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CFD Analysis on BS6 Exhaust System of Two-wheeler

Pradeep Chavan, Praveen Kumar Rai*, Ramavath Durga and Nilabh Dish

Department of Mechanical Engineering, Bharat Institute of Engineering and Technology, Hyderabad, Telangana, India

***Correspondence to:**
Praveen Kumar Rai
Department of Mechanical Engineering,
Bharat Institute of Engineering and Technology,
Hyderabad, Telangana, India.
E-mail: praveen.me65@gmail.com

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Abstract

This work focuses on the exhaust BS6 for two-wheeler vehicles. Study included the CFD analysis and experiment have been performed on the current design of the exhaust BS6 with boundary conditions as per engines. BS6 exhaust system with layer and BS6 exhaust system without layer differences going to be obtain. The design of the BS6 exhaust system will be generated according to requirements. Exhaust gas temperatures, velocities, and back pressure have been evaluated and verified through Finite Element Analysis by using CFD module of ANSYS. Also, the modal analysis is performed to study the effect of geometric change on natural frequency of system. Actual testing has been performed by manufacturing modified exhaust BS6 and test it on the two-wheeler engine test rig for back pressure and noise. BS6 exhaust system with layer gives better results as compared to BS6 exhaust system. Without layer and also transmission loss of BS6 exhaust system with layer is net 17.52(k), which is more than requirement and satisfactory.

Keywords

BS6 exhaust system, Finite element analysis, CFD analysis

Introduction

BS6 are installed within the exhaust system of most internal combustion engines, although the BS6 is not designed to serve any primary exhaust function. The BS6 is engineered as an acoustic sound proofing device designed to reduce the loudness of the sound pressure created by the engine by way of acoustic quieting. For the majority of such systems, however, the general rule of "more power, more noise" applies. Several such exhaust systems that utilize various designs and construction methods: Vector BS6 - for larger diesel trucks, uses many concentric cones, or for performance automotive applications, using angled baffles to cause exhaust impulses to cancel each other out [1, 2]. Spiral baffle BS6 - for regular cars, uses a spiral-shaped baffle system. Aero turbine BS6 - creates partial vacuums at carefully spaced-out time intervals to create negative back pressure, effectively 'sucking' the exhaust out of the combustion cylinder. In Automobile, the exhaust system is made up of several components that work together to decrease exhaust noise and give a channel to deplete gases to leave the motor by advancing out underneath the vehicle [3, 4]. This pathway is utilized to hold destructive gases back from entering the vehicle and making tenants debilitated. Much of the time, the exhaust framework will put forth the removed vapor cleaner trying to decrease discharges and shield the climate from additional harm. Exhaust gases are gathered from the cylinder head in the motor by a ventilation system. These exhaust gases then travel through an exhaust framework which takes out hurtful parts including carbon monoxide and hydrogen monoxide which are changed over into inert gases. The gases then, by then go through a silencer or suppressor.

Emission standards are the legal requirements governing air pollution released into the atmosphere [5, 6]. There are some emission standards which allowable only some specific air pollutants which are released in specific source over particular time frame. It is basically manufactured to reach good air quality standards and also protect human life [6, 7].

Bhat et al. [3] present their thesis work on “Analysis of Combustion and Emission in SI Engine”. A computational model of IC engine is modeled, and computational fluid dynamics has completed by utilizing FLUENT. In the analysis, combustion parameters like fluid flow, mixing, turbulence, and back pressure are analyzed by utilizing. Combustion performance, temperature characteristic, pressure and emission parameters of CO, HC and NOx will be recorded and analyzed at different flow rates of hydrogen. In this task a system of different proposed designs of cylinder heads is modelled and in view of the boundary conditions that model is analyzed. Compare all the analysis output data decide the best enhanced design with the satisfaction of all characteristics. Avcu et al. [7] introduced a paper on “Modeling and Analysis of Exhaust Manifold” using computational fluid dynamics analysis is performed on exhaust system to concentrate on flow characteristics like pressure, velocity, and temperature. The inlet temperature is taken as 900 K, and analysis is performed by two distinct materials like stainless steel and gray cast iron. Temperature, pressure, and velocity are noted and classified. Pressure drop and increment of stream speed from inlet to outlet of hot gases are noted according to geometry of model. Temperature after force convection during plunging of vehicle is determined by programming is noted and classified as 416 Shao [9] introduced their work, “Design, analysis of Flow Characteristics of Exhaust System and Effect of Back Pressure on Engine performance”. They effectively designed the exhaust system. Through CFD analysis, they considered the backpressures of different exhaust diffuser systems. From the analysis they conclude that the increase in inlet cone angle increases the pressure of the flow which leads to the decrease in the distribution zones. Agrawal and Devkare [13] work focuses on the exhaust mufflers for two-wheeler vehicles. The study will include CFD analysis and fluid structural interaction analysis to be performed on the current design of the exhaust muffler with boundary conditions as per engines.

