Study On Noise Attenuation Of Multi-cylinder Diesel Engine with Resonative Muffler

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ABSTRACT

Man's desire for pollution free atmosphere needs control of air pollution and noise pollution. The principal sources of noise in automotive engines are intake noise, radiator noise, combustion noise, exhaust noise etc. Out of these exhaust noise is predominant and it is to be controlled. Noise pollution affects human beings physiologically and psychologically. The cardiac patient may get cardiac arrest due to excessive dose of noise for a longer period of time. In this paper one reactive muffler for a multi-cylinder diesel engine is designed and modified. More attenuation is given by making some changes in its configurations.

The Bond graph technique has been applied for the analytical results of the muffler. The modeling of acoustics and other systems are easily and logically achieved through BOND GRAPH Technique[1,2,3]. Bond graph is invented by Paynter and is a method of representation of physical system by means of symbols and lines, identifying power flow paths and lumped parameter elements of resistance, capacitance and inductance.

The Bond graph model is created by taking wave propagation in acoustic material into consideration. The analysis of Bond Graph model was carried out by using software COSMO-KGP. These results were compared with the experimental results and are found to be in close agreement.

KEYWORD

Bond Graph, Resonative Muffler and Transformer

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NOMENCLATURE

BSFC	Brake Specific Fuel Consumption
C	Compliance
db	Decibel
e	Effort
f	Frequency
f_1	Flow
GY	Gyrator
I	Inertance
P	Parallel Junction
S	Series junction
SE	Source of Effort
SF	Source Flow
SF1	Mass flow rate of exhaust gas measured by activated C element
SPL	Sound Pressure Level
TF	Transformer
ω	Angular Velocity
r	Resistance
t	Time

INTRODUCTION

A designer of engineering system is often perplexed when he or she embarks on designing a system, which resides in multi energy domains, which may have considerable complexities. He or she consults various domains' experts. However putting their expertise together to render a system model turns out to be even more baffling. Therefore a need for unified approach to system modeling and dynamics is deeply felt. In the present day multi disciplinary research activities, such situations are common. A programmatic and unified approach to engineering system analysis and design is the bond graph.

WHAT IS BOND GRAPH?

Bond graphs [1, 2, and 3] are pictorial representations of the essential dynamics of physical system, which occur through exchange of power amongst the basic element of the system, and its environment. Power being the common currency exchange, interactions in several energy domains can be represented in a unified manner. Complex physical ideas may be represented by modelers and designers with extreme ease. Models can be quickly synthesized and easily modified making it a powerful tool for system synthesis and consolidation of innovative ideas immensely reducing the stages and the cost of prototyping. The entire process is algorithmic and extremely suitable for implementation on computing machines.

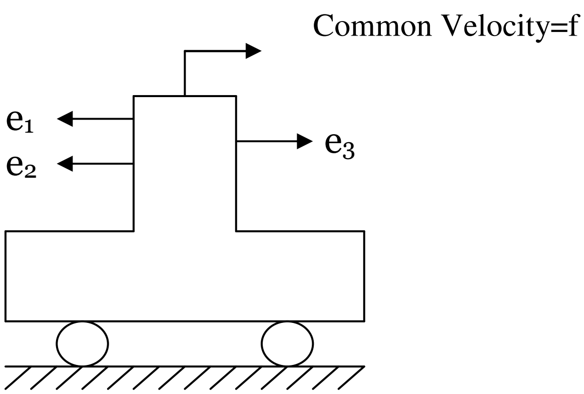
SOME BASIC BOND GRAPH ELEMENTS

In bond graph one need to recognize only four basic variables effort (e), flow (f), time integral of effort (p) and time integral of flow (q).

