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DESIGN AND ANALYSIS OF EXHAUST GAS RESONATOR

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Abstract*:* Noise pollution is on the rise with the increasing automobiles. Muffler is an essential component in the automobile which is used to reduce the noise from the engine. In this paper, there is a detailed literature review of papers related to the muffler considering the frequency analysis of the exhaust noise as an important aspect. Design, fabrication and model analysis methods of the muffler are also discussed.

Key words: ***Silencer, Muffler, Exhaust Gas Resonator, Frequency Analysis.***

INTRODUCTION

Exhaust Gas resonator is also termed as muffler or silencer. It is used for reducing the noise emitted by exhaust of an internal combustion engine, which is a major source of noise pollution. In certain cases, it is also used for changing the exhaust note of the automobile as desired. During the working of engine, it has to be ensured that there is no resonance at any speed. Thus the muffler is tuned such that there is no resonance at the low frequencies. Every automobile has a distinct exhaust note. The timbre of this sound can be analyzed by frequency analyzer and manipulated with change in the length of the resonating chamber. Changing the length of the resonating chamber changes the sound level i.e. shorter length of resonating chamber causes more noise reduction. Adding more walls in the resonating chamber reduces the noise but it also increases engine back pressure. Back pressure decreases engine efficiency and is undesirable beyond a point. Thus, a balance is to be struck between back pressure and exhaust noise level. There are two types of silencers: absorptive silencer and reactive silencer. Absorptive silencer absorbs the sound and has less back pressure and is usually used in 2 wheelers. Reactive silencer causes the pressure waves of engine exhaust gases to collide with themselves causing a reduction is noise level. They are generally used in 4 wheelers and have a high backpressure. In high performance automobiles, where sound is not an issue, the silencer is designed in such a way that the back pressure is least. Apart from noise considerations, there are various other parameters to consider while designing a silencer, like, Aerodynamical Criterion, Mechanical Criterion, Geometrical Criterion and Economical Criterion [1]. The muffler should be cheap and inexpensive while it is sturdy enough to handle the mechanical jerks of an automobile in motion. The availability of space is also an important consideration for design. The design should be aerodynamically sound.

LITERATURE REVIEW

Shubham Pal et al. [15] constructed a tunable resonator is used whose length can be varied by using a piston that can be set at different positions. Noise level was also measured at the different positions of resonator to check the effect of variation of length of silencer that shows the smaller the resonator size better is insertion loss. A muffler for stationary petrol engine (engine test rig) has been designed. Sound level was measured before and muffler installation at different position of resonator piston & the effect of resonator length was studied. Jigar H et al. [12] studied different types of mufflers and design of exhaust system belonging engine. The object of this study was to decide muffler design which one reduces a large amount of noise level and back pressure of engine. There is different parameters to take into consideration. These parameters affect the muffler efficiency. K.L.Koai et al. [3] employed finite element approximation to simulate a general acoustic environment of tluee dimensional nature, while the Helmholtz resonators were represented by boundary conditions with suitable amount of impedance at the frequency of interest. As a result of variational formulation of the acoustic wave equation, the impedance boundary condition turned out to be damping terms in the second order matrix equations. The noise reduction effects of various Helmholtz resonator arrangement. Discussions on the damping coefficients based on lumped parameter and distributed model formulation were both made. Amit Kumar Gupta et al. [25] presented an improvement of acoustical transmission loss on single expansion chamber muffler by using Helmholtz resonator with same gas volume. A reactive muffler is an important noise control equipment for reduction of exhaust noise and other noise source which involves the flow of gases. Here basic term was used for noise attenuation namely transmission loss. An experimental method for muffler's transmission loss measurement for central inlet and central outlet muffler shows the validation of result.in Finite element analysis tools the wave 1-D is also used to validate the results. It involved an improvement of transmission loss on first cut off frequency by the modeling of Helmholtz resonator. Mahd Nasir Kassim et al. [18] presented a pollutant of concern to the mankind was the exhaust noise in the internal combustion engine. However, this noise could be reduced sufficiently by means of a well designed muffler. The suitable design and development will help to reduce the noise level. The author design and fabricate a reactive muffler, spherical and cylinder shapes, afterward compared the noise level for these shapes with parallel and series connections.

