Optimization of Power and Torque with Reduction of Exhaust Noise

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Abstract- **This research paper aims an introduction to a totally advanced muffler which aims at optimizing the power and torque of engine by having a relatively lower backpressure in exhaust system compared to OEM mufflers. This is obtained by providing the exhaust gases with a calculated flow path in order to reduce the exhaust gas backpressure. This also in turn improves the sfc and efficiency of the engine. The limiting condition is that this designed muffler should satisfy the noise level norms in India and it does satisfy them.**

***Keywords*- KTM Duke 390, Muffler, Noise Level Norms**

1. INTRODUCTION

The Muffler is an important component in exhaust systems an internal combustion engine. It can be considered an acoustic noise reducing device designed for reducing sound levels.

The principle used is acoustic quieting, where the sound pressure waves are either cancelled out by distractive interference by series of resonating chambers baffles which are harmonically tuned for wave cancellation or absorbed by a sound absorbing material like glass wool or Rockwool. But there is also an side effect of using muffler as there is an increase in backpressure and reduction in engine efficiency. This is due to the compound path designed for noise reduction, which is also the exit of exhaust gases flow. Due to the increase in the obstruction of exhaust gases flow from the engine to the atmosphere, there is an increase in backpressure and hence a reduction in power. The effect of length variation on noise transmission loss is seen and the study concluded that a smaller resonator size has a better noise attenuation

2. MUFFLER CONFIGURATION

A. Baffle Type Muffler: The muffler shown in Fig. 1 consists of a baffle, or obstruction, placed in the exhaust gas flow path. The baffle/baffles obstruct the free flow of the exhaust gases. The basic principle of this type of muffler is to avoid a straight flow of gases. It has good potential for noise reduction but the loss in engine power is too high.

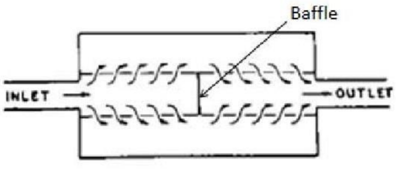

Fig. 1. Baffle type muffler

B. Wave Cancellation Type Muffler

As the name suggests, the muffler shown in Fig. 2 works on the principle of wave cancellation. Here, inside the muffler, the gases split into two paths. The length of both paths is calculated so that crests of one wave overlap with troughs of other. Due to this effect, the noise level is completely reduced to its minimum. The only disadvantage is that the noise of only one particular frequency is attenuated.

Fig. 2. Wave Cancellation type muffler

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C. Resonance Type Muffler

The muffler shown in Fig. 3 is also called Helmholtz muffler. Here, there are many ports with resonators and all these ports are connected to the main exhaust gas pipe. The main advantage is, as there is no resistance to gas, that there is very little obstruction to gas flow and thus a very little reduction of engine power.

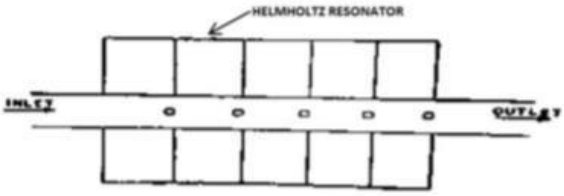


Fig. 3. Resonance type muffler

D. Absorber Type Muffler

In the muffler shown in Fig. 4, the sound is absorbed by a material which is mostly glasswool. The absorber is wrapped over the straight perforated exhaust gas pipe. The absorber gathers noise of all the existing frequencies. The advantage is that it has a very low backpressure, but it has a very low noise reduction over large frequency range.

$$D^2 = \frac{cc}{(P+3) * 25}$$

Where, D = Diameter of Exhaust Pipe
P = Length of Exhaust Pipe
CC = Cylinder Volume

Formulation

Exhaust Pipe Design of exhaust system involves evaluation of pipe diameter, length, and geometry. To control back pressure an ideal length is required to allow for reflected pressure waves to arrive back at the exhaust port in time for the valve overlap period. Changes in exhaust gas temperature throughout the engine revs results in a dynamic speed of sound, c, and therefore the optimum length can only be accounted for at one engine speed and its modes thereafter. Also, any change in geometry within the exhaust system will result in reflected pressure waves, and also

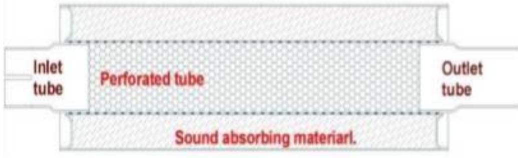


Fig. 4. Absorber type muffler

E. Combined Resonance and Absorber Type Muffler

The muffler shown in Fig. 5 is the combination of the resonance type muffler and the absorber type muffler. It combines the advantages of both mufflers, resulting in having more noise attenuation and low backpressure.

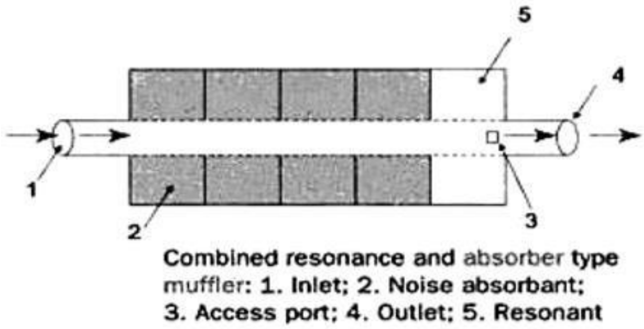


Fig. 5. Combined Resonance and Absorber type muffler

3. AIM AND PROBLEM FORMULATION

From diagrams it can be said that the absorptive type muffler is the closest to satisfy the requirement of having minimum flow restriction, but it has least noise attenuation. Therefore, the aim of the work is to design a modified type of absorptive muffler which will have a desired noise reduction and which will improve the engine brake power as well as meet the noise pollution norms. This includes the observation and study of engine brake power from 0 to 10,000 rpm of engine and the noise transmission loss over a sound frequency range from 0 to 500 Hz, for different mufflers attached to the engine. KTM Duke 390 engine is selected for this study. For simulation, this engine is modeled in Ricardo WaveBuild. The muffler is designed in Ricardo Wavebuild3D.

