Vehicle Sound Quality Evaluation through Virtual Prototyping

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Abstract— This paper is concentrated for evaluating the sound quality of exhaust noise in the exhaust system design and development process. The present study shows the feasibility of using non-conventional noise cancellation technique. The effectiveness of such a technique is investigated using Ricardo WAVE, a computational engine simulation technique that uses a one-dimensional finite-difference formulation. The graphical interpretation using octave frequency spectra and 3-D colour maps of both an unmodified and a bridged engine are presented for both steady state and transient engine cases. A sound quality analysis is also presented using the psychoacoustic metrics of Loudness, Fluctuation, Strength and Boom. The main aim of this paper is to use of 1-D tool to simulate sound quality performance. Both cases like steady state and transient state conditions are simulated to evaluate vehicle sound quality with changing the exhaust configuration.

Key words: Acoustic wave propagation, Sound Quality Analysis, Wave 1-D

I. INTRODUCTION

The sound quality of vehicle interior noise has become a very important task for the acoustic engineers. As vehicles become more and more quiet, the customer's sensitiveness for the acoustical comfort increases. On the one hand, no disturbing noises should be heard and on the other hand, the perceived sound quality, for example from the power train, should fulfill the expectations of the listener with respect to the sound design. The subjective judgment of pleasantness or sound comfort is influenced by both sound and vibration [1]. Vehicle sound quality measurement is essential part in view of growing economy, increased market requirement and aspirations of the customer. Now a day's government rules and norms are stringent about vehicle noise pollution. Here virtual prototype plays an important role to achieve the desired sound quality of vehicle. "Sound Quality" describes those characteristics of sound which allow the ear to distinguish sounds like accuracy, enjoy-ability, or intelligibility [2].

II. METHODOLOGY

- Measurement of Static Noise and transient Noise of vehicle by using 1D simulation.
- BY establishing Color Map by using 1D simulation.
- Frequency spectrum analysis by EFA.
- An Improvement of Sound Quality by the modification of vehicle element like Intake, exhaust etc.

III. SOUND QUALITY SIMULATION

The virtual simulation tool RICARDO WAVE is used for sound quality investigation. Wave is a computer aided engineering code developed by Ricardo to analyze the dynamics of pressure waves, mass flows and energy losses in intake and exhaust manifolds of various systems. This is accomplished by applying a one-dimensional finite difference approach of the theoretical thermo fluid equations of the working fluids of the defined system. In order to analyze the sound quality of an engine with WAVE ,it must first be created with the preprocessor WAVEBUILD. This canvas provides the ability to create and synthesize all of the building blocks representing the various ducts, volumes and other engine component. WAVEBUILD also allows for the input of the required physical data and operating conditions of the engine [4]. For this purpose 4 cylinder, 8 valve model used for the simulation, the model appears as in figure1.

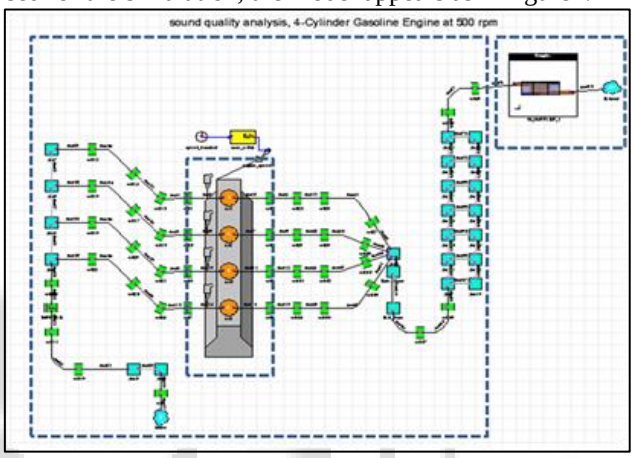

Figure 1: Ricardo Wave 1-D GUI for sound quality analysis

Sound quality was determined for steady state conditions for engine speeds from 500 to 5000 rpm. Similar analysis were performed for transient runs between the same rpm range. The coordinate system used for simulation is global and the exhaust is set at the position.

A. Post Processing In Wave Post

Wave post can create both "acoustic plots" and "audio outputs" from data obtained in an acquisition. This enables you to create both 2D & 3D plots, to view the results of acquisitions. Figure 2 are color map representations of the induction noise. Figure 3 shows the SPL vs frequency graph of the induction noise for the rpm range of engine model for transient and steady state.

