DESIGN AND ANALYSIS OF AUTOMOBILE MUFFLER
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ABSTRACT
The paper deals with the design of a commercial automotive muffler, which is being used in current automobile vehicles. Initially the muffler is designed in the basic 3D modelling can be done using commercial CAD software package and can be imported into Commercial FEM software using a neutral file format. The propensity to model these mufflers relies vastly on the thermal performance of the material, impedance and the perforations. In muffler the hot gases passes through, which may affect the properties of the muffler. So we have analyzed the thermal properties of the muffler. And defines the heat transfer occurring inside the muffler. The heat flow causes the variation in the properties of the muffler.

DESIGN METHODOLOGY
The major criteria that are to be considered for muffler design are acoustical, aero dynamical, mechanical, geometrical and economic factors. The aero dynamical factor specifies the maximum acceptable back pressure through the muffler for a given temperature and mass flow rate. The mechanical criteria specify the material that is used for the fabrication of the muffler. The geometrical criterion specifies the shape.

A. Muffler Internals Design
The muffler internal constructions is mainly based on number of baffles, diameter of the pipe, length of the pipe and number of perforations. The amount of absorption materials to meet the back pressure and acoustics targets.

POSSIBLE MUFFLER DESIGNS
There are numerous types of automotive mufflers currently in the market place and described below are the key features and benefits of various muffler designs that may be found on a vehicle. The following types of mufflers have been widely tested and the general observations from such tests are described. The commercial automotive mufflers usually consist of circular or elliptical cross section. A circular shaped cross section is best suited in a vehicle as it delays the onset of higher order modes. Most formulas that are used to predict the transmission loss of a muffler assume plane wave propagation. The properties of the following designs are only valid up to the cut off frequency, where higher order modes occur. Generally for all mufflers maximum transmission loss occurs at odd multiples of a quarter wavelength.
The most basic type of silencing element that may be used for intake and exhaust mufflers is the expansion chamber. It consists of an inlet tube, an expansion chamber and an outlet tube as shown in Figure. The inlet and outlet tubes may be coaxial known as a concentric expansion chamber or offset known as an offset expansion chamber.

**MUFFLER DESIGN**

Generally an exhaust muffler is required to satisfy some basic requirements such as adequate insertion loss, low back pressure, muffler sizing which could affect the cost and durability to withstand with rough use, some considerations should be taken for an optimal muffler design.

- Mufflers with extended tube chambers are better than simple chambers.
- There might be a slight difference in insertion loss with flow reversal chambers compared to extended tube.
- The efficiency increases with no. of chambers.
- The increase in the number of chambers generally increases the insertion loss at higher frequencies but decreases it at lower frequencies.

**STEP 1: BENCHMARKING**

Engine data:
- Bore (D) = 80 mm
- Stroke (L) = 98 mm
- No. Cylinders (n) = 3
- Engine power (P) = 65 hp Max.
- RPM (N) = 3500 rpm

Allowable back pressure for muffler = 10 in H$_2$O Transmission Loss Noise target = 30 dB

**STEP 2: TARGET FREQUENCIES**

To find fundamental frequency
- Cylinder firing rate (CFR) = Engine Speed in RPM/120 (4 stroke) = 3500/120
- CFR = 29.167 Hz
- Engine firing rate (EFR) = n x (CFR), where n is the number of cylinders
  - EFR = 3 x 29.167
  - EFR = 87.50 Hz

**STEP 3: MUFFLER VOLUME CALCULATION**

Volume swept by each cylinder
- Swept volume = $\pi /4 \times D^2 \times L$
  - $= \frac{\pi}{4} \times 80^2 \times 98$
  - $= 0.49$

Total Swept volume in Liters (Vs) = 1.478
- Volume to be consider for calculation
  - Volume = (n) x Vs / 2 = 0.74 Lit.

Silencer volume: Volume of silencer must be at least 12 to 25 times the volume considered.
- Volume can be adjusted depending on the space constraint.
- Factor consider is = 16
- Silencer Volume = Factor x Consider Volume
  - = 11.83Lit

**STEP 4: INTERNAL CONFIGURATION OF MUFFLER & CONCEPT DESIGN**

The diameter of the hole to be drilled / punched on the pipe is calculated by a thumb rule as given below:
- $d_1 = 1.29/ \sqrt{N}$
  - $= 1.29/ \sqrt{3500}$
  - $= 0.0218 m$
The muffler model was created in some particular dimensions like diameter of the big end and small end and the I-section of the beam and the fillet radius of the muffler and thickness of the muffler.

**THERMAL ANALYSIS**

The exhaust muffler model in CATIA it is analysed in ANSYS WORKBENCH 14.5. The thermal analysis has been made under the material and dimensional specification.

**Table : Material Properties of Muffler**

<table>
<thead>
<tr>
<th>Property</th>
<th>Units</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Density</td>
<td>g/cm³</td>
<td>7.7</td>
</tr>
<tr>
<td>Specific heat</td>
<td>J/(kg*K)</td>
<td>500</td>
</tr>
<tr>
<td>Thermal Conductivity</td>
<td>W/(m*K)</td>
<td>16.2</td>
</tr>
</tbody>
</table>

**Table : Geometrical Dimensions of Muffler**

<table>
<thead>
<tr>
<th>Entity</th>
<th>Dimensions (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Shell length</td>
<td>260</td>
</tr>
<tr>
<td>Shell Dia</td>
<td>130</td>
</tr>
<tr>
<td>Inlet pipe Dia</td>
<td>31.80</td>
</tr>
</tbody>
</table>

The Modelled muffler is Meshed using CATIA and the steady state heat flow is analysed. The analysis is done at the temperature of 50°C. Then the Steady state Thermal analysis is analysed.
Fig – Steady State Thermal analysis
The steady state thermal analysis is performed in the muffler and the results are plotted. This is observed as a result of temperature in the flow will be maximum at the end of the muffler.

**CONCLUSION**

The thermal analysis of the muffler has been assessed. The result of the simulated muffler models obtained with the use of CATIA modelling is very helpful. The following conclusion has been made from this analysis. It is observed that for a temperature inlet boundary condition in model, the gases enter the muffler and maintain the steady state heat flow. From Figure it has been observed that for a thermal inlet boundary condition in model, the exhaust from the engine enters the muffler at a particular temperature as mentioned. This also explains that the heat flux will be minimum at the initial point of the muffler and maximum at the opening.

There is increase to a magnitude in temperature as shown in figure in the expansion chamber once the exhaust gas passes through the opening.

**REFERENCE**


