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A Review on Reduction of Intake Noise in an I.C. Engine

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***Abstract*— In order to reduce the intake noise in an Internal Combustion Engine used in Automobile There needs to be an efficient, low noise intake system which does not affect the performance of the engine in any factors. The performance of the I.C. Engine depends on volumetric efficiency, based on this parameter Helmhotz resonance principal the intake system was optimized aimed to reduce the intake noise frequency. The air intake system of an automobile engine is divided into the dirty side from the passage where air intake begins through to the air cleaner and the clean side from the sir cleaner to the section just in front of the air intake manifold. This paper focuses on the methods to reduce noise reduction.**

***Index Terms*—volumetric efficiency, Helmhotz resonator, intake manifold, intake noise**

I. Introduction

In recent years, as people realize the danger of noise, environment protection departments around the world have listed it as a kind of pollution and made a series of rules to restrict it. This made a big challenge to vehicle, especially motorcycle which has a high level of noise. In the vehicle noise, the noise reduction of the air intake system plays a very important role. The entire system that the car takes in outside air to the engine cylinder is called the air intake system. The intake system consists of a breathing tube, duct, resonator, air cleaner, throttle and manifold.

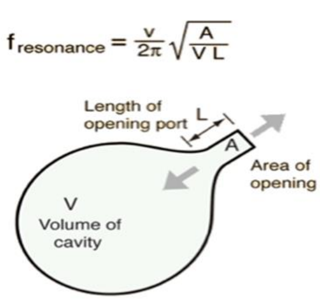

Fig. 1. Helmholtz resonator design

The noise below 600 Hz generated here is called intake noise. This noise is known to be mainly due to the pressure pulsations and resonance phenomena of the air flow inside the intake system. From NVH's point of view, the intake noise is very important, accounting for about 30% of the total vehicle noise. Although the Helmholtz resonator is currently used to suppress the highest frequency of intake noise, it always requires a neck and a cavity due to its characteristics and is greatly limited in the nacelle in a limited space. In the normal development and design of vehicles, taking into account the audible frequency audible frequency (16Hz ~ 20 kHz), is trying to reduce the intake noise of 60 ~ 200Hz. In particular, an intake system is recently being installed with pipes made of PET (polyethylene terephthalate) materials and resonators and the like in order to reduce exhaust noise and intake noise of the engine. In this paper we shall be focusing on these important aspects.

II. Basic of IC Engine Intake Noise

Engine intake noise is generated by pressure fluctuations which are caused by the periodic opening and closing of intake valve. When intake valve opens, the piston will move from top dead center (TDC) to bottom dead center (BDC) to suck fresh air. Meanwhile, the pulse noise is generated with the forming of pressure pulse. The air flows through intake valve cross-section at a high velocity and forms an eddy noise. The main frequency of eddy noise is in the range of 1000~2000Hz. In addition, if the natural frequency of air column is identical with the main frequency of periodic intake noise, it will cause air resonance and make the noise more obvious. When intake valve closes, it will cause the air pressure and velocity fluctuation. The fluctuation which includes compression wave and rarefaction wave transmits from intake valve to open-end along the pipe, and it reflections many times between the pipe open-end and closed valve. Consequently, the fluctuation noise is generated. Since motorcycle engine has only one cylinder, which is different from multi-cylinder engine, there is no coupling effect of intake pressure wave between each cylinder. The noise characteristics, such as basic frequency and spectrum, are different from multi-cylinder engine

A. Procedure to Find Intake Noise

The methodology to predict noise radiation of IC engine can be divided in three steps [1]. First step is to predict the excitation forces by carrying out Multi body dynamic (MBD) simulation. MBD simulation is carried out at a specified operating condition of the engine and takes into consideration the effect of combustion pressure and inertia forces of engine powertrain. Second step is to build the FE model for the engine and carry out vibration analysis under combustion load. Major components of engine are assembled to build FE model. Excitation forces from MBD simulation are applied to FE model of the engine to carry out vibration analysis and thus predict response on the engine outer surface. In the third step, nodal accelerations obtained from vibration analysis are used as an input to carry out acoustic analysis. SPL is predicted at a specified distance from the engine for the desired frequency range. The present work focuses on acoustic radiation analysis of a single cylinder motorcycle engine using acoustic module of COMSOL multiphasic.

B. Calculation to Reduce Intake Noise

In an I.C. Engine of any type, the formation of pressure pulse noise is mainly due to the periodic opening and closing of intake valve. Thus the noise frequency is decided by the engine speed it can be calculated by,

$$f = 2N*i/60n \quad (1)$$

where, N: engine speed
i : number of cylinders
n: stroke number

When intake valve is closed, the intake pipe will turn into a constant cross-section pipe one end of which is closing but the other is opening. As a result, a gas-column resonance system is formed. And the natural frequency of resonance can be calculated according to formula

$$f=(2j-1)*c/4l \quad (2)$$

Where, j= harmonic order.
c= sound velocity.
l= pipe length.