Transmission loss and transmission coefficient were calculated experimentally and theoretically for one, double and three mufflers in parallel and in series. Exhaust noise levels aid the manufacturer in determining the correct muffler to meet the required noise reduction. These mufflers tested in frequency ranging between (50-600) Hz. The rustles showed that the parallel connection is best than the series connection. M.L Munjal et al. [9] dealt with evaluating approximate source characteristics required for prediction of the unmuffled intake and exhaust noise, making use of the electroacoustical analogies. Breakthroughs were achieved in the prediction and control of breakout noise from the elliptical and circular muffler shell as well as the end plates of typical mufflers. Diesel particulate filters and inlet air cleaners were also modeled acoustically. Some of these recent advances are the subject of this review paper. Igolkin A.A et al. [5] considered the main principles of reducing the noise of power engineering equipment. The efficiency of using mufflers for reducing the exhaust noise of power engineering equipment was justified. A design pattern of a pneumatic muffler was chosen. A mathematical model for calculating the level of noise of the pneumatic systems exhaust jet was developed. The model takes into account the installation of a noise muffler. It describes the impact of the noise muffler on the pneumatic systems fast acting. The results of simulating transition processes in the pneumatic system were presented, taking into consideration the installation of a noise muffler. Design data on pressure drop in the pneumatic capacity were compared with the experimental data. On the basis of the model developed the exhaust noise of power engineering equipment was calculated with and without a muffler. Rahul D. Nazirkar et al. [16] verified that for an automotive exhaust system the noise level, transmission loss & back pressure are the most important parameters for the driver & engine performance. In order to improve the design efficiency of muffler, resonating of the exhaust muffler should be avoided by its natural frequency. Mufflers are most important part of the engine system and are commonly used in the exhaust system to minimize the sound transmission level which is caused by exhaust gases. The solid modeling of exhaust muffler was created by CATIA-V5 and modal analysis was carried out by ANSYS to study the vibration and natural frequency of muffler. So as to differentiate between the working frequency from natural frequency and avoid resonating. Dr. B Ventakataraman et al. [17] presented an internal combustion engine produces excessive exhaust noise. A good exhaust system should control and keep the exhaust noise within the passable limit. Passive noise control techniques were employed to control the exhaust noises. Mufflers acts as a passive noise control elements in an exhaust system which attenuates noise by reflecting the sound wave and cancels it by destructive interferences and by absorbing the sound and dissipate into heat using absorptive materials .The muffler using absorptive materials for attenuating noise can cover a wide range of higher frequencies creating less back pressure while a reflection type muffler works well in lower and mid range frequencies but produces higher back pressure. This papers discussed the experimental results and performance evaluation of both absorption and reflective mufflers which are calculated by sound transmission loss (STL) experiment technique. J. Kanna Kumar et al. [14] presented that an automobile emission is one of the major problems in environment. He conducted tests on the effect of inlet fuel preheating and results showed significant improvement in the engine performance and reduction in the emission levels. Better performance and emission levels were observed when the engine runs at fuel inlet temperature of 600C. Sujit Kumar Jha et al. [7] determined the frequencies that appear at the modes, which have the more adverse effect during the operation of the automobile. An impact test was conducted by applying the force using a hard head hammer, and data generated was used for plotting a graph of the transfer functions using MATLAB. Results suggested that increasing the mass increases the damping and lowers the modes of the transfer function. Further research identified higher strength materials that can withstand the higher gas temperatures as well as the corrosion and erosion by the gas emitted from the engine. Murari Mohon Roy et al. [6] investigated the effect of engine backpressure on the performance and emissions of a CI engine under different speed and load conditions. A 4-stroke single cylinder naturally aspirated direct injection (DI) diesel engine was used for the investigation. The result showed that, the brake thermal efficiency and brake specific fuel consumption (bsfc) are almost unchanged with increasing backpressure The NOx emission became constant or a little decreased with increasing backpressure. The formation of CO was slightly higher with increase of load and back pressure at low engine speed condition. However, under high speed conditions, CO reduced significantly with increasing backpressure for all load conditions. The odor level was similar or a little higher with increasing backpressure for all engine speed and load conditions. Hence, backpressure up to a certain level was not detrimental for a CI engine. M.P.Tambe et al. [21] reviewed that main drawback of I.C. engines working is that it is a major source of noise pollution. Attaching a muffler in the exhaust pipe is the good option for reducing noise. But muffler requires specific design and construction considering various noise parameters produced by the engine. Design consideration was attenuation of sound in regular mufflers which caused a great amount of back pressure at the exhaust port thus losing power, increasing fuel consumption and piston effort to exhale the gases out. For high performance engines the free flow exhaust is made in which the sound level is not important but zero or less back pressure is. There is no intermediate muffler type in between both these, so semi active muffler is a step between these two, in which it attenuates sound when engine is running at low rpm, and converts in free flow when engine at higher revs. Daniel et al. [19] discussed the general principle of muffler design and explains the main advantages of various types of mufflers. When designing a muffler for any application there are several functional requirements that should be considered which includes both acoustic and non-acoustical design issues. Amitava Ghosh Dastidar et al. [8] studied the performance of the emission control system particularly by the catalytic converter and the noise control. A comparison was made of the exhaust gas emission providing with catalytic converter or not and an exhaust gas analyzer was used to collect experimental data. All the experimental data and