Materials and Methods

Tuning engine noise

BS6s are mounted in line with your exhaust pipes, typically towards the very end before the exhaust tips. They feature a series of perforated tubes or baffled chambers which are designed to tune and minimize your engine’s sound output. As noise comes into the BS6, the sound waves bounce around against the baffles, creating opposing sound waves that cancel each other out. And much like an acoustical engineer designing an instrument or a concert hall, BS6 manufacturers know how to “tune” the baffles and chambers to create a desired sonic effect. So, whether you want to cut as much sound as possible or get a focused sound with an amplified growl range, there’s a performance BS6 out there for you [10, 11].

Back pressure

Engine exhaust back pressure is defined as the exhaust gas pressure that is produced by the engine to overcome the hydraulic resistance of the exhaust system in order to discharge the gases into the atmosphere. For this discussion, the exhaust back pressure is the gage pressure in the exhaust system at the outlet of the exhaust turbine in turbocharged engines or the pressure at the outlet of the exhaust manifold in naturally aspirated engines [13].

Back pressure limits

All engines have a maximum allowable engine back pressure specified by the engine manufacturer. Operating the engine at excessive back pressure might invalidate the engine warranty. To facilitate retrofitting of existing engines with DPFs, especially using passive filter systems, emission control manufacturers, and engine users have been requesting that engine manufacturers increase the maximum allowed back pressure limits on their engines Engine manufacturers are usually much more conservative on their back pressure limits. For example, diesel generator set engines from Caterpillar, Cummins, John Deere, and DDC/MTU [12].

Effects of increased back pressure

At increased back pressure levels, the engine has to compress the exhaust gases to a higher pressure which involves additional mechanical work and/or less energy extracted by the exhaust turbine which can affect intake manifold boost pressure. This can lead to an increase in fuel consumption, PM and CO emissions and exhaust temperature. Increased backpressure may affect the performance of the turbocharger, causing changes in the air-to-fuel ratio-usually enrichment - which may be a source of emissions and engine performance problems. The magnitude of the effect depends on the type of the charge air systems. Increased exhaust pressure may also prevent some exhaust gases from leaving the cylinder (especially in naturally aspirated engines), creating an internal exhaust gas recirculation responsible for some NOx reduction. Slight NOx reductions reported with some DPF system, usually limited to 2 - 3% percent, are possibly explained by this effect. Excessive exhaust pressures can increase the likelihood of failure of turbocharger seals, resulting in oil leak agent the exhaust system. In systems with catalytic DPFs or other catalysts, such oil leak can also result in the catalyst deactivation by phosphorus and/or other catalyst poisons present in the oil. All engines have a maximum allowable engine back pressure specified by the engine manufacturer. Operating the engine at excessive backpressure might invalidate the engine warranty. It is generally accepted by automotive engineers that for every inch of Hg of backpressure (that’s Mercury - inches of Hg is a unit for measuring pressure) approximately 1 - 2 HP is lost depending on the displacement and efficiency of the engine, the combustion chamber design, etc.

Characteristics of BS6

A The design of a noise BS6 incorporated into a pneumo system. On the basis of the developed mathematical model transition processes in the pneumonia system were calculated with regard to a noise BS6 installed so as to investigate the impact of the installed noise BS6 on the speed of the pneumonia system's operation. The performance of a BS6 is characterized using 3 different measures: Insertion loss, IL; Transmission loss, TL; and Noise reduction, NR.

Insertion loss is defined as "the ratio (in dB) between the acoustic power radiated at the outlet of a reference system and the system investigated, with both systems driven by the same source" [2]. The reference is usually a straight pipe with the same length as the investigated system. Transmission loss is defined as "the ratio (in dB) of the incident power to the power transmitted for a given termination" [2]. Normally a reflection free pipe. Noise reduction is defined as the "difference in sound pressure level (in dB) at two arbitrarily selected points in the exhaust pipe and tailpipe" [3], (upstream and downstream side of the BS6). In this work, transmission loss, TL, will be used as the measurement of the BS6 performance.