The basic bond graph elements consist of

1. JUNCTIONS There are two types of junctions used in bond graph viz.(a) S-Junction (1 junction) (b) P- Junction (0 Junction)

(a)S- JUNCTION shown in the following figure (Fig. 1(a))



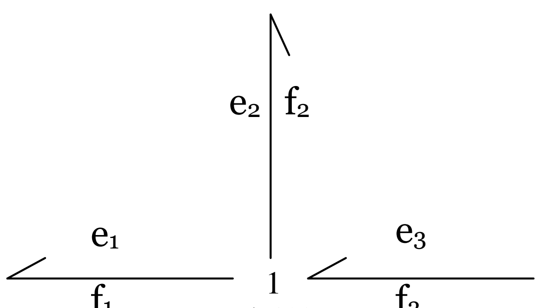


Fig1(a)

The constitutive law for this type of junction is all velocities are equal, given by $f_1 = f_2 = f_3 = f$ here the algebraic sum of powers at junction is zero, given by

$-e_1 f_1 - e_2 f_2 + e_3 f_3 = 0$ i.e. $e_3 - e_1 - e_2 = 0$

So in S-Junction algebraic sum of all effort is zero.

(b)P JUNCTION Shown in the following figure (Fig. 1(b))

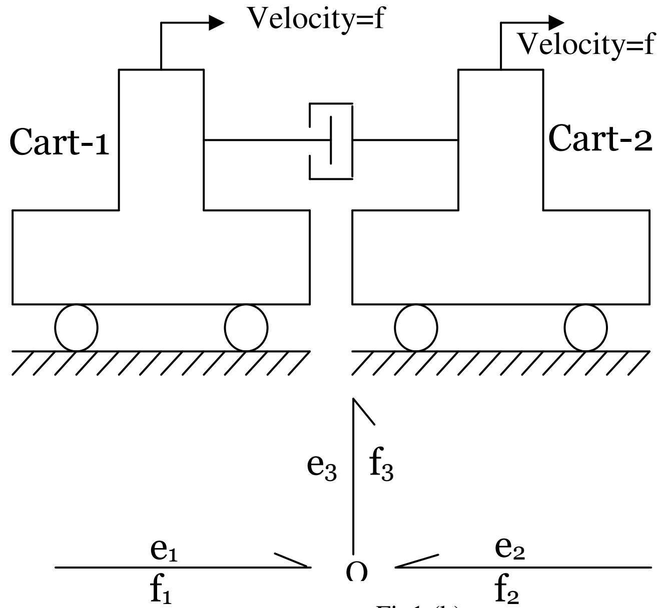


Fig1 (b)

The constitutive law for this type of junction is all forces are equal i.e. $e_1 = e_2 = e_3 = e$ (say).

Since the algebraic sum of power at a junction is zero i.e. $e_1 f_1 - e_2 f_2 + e_3 f_3 = 0$

i.e. $f_1 - f_2 - f_3 = 0$

So in P junction the sum of flow is zero.

2. TWO PORT ELEMENTS Two types of two port elements transformer and gyrator are used in bond graph

TRANSFORMER Fig 2(a)

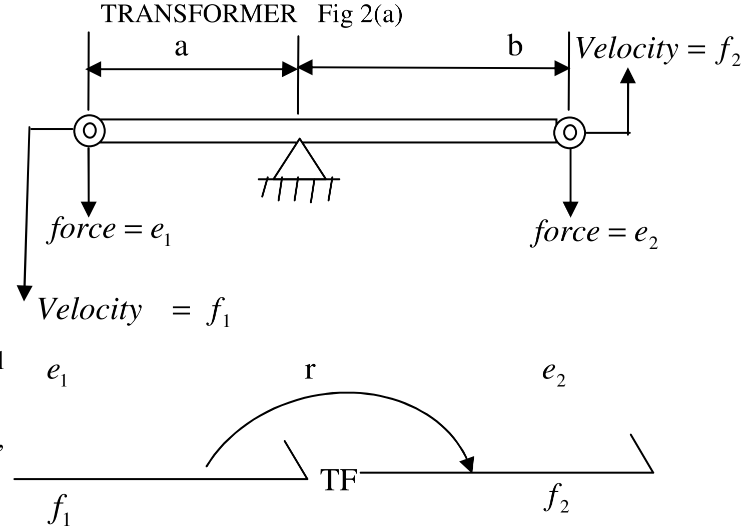


Fig 2(a)