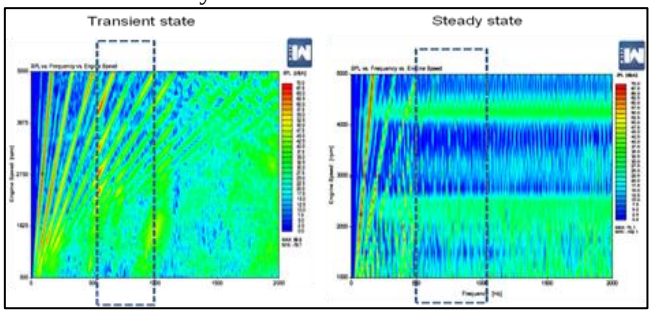

Figure 2: Colormap Representation for Transient and Steady State

Here ,the various colours represent the amplitude of the predicted sound pressure level. Similarly ,figure illustrates the same for the engine at steady state. The yellow and orange streaks representing the fundamental and subsequent harmonic frequencies are more apparent with more red showing on the map of model at transient state [3][9]. This shows higher amplitudes of sound at the fundamental frequencies which are obviously associated with the speed of engine . Also, the steady state engine simulation has less of the higher sound pressure level represented by the green color. Similarly ,it has more of the lower sound pressure level represented by the mid and dark blue shades.

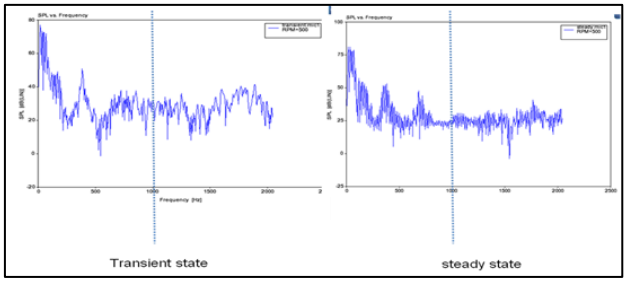

Fig. 3: SPL Vs Frequency Graph for transient and steady state.

IV. SOUND QUALITY MANIPULATION

Sound quality can be modified either by Intake noise cancellation or by Exhaust noise cancellation. A muffler is a noise reduction element on exhaust system. The basic term used for noise attenuation is transmission loss (TL). **Sound quality** can be modified either by Intake noise cancellation or by Exhaust. A muffler is noise reduction element on exhaust system. The basic term used for noise attenuation is transmission loss (TL) [11].

For manipulation of sound quality of the engine the volume of muffler is keeping constant for central inlet and outlet.

Following design conditions are applied to analyzing the manipulation of sound quality of the engine-

- Volume of the muffler is kept constant for all the modelling and design work and by keeping the length of muffler as constant i.e. 500mm.
- Modelling of cylindrical central inlet and outlet by keeping the same volume, i.e. diameter 130mm and by keeping the diameter of central inlet and outlet tail pipe as constant i.e. 35mm.
- Modelling of circular expansion chamber by keeping the length of inlet and outlet tail pipe as 100mm.

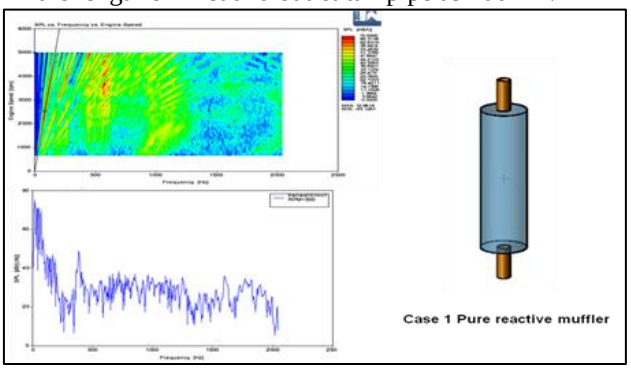

Fig. 4: Schematic representation of colormap and SPL vs Frequency graph for pure reactive muffler

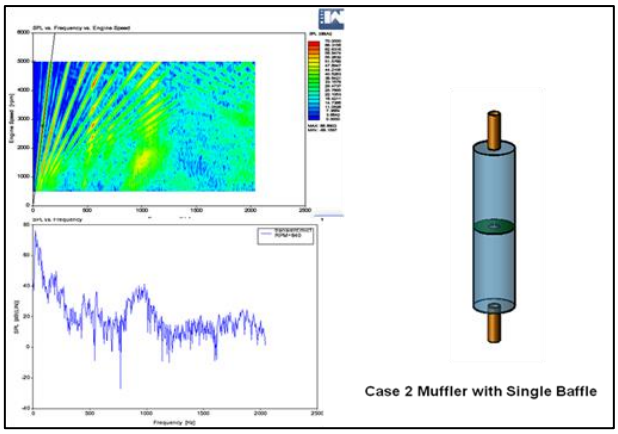

Fig. 5: Schematic representation of colormap and SPL vs Frequency graph for muffler with single baffle plate.

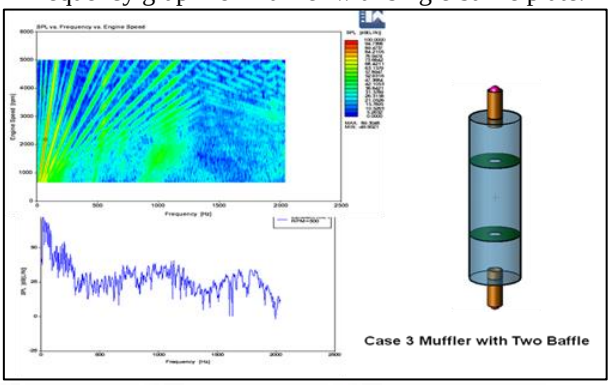

Fig. 6: Schematic representation of colormap and SPL vs Frequency graph for muffler with two baffle plates.

