation of novel design concept proposed to gain acoustic advantage on air intake system. It consists of outer cylinder shell (A), inner cylinder shell (B), inlet pipe (C), and an outlet pipe (D). A and B are concentrically placed with C and D inserted axially with perforations within the fitment zone. The noise silencing effect achieved by proposed air intake muffler concept is depicted in Figure 2.0.

The idea of concentricity of (A) and (B), in combination with optimization of perforations on (C) and (D) would, result in achieving a broad range of noise attenuation behavior; which else could have been possible only by increasing the overall sizing of air intake silencing device (in terms of length and height as practiced for a conventional design). This concept has been designed, verified as of now and taken forward for implementation as a production solution (after validation).

Air (sound waves) enter through inlet pipe to the muffler, wherein at first, some amount of air charge is directed to outer cylinder (A) through perforation on inlet pipe that lie between the outer cylinder shell and the inner cylinder shell, and the un-escaped air then moves forward to inner cylinder (B). The perforation on the inlet pipe, allow some amount of air charge to escape in similar manner inside (B). The orifice end of the inlet pipe redirects some amount of air charge in reverse direction (marked with blue arrows) along the same axis, all these reciprocations results is attenuation of noise.

When a sound wave passes from small space to a large space, an instance of sound is reflected back towards source and thus sound energy is converted to wave energy. Also when sound wave hit walls of inner and outer shell, it reciprocates the sound wave canceling each other. Thus most of sound energy is converted into wave energy because of wave reflection and this action gets repeated continuously resulting noise attenuation during the flow path at various levels with design concept.

Construction of outlet pipe (D) of air intake muffler is also perforated to create a similar progressive attenuation behavior on the contraction side (engine side) of air intake muffler. Outlet of air intake muffler is connected to air cleaner

assembly through hump hose which channelizes the air to air cleaner assembly.

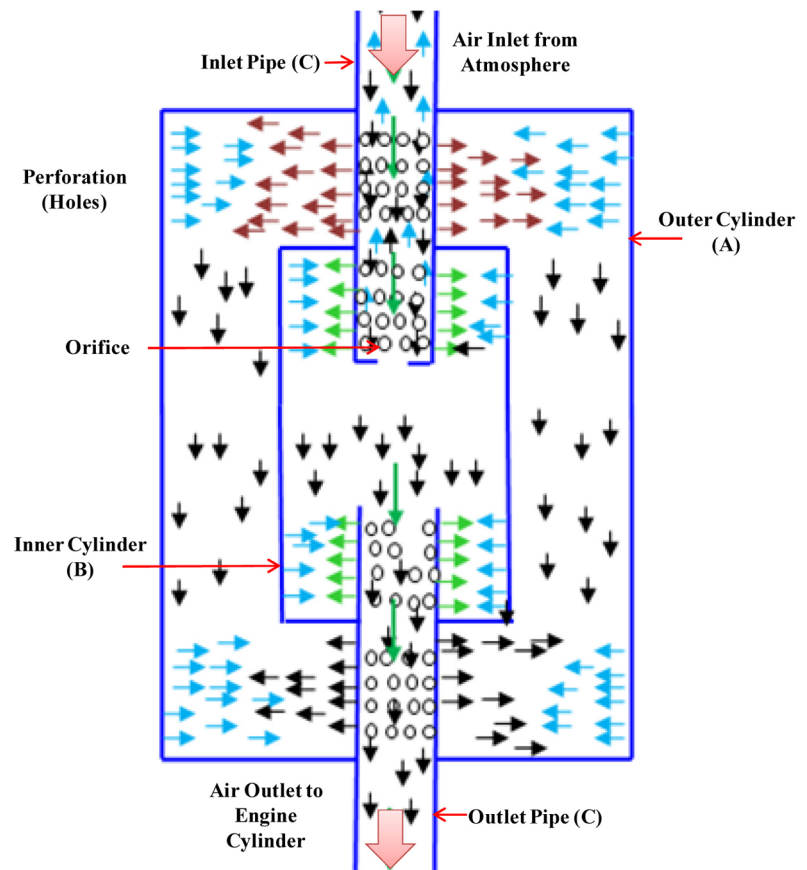


Figure 2.0. Detailed View of Air Intake Muffler [Patent No: 91/CHE/2010]

As the resonance is along the axial direction, due to peculiarity of the proposed design (which creating axial streamlines), possibility of vibration of air intake mufflers circumferential surface is reduced. Hence the brake out noise is also expected to be negligible.

The sizing of perforation on inlet and outlet pipes is a tradeoff/iterative process which is in consideration to the air intake requirement (from engine sizing), gross cross-sectional area (no. of holes X cross sectional area of each hole). This results in free movement of sound wave within the flow paths, which minimizing unwanted harmonics. The dimensions of air intake muffler is decided based on various factors like the frequencies that need to be eliminated, space constraints, allowable airflow to engine and system layout etc as discussed.

The provision of the air intake muffler concept of AIS has not caused any adverse effect on the performance of the engine, because the design concept has not affected the flow behavior of AIS due to introduction Air intake muffler designed as a scope of work is with extended inlet and outlet perforations