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A mass less lever can be represented by a transformer in bond graph. The relationship between the velocities of two ends is given by $f_2 = \frac{b}{a} f_1$

Conservation of energy implies $e_2 = \frac{a}{b} e_1$ In the bond graph r denotes modulus of transformer and has a value $\frac{b}{a}$. The arrow over the TF element represents the sense in which modulus is to be used with follow $f_2 = rf_1$ and $e_2 = \frac{1}{r} e_1$. If the modulus of transformer is in terms of system variable then the transformer is called a modulated transformer (M T F).

b) GYRATOR Fig-2(b)

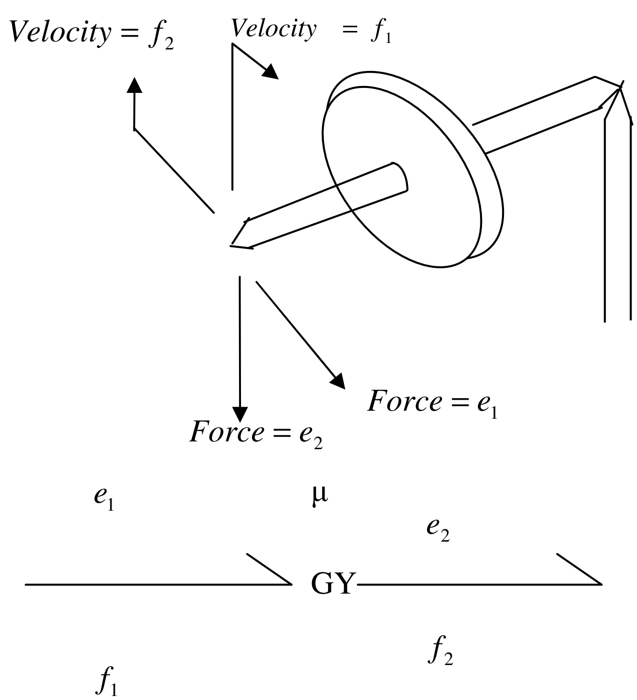


Fig2(b)

Another two port element is gyrator. It of course, conserves power, but an active bond communicates only one of these two possible signals in a single direction.

3. DIFFERENTIAL CASUALTY AND ITS REMEDY

Differential causalities occur in systems having a storage element with out integral casualty. In such cases the state variables associated with this storage element become redundant as these are now completely determined by algebraic relations from other state variables. This involves differentiation, which are computationally troublesome. Hence these should be avoided.

4. I- ELEMENT Proper casualty of the element should be determined by the constitutive law $P = \int_0^T edt$

In this relation effort is the cause and momentum (hence velocity) is the consequence.

The proper casualty is shown in the following figure (Fig- 3(a))

Fig3(a)

5. C- ELEMENT The consecutive law in this case is given by $Q = \int_0^T fdt$ or $e = k\int_0^T fdt$

Here flow is the cause and effort in the consequence.

6. R- ELEMENT

Any casualty can be assigned to this element. The constitutive laws for this case

Are $e = Rf$ and $f = \frac{1}{R} C$

RESONATIVE MUFFLER

The pictorial view of the Resonative Muffler and its bond graph model is shown in the following figures