Results and Discussion

BS6 exhaust system of CFD analysis

Using CFD software to establish the 3D model of the exhaust pipe, as shown in figure 1. The model parameters are shown in table 1. In order to control the automobile harmful gases such as NOx, HC, and CO, the three-way catalytic converter must be installed in the exhaust pipe. The harmful gases can be converted into harmless carbon dioxide, water, and nitrogen by oxidizing and reducing gases. The carrier component of the three-way catalytic converter is a porous ceramic material, which is installed in the specific position of the exhaust pipe and is the most important equipment in the automobile exhaust system. The three-way catalytic converter and oxygen sensor are generally installed in the exhaust manifold (natural gas engine) or after the turbocharger (turbocharged gasoline engine).

Mosaic mesh is a patent pending Ansys fluent meshing technology for computational fluid dynamic simulations. It accelerates the meshing process with a reduced face count, higher quality cells, and efficient parallel scalability. Mosaic meshing technology enables polyhedral connections between disparate mesh types. Design of the BS6 exhaust system with layer will be generated according to requirements. Exhaust gas temperatures net: 17.52 (K), velocities: 1.121 (m/s), and back pressure (Pa): 6.933.

Figure 1a shows the BS6 exhaust system with layer geometry file and figure 1b BS6 exhaust system with Layer mesh file. In figure 2a BS6 exhaust system with layer velocity streamlines have been evaluated with CFD module. BS6 exhaust system with layer pressure volume has been presented in figure 2b. BS6 exhaust system with layer density volume has been shown in figure 3a and BS6 exhaust system with layer temperature volume has been analyzed in figure 3b. BS6 exhaust system without geometry layer has been presented in figure 4a and the meshing BS6 exhaust system without layer has been done in figure 4b. Figure 5a and 5b shows the BS6 exhaust system without layer pressure contour and BS6 exhaust system without layer velocity streamlines. Figure 6 shows the BS6 exhaust system without layer density volume. Table 1 and table 3 are the results of the mass flow rate in

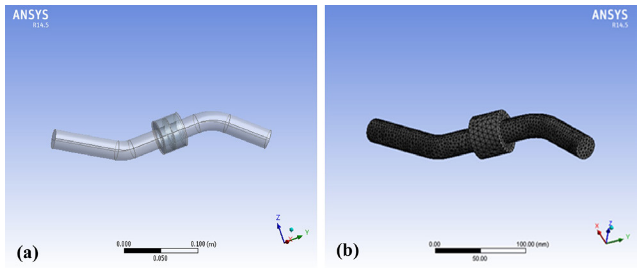

Figure 1: BS6 exhaust system with **(a)** layer geometry file and **(b)** layer mesh file.

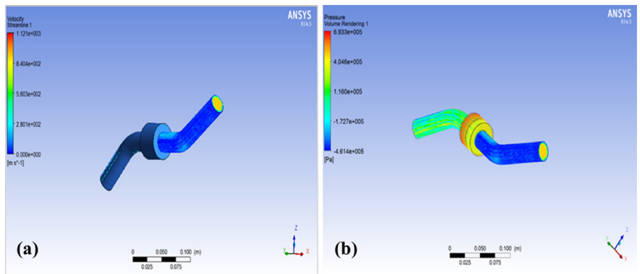

Figure 2: BS6 exhaust system with **(a)** layer velocity streamlines and **(b)** layer pressure volume.

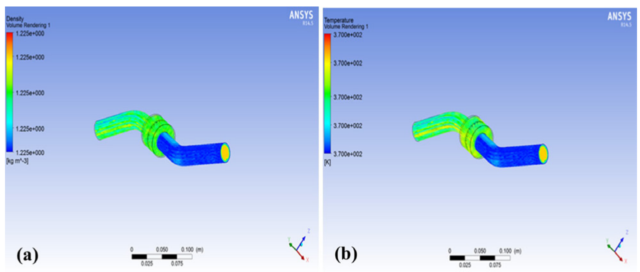

Figure 3: BS6 exhaust system with **(a)** layer density volume and **(b)** layer temperature volume.

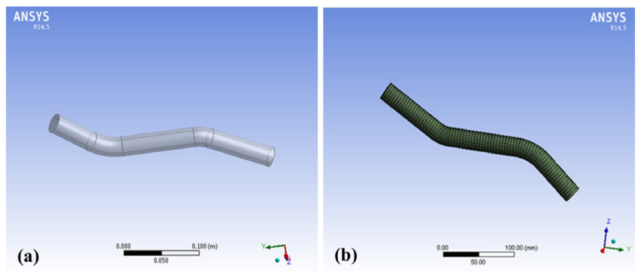

Figure 4: BS6 exhaust system **(a)** without geometry layer and **(b)** without layer meshing.