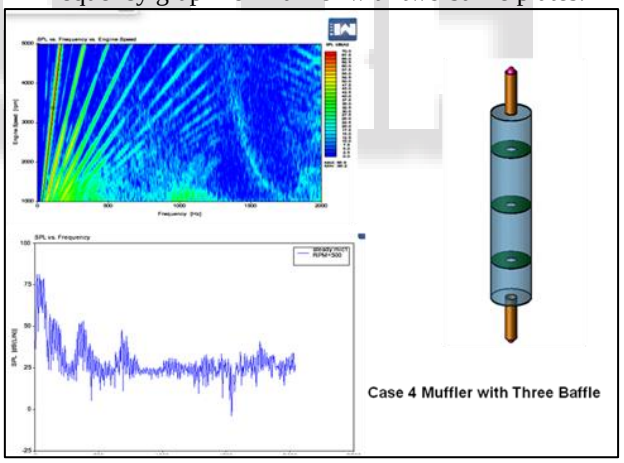

Fig. 7: Schematic representation of colormap and SPL vs Frequency graph for muffler with three baffle plates.

V. RESULTS AND DISCUSSION

Table1 shows the validation of results the comparison of empty muffler and muffler with One, Two and Three baffle plates from figure 3 shows the low Sound Pressure Level can be achieved in muffler with three baffle plates for 2nd order.

Types of Muffler	Phones	Sones	Sharpness	Boom
Simple Muffler	34.73	0.8	1.45	54.03
Single Plate Baffle	23.66	0.2	1.01	47.87
Two Plate Baffle	12.21	0.07	0.81	47.51
Three Plate Baffle	8.62	0.015	0.54	46.54

Table 1: Sound Quality comparison of pure reactive muffler and mufflers with baffle plate

From the above result Muffler with Three Plate baffle shows low SPL.

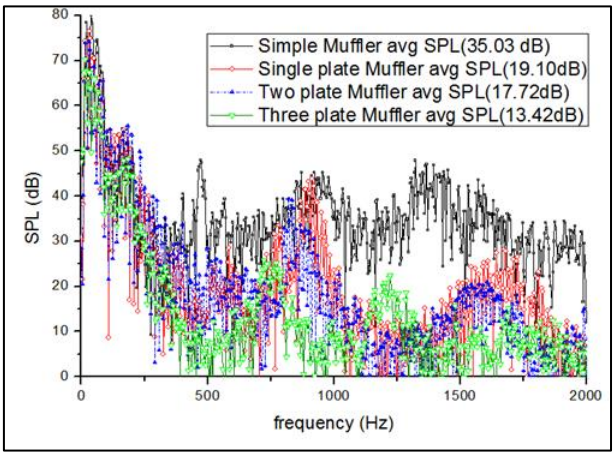

Figure 8: SPL Vs Frequency comparison Graph for simple muffler and mufflers with single, two and three baffle plates.

VI. CONCLUSIONS AND FUTURE WORK

For the conditions investigated, it has been shown that the baffle plate in exhaust muffler has a positive influence on both the amplitude and the sound quality of a vehicle noise. The focus of this paper was the realized acoustical results of the modified muffler and did not report on some of the other engine performance criteria, particularly the influence of the additional exhaust gas recirculation.

The muffler which we have investigated further can be investigated by modifying baffle plates. So, in future the muffler can be modified by baffle cut-off ratio and by filling empty muffler with rock wool. Also there is a scope to calculate back pressure.

REFERENCES

[1] A.K. Gupta "Sound Quality Performance of pure Reactive and Pure Absorptive Muffler by Simulation", International Advanced Research Journal in Science, Engineering and Technology Vol. 3, Issue 4, April 2016.
[2] M. Allman-Ward, R. Williams, G. Dunne and P. Jennings, "The evaluation of vehicle sound quality using an NVH simulator" Proceedings of the 33rd International Congress and Exposition on Noise Control Engineering 2004.
[3] G. Cerrato, A. Crewe, R. Williams, "Sound Quality evaluation", Sound&Vibration, May 1997 4. Ricardo Software:
[4] M A Panzza Evaluation of Noise Level Inside Cab of a Bi-Fuel Passenger Vehicle, WSEAS.
[5] Xu Wang, Vehicle noise and vibration refinement, Woodhead Publishing, 2010.
[6] N. Hirate amd M. komada "engine sound development" Toyota Motor Engineering & manufacturing north America , 2003.
[7] Kalyan s. hatti , A shahul hameed " Vehicle Noise reduction –An approach". Ashok Leyland technical centre, chennai.
[8] Ming –Ran lee and Mark Mccarthy, "Exhaust System design For Sound Quality", Ford motor company,. 2009.
[9] S. Rajadurai, R GokulRaj, K.J. Rajkumar "Countermeasures to Reduce Muffler Shell Radiation Noise". Mahindra World City Chennai, Tamil Nadu.7 july,2015