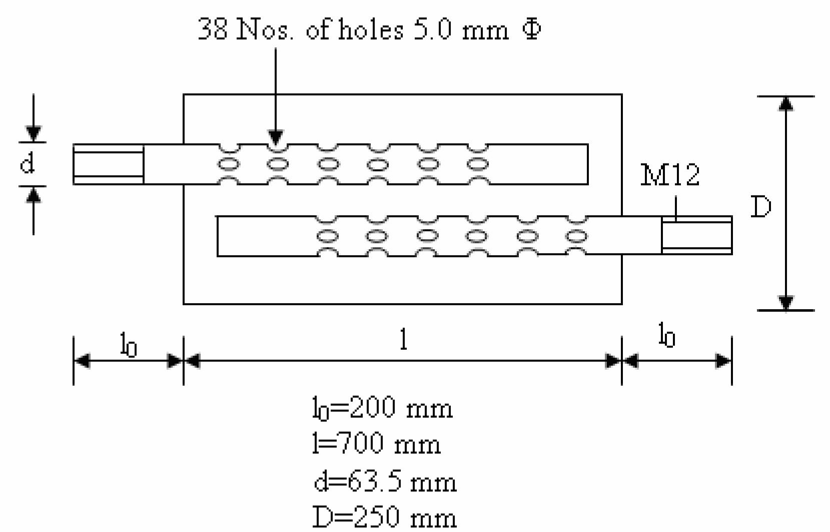


Fig.4 (a) Resonative Muffler

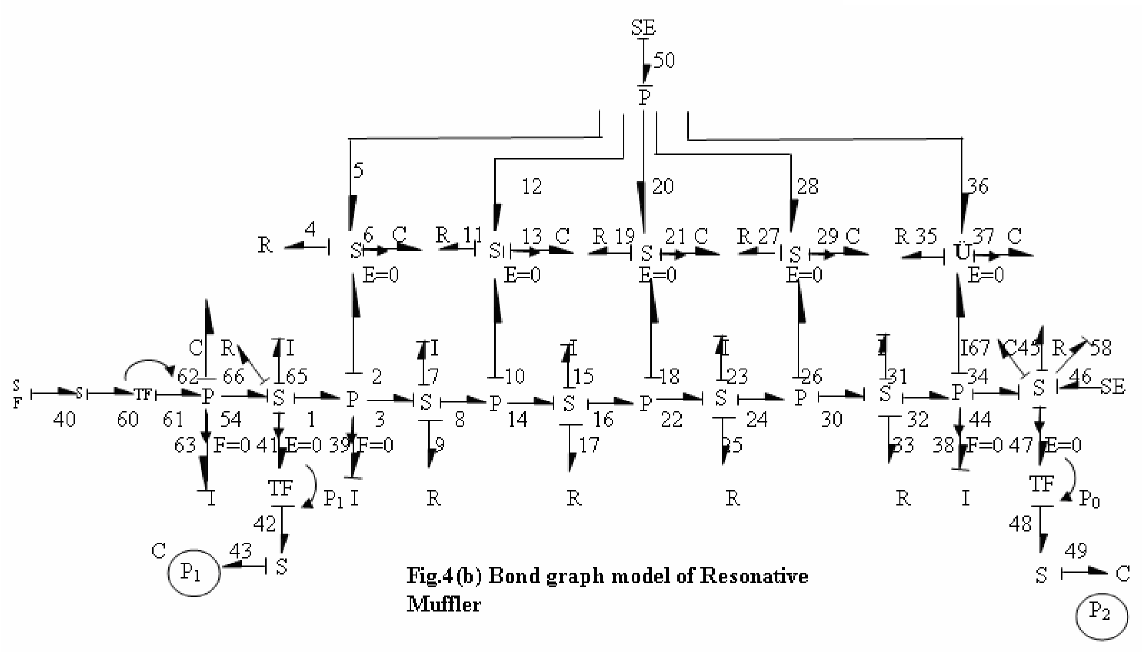


Fig.4 (b) Bond graph model of Resonative Muffler

DESCRIPTION OF THE SYSTEM BOND GRAPH OF THE RESONATIVE MUFFLER

The muffler input is the mass flow rate, represented by SF40. The mass flow rate is multiplied by inverse of density, i.e. $\frac{1}{\rho_0}$ to give volume flow rate. The volume flow rate is observed by activated I element at bond 63. As the pressure input to the muffler changes $\frac{1}{\rho}$ goes on changing. This effect is incorporated by TF60-61. This TF60-61 is modulated as $\frac{1}{\rho}$ i.e. inverse of gas density.