The analysis is divided in 3 parts:

1. Pre-processor: WaveBuild.
2. Solver: Wave.
3. Post- processor: WavePost.

significantly affect the length of the exhaust pipes. Because of the complicated nature of the scavenging effects, literature reviews often provide guideline equations which are suited to a specific engine assuming an ideal straight exhaust pipe. Two equations by Smith equation (1972) and Bell equation (1988) give estimates lengths from cylinder characteristics and expected engine speeds and are given by

$$P = \frac{ASD^2}{1400 * d^2} \text{ feet}$$

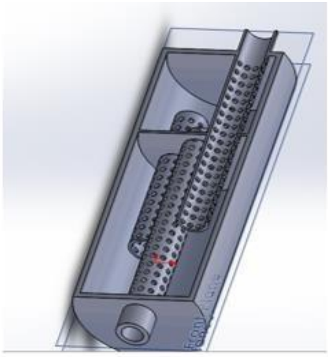
$$P = \frac{850(180 + B)}{R} - 3 \text{ inch}$$

where P represents pipe length, A is exhaust open period in degrees, S is stroke length in inches, D is cylinder bore in inches, d is exhaust valve port diameter in inches, B is the degree of exhaust opens before BDC (bottom dead centre), and R is the target rpm. Equations (1) and (2) result in pipe length estimates of 533 mm and 763 mm. respectively. So, for better result 615 mm, length of exhaust pipe is finalized. At low engine speeds, high exhaust gas velocities are necessary to achieve quick throttle response. By means of conservation of mass, a small diameter exhaust pipe will result in higher gas velocity, conducive to throttle response for acceleration. However, without sufficient cross sectional area, small diameter pipes may limit the mass flow rate needed to expel all combusted gases at higher rpm. Therefore, a compromise must be met to sufficiently provide high velocity flow with proper flow rate at peak engine speeds. Using tabulated data from Bell equation (1988) which accounts for both gas velocity and mass flow rate, a pipe diameter of 1.6 inch. It was found to provide sufficient flow for engine speeds up to 8,000 rpm.

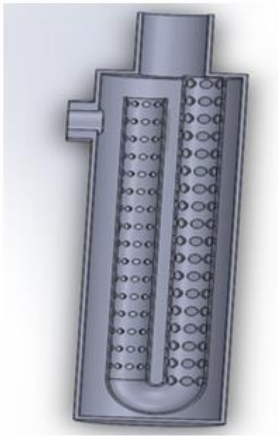
Parameter	**Description**
Shape	Cylindrical
Diameter	100 [mm]
Length	350 [mm]
Absorptive material	Glasswool

4. DESIGNING WAVEBUILD MODELS

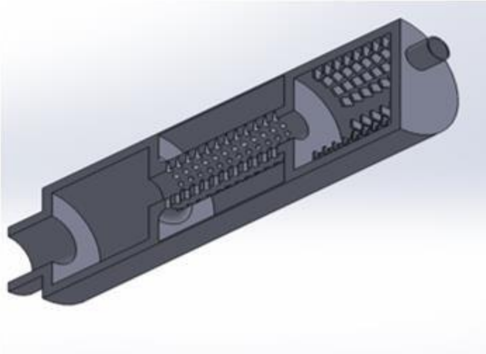
a) Absorbing with reflective type muffler:



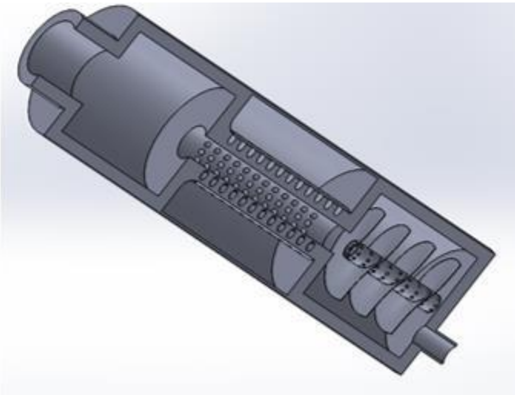
b) Absorbing type muffler:



c) Absorbing type muffler with baffle plates



d) Absorbing and resonating type muffler: e)



DESIGNING WAVEBUILD MODELS

There are two important parts; the first is to design the complete engine system (for tests related to measuring power of engine) and the other is to design acoustic and noise simulations environment (for tests related to sound measurement) in Ricardo WaveBuild software. The following sections will give detailed information about the steps to design each one of them.

WAVEBUILD MODEL FOR KTM DUKE 390 ENGINE

For simulating any component related to the engine, its model has to be built in WaveBuild. WaveBuild is used as pre-processor for WAVE analysis. It is the primary step in every simulation. Here, all the parameters which are required to define the engine system, like operating conditions, intake system (throttle body, plenum, runner, fuel injector), engine parameters (bore, stroke, valve timings, port lengths, etc.), exhaust system (exhaust header lengths, muffler) are given as input to accurately simulate the required scenario. In this way, the entire model is prepared for analysis in WAVE solver. The advantages of using software over practical experiments are:

- Manufacturing costs can be avoided.
- It is easier to study the system where controlled experiments are not possible.
- Comparatively large number of iterations can be done in less time.
- It is easy to obtain and monitor various parameters like mass flow, temperature, noise level, etc.

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