When the pipe length is equal to odd times of 1/4 wave length, it will cause resonance with small amplitude. The longer the pipe is, the lower the resonant frequency is, and the greater the damping is. Air eddy in intake system will form eddy noise while encountering obstacles. The frequency can be calculated according to formula.

$$f=(s\,h*v/d)*j \quad (3)$$

where, sh: Strouhal number.
v: air flow velocity at the valve.
d: valve diameter.

C. Noise Reduction Principle of Helmholtz Resonator

The structure of offshoot style Helmholtz resonator muffler is shown, and the noise reduction principle of Helmholtz resonator can be described as follows: When the sound wave transmits from main channel to the intersection of resonator hole, the acoustic resistance will change. As a result, part of sound energy reflects back and part of sound energy passes through the hole and resonator. Because of the loss effect of acoustic resistance, acoustic mass and acoustic capacitance of Helmholtz resonator, part of sound energy is consumed while only part of sound energy transmits along the pipeline. By this means, it can achieve the purpose of noise reduction. Especially, if the sound wave frequency closes or equals to the natural frequency of Helmholtz resonator, it will arouse resonance. In this case, the resonator will absorb and consume large amount of sound energy. At that time, it has the best effect on noise reduction.

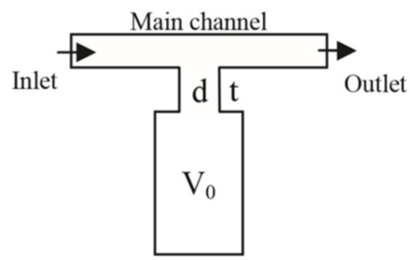

Fig. 2. The structure of Helmholtz resonator

The Helmholtz resonator or the Helmholtz oscillator is a container with a gas (usually air) with a naked eye (or neck or port). Due to the "resilience" of the interior air, the volume of air in and near the aperture vibrates. Although Figure 1 shows a simplified typical resonator, a Helmholtz resonator for an intake and exhaust system of a car generally has a different form from Fig. 1, is easy to produce due to space limitations, Noise and other adjacent components. Like eq. (1) as shown.

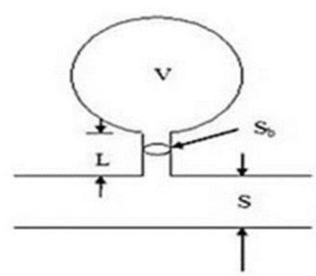

Fig. 3. The simplified resonator

Design of intake resonance system Through the previous calculation, we know that the peak frequencies of original engine intake noise are 425Hz and 850Hz, as shown in Fig. 3. According to acoustical theory, the vast majority of sound energy centralizes in the two frequencies. Therefore, the Helmholtz resonator can be designed based on resonant principle aimed at the two frequencies. The main parameters of this design can be calculated according to formula

$$f_0 = (c/2\pi)\sqrt{s/l_0 * v_0} \quad (4)$$

where, f_0: resonance frequency
l_0: equivalent length of connecting pipe

$l = t + \pi * d/4$
t: pipe length
d: pipe diameter
S: pipe sectional area
v_0: resonator volume

III. Acoustic Modeling Of Air Intake System

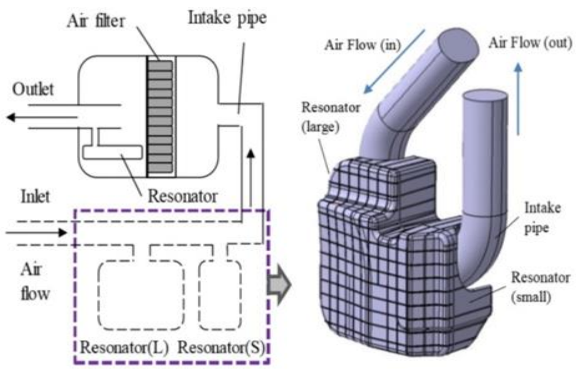

Fig. 4. Model of air intake system

The gas dynamics of IC-engines can essentially be described by a set of coupled nonlinear equations for conservation of mass, momentum and energy. In the general case analytical solutions to these equations cannot be found and numerical models based on various approximations are necessary. A very powerful and often-used simplification for IC-engine intake or exhaust ducts is to consider one-dimensional (1D) fields only. This assumption implies that the variables of pressure, density, velocity and temperature are treated as being constant over the cross-section of the duct under consideration. From this the solution of the coupled nonlinear equations will be greatly simplified. Another possible simplification is to assume small perturbations and perform a linearization of the governing equations. When there is a homogeneous mean flow present, the final result will be the convective wave equation and then 3D effects can also be addressed without too much difficulty. If only plane waves are considered, the wave equation will be reduced to a 1D linear wave problem, which can be efficiently analyzed via so called two-port (four-pole) methods.

IV. Conclusion

A method to predict I.C. engine noise under combustion load is presented. Structural modifications can be carried out in engine structure in the initial design phase to achieve overall noise reduction. This approach can thus lead to substantial savings in terms of cost and reduction in product development time. Using Helmhotz resonator a substantial reduction in noise.

Acknowledgement

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