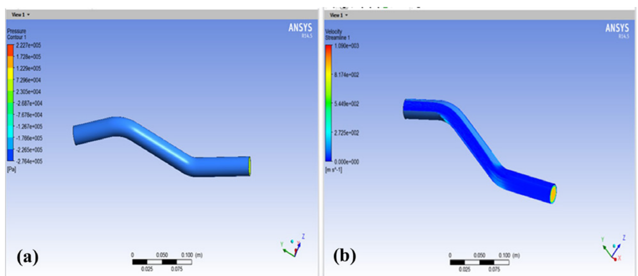

Figure 5: BS6 exhaust system **(a)** without layer pressure contour and **(b)** without layer velocity streamlines.

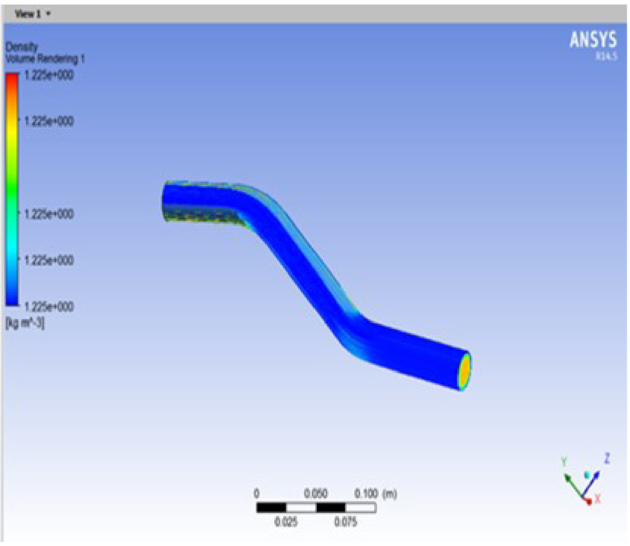

Figure 6: BS6 exhaust system without layer density volume.

Table 4: Total heat transfer rate (W).

Heat Transfer Rate	Units (Watt)
Inlet	38584.746
Outlet	-38569.504
Wall-part body	0
Net	15.242188

Table 5: Comparative results.

System	Velocity (m/s)	Pressure (Pa)	Temperature (K)	Mass Flow (kg/s)
BS6 Exhaust system with layer	1.121	6.933	17.52	-0.0025686026
BS6 Exhaust system without layer	1.090	2.227	15.242	0.00021034479

(kg/s) also table 2 and table 4 show the total Heat Transfer Rate in (W). Comparative results have been done the table 5.

Conclusion

In this article the exhaust gas temperatures, velocities, and back pressure have been evaluated and verified through finite element analysis by using CFD module of ANSYS. Also, the modal analysis is performed to study the effect of geometric change on natural frequency of system. The following conclusions have been found.

- BS6 exhaust system with layer gives better results as compared to BS6 exhaust system. Without layer transmission loss of BS6 exhaust system with layer is net 17.52(k), which is more than requirement and satisfactory.
- Design and analysis of BS6 exhaust system with layer guard is done in CATIA V5 and data have been shown in the table.
- Modelling of BS6 exhaust system with layer is done with proper dimensions and as per requirement of industry.
- Actual testing has been performed by manufacturing modified exhaust BS6 and test it on the two-wheeler engine test rig for back pressure and noise.
- Dynamic analysis is carried out to determine the mode shapes and stresses and deformations in the BS6 exhaust system with layer using CFD analysis.

Table 1: Mass flow rate (kg/s).

Mass Flow Rate	Units (kg/s)
Inlet	0.53299326
Interior-part body	0.35050052
Outlet	-0.53556186
Wall-part body	0
Net	-0.0025686026

Table 2: Total heat transfer rate (W).

Heat Transfer Rate	Units (Watt)
Inlet	38541.809
Outlet	-38727.492
Wall-part body	0
Net	17.52

Table 3: Mass flow rate (kg/s).

Mass Flow Rate	Units (kg/s)
Inlet	0.5335871
Interior-part body	42.262409
Outlet	-0.53337675
Wall-part body	0
Net	0.00021034479

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None.

Conflict of Interest

None.

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