graphical representation concludes that the carbon content in the exhaust gas from the car, Toyota E-90 has been reduced to a great extent with the help of catalytic converter & the noise has been reduced as well for the proper attachment of muffler in exhaust system. Oke P. K. et al. [13] fabricated an exhaust/silencer system, that is capable of reducing exhaust noise, for use in a domestic generator. Experiment was carried out with the factory fitted silencer and the fabricated silencer. The fabricated exhaust system was able to reduce noise of 8.06% compared to 4.16% obtained with the factory fitted silencer. Also, the fuel consumption rate of the generator was lower when the fabricated exhaust system was used. This showed that (in the long-run) the new exhaust system would efficiently serve as alternative to the old system. Puneetha C G et al. [20] studied comprehensively, analyzing four different models of exhaust muffler and concludes the best possible design for least pressure drop. The essential function of a muffler was to route the exhaust gases from the engine exhaust manifold while reducing the noise and back-pressure. One important characteristic of mufflers was how much backpressure they produce. Because all of the turns and holes the exhaust go through, they produce a fairly high backpressure. This subtracted a little from the power of the engine. G. Lampugnani et al. [2] considered particularly the suction muffler design and related experimental techniques developed to optimize the noise attenuation factor and pressure losses. The need of keeping the suction pressure drops as minimum as possible, forces in oversizing the suction ports and ducts. By this fact, some more noise is generated by the suction process. Indira Priyadarsini et al. [23] dealt with four different models of chambered exhaust muffler and concluded the best possible design for least pressure drop. Flow trajectories were viewed to know the flow of exhaust gases through the muffler. The cut plots for pressure and exhaust gas velocity were viewed. The findings were tabulated to conclude the best exhaust muffler. Nadar Vivekraj Selvaraj et al. [24] studied the effect of radial jets at the upstream of muffler on temperature and acoustic pressure. The radial jets were introduced at different reservoir pressure at the downstream of muffler. The simulation study was carried out to determine the temperature and pressure distribution inside the silencer with and without radial jets and experiments were carried out to validate the result. The study concluded that the technique was effective to reduce the temperature of exhaust and noise. Prof. B.S. Patel et al. [10] considered particularly the suction muffler design and related experimental techniques developed to optimize the noise attenuation factor and pressure losses. The need of keeping the suction pressure drops as minimum as possible, forces in oversizing the suction ports and ducts. By this fact, some more noise was generated by the suction process. Sandepp G Thorat et al. [22] studied various modifications desired in the silencer design of upcoming Eicher tractor to fulfill the current standards,. As per the various studies reactive mufflers with extended inlet and outlet pipes into muffler, which is not present in current design can significantly reduce the noise level. Helmholtz resonator can also be introduced to cancel the noise of dominating frequencies. Also a sound absorbing material like glass fibers and steel wool can be incorporated for better results. Further, the design modifications were to be verified for noise reduction by COMSOL Multi-physics software. Also the numerical results for transmission loss will be verified with experimentally measured results.M. Rahman et al. [4] studied that attaching a muffler in the exhaust pipe is the most effective means of reducing noise. The conventional design does not include much of a parametric noise analysis or other engine characteristics. A muffler for stationary petrol engine has been designed and manufactured. The performance characteristics, i.e. noise reduction capability of the muffler, has been tested and compared with that of the conventional muffler. The result has been found to be quit satisfactory. Zhixia HE et al. [11] studied all kinds of spray, combustion, and emission models and then a new 3-D spray model coupled with the cavitating flow inside the nozzle put forward to well consider the primary atomization induced by cavitating flow and turbulence in nozzle holes. The model, combined with combustion and emission models were used for simulating the single-injection combustion of 1015 diesel engine and validated through comparing the results from simulation with those from experiment. With the above verified models, different injection strategies were further investigated to reveal the effect of pilot injection timing, quantity, and main injection timing on combustion noise and exhaust emission of diesel engine. Eric Sandgren et al. [1] demonstrated the application of nonlinear programming methods to the design of compressor muffler systems. A simplified muffler geometry is assumed and a standard impedance analysis approach is employed. A square wave volume velocity muffler input is assumed, and muffler design parameters are selected using modern optimization techniques. The resulting optimal design most closely approximates specifications within the muffler class considered.

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