The inlet pipe of the muffler is represented by the junctions 5 64 66 65 41. Inertia of the inlet pipe is calculated by bond I

65 while resistance to the gas flow due to wall friction of the pipe and turbulence of the gas is represented by bond R66. The power input to the muffler is calculated by bond

C43.TF41-42 is effort activated. The TF 41-42 is modulated as input pressure to the muffler p_1 .

The schematic diagram of the Resonative muffler and its bond graph model is shown in Fig4(a) and Fig.4(b) respectively. The muffler comprise of two M.S. pipes on which equal number of holes are drills as per designed dimensions. These two pipes are inlet and outlet pipe of the muffler arranged eccentrically in the expansion chamber as shown in Fig.4(a). No baffles are provided for the support in the expansion chamber.

The inlet pipe of the muffler is joined to the exhaust manifold (pipe) of the engine. The exhaust gas entering into the inlet pipe and then to the expansion chamber. The inlet pipe extended in the expansion chamber has number of small holes drilled on the periphery of the pipe as per designed dimensions. The exhaust gas is entering in the cavity of expansion chamber through holes. These holes are working kike a Helmholtz Resonator. The gas has different paths to follow. This creates sound waves. These sound waves are entering into holes of extended outlet pipe. Some of the sound waves strikes the solid boundary of the expansion chamber and gets refracted. These refracted waves come across incoming sound waves and canceling (weakness) effect of each other. Thus sound waves get muffled. Some of the sound waves does not enter in the holes and directly passes through the open outlet pipe within the expansion chamber. These waves entering into the extended outlet pipe, through holes or through open end. Both inlet and outlet pipes are open from ends. Refer bond graph model as shown in Fig.4(b). Here inlet and outlet pipe are considered as a single pipe (coaxial) and few number of holes are taken into consideration for the simplicity of the model.

The pipe is divided into five numbers of sections. So that each section can represent a lumped parameters. Elements at junctions P (1 2 3 39) and at junction S (3 7 8 9) represent the first section. Holes in the tube are represented at junctions P (1 2 3 39) P (8 10 14) P (16 18 22) P (24 26 30) and P (32 67 44 48).

Activity of sound wave within expansion chamber is represented by junctions S (2 4 5 6) S (10 11 12 13) S (18 19 20 21) S (26 27 28 29) and S (34 35 36 37). Sound wave are striking the wall of expansion chamber and refracting back towards the holes of the pipe. This refraction is identical for all sections. It can be considered as a source of Effort in the bond graph. This source of effort represented as SE 50. Each section of expansion chamber is considered as a Helmholtz Resonator.

Activated element C6 C13 C21 C29 and C37 observe flow pattern of sound waves at particular Helmholtz Resonators. R4, R11, R19, R27 and R35 represent corresponding damping for the above mentioned compliances. The mass moment of inertia of various type of sections are calculated by bonds I7, I15, I23, I31, I38 and I39, while resistance to the flow at particular section is represented by bonds R4, R17, R25, R37.

The flow output of the muffler is measured by the activated element C45. This is the volume flow rate of the gas. This is read at junction S 67 45 68 46 47. This junction also represents outlet pipe of the muffler inertia parameter measured by I68 while R 67 gives resistance to the flow.

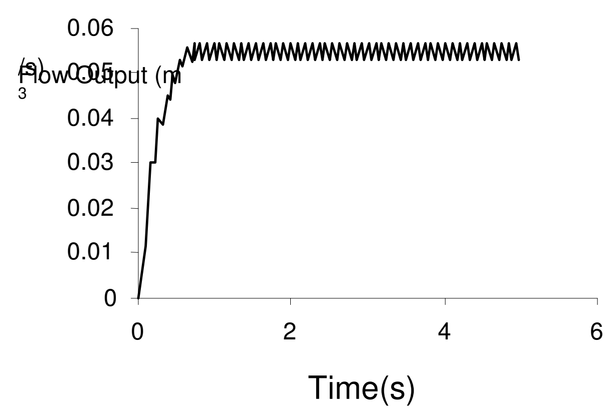
The power output of the muffler is measure at bond C49. This bond is associated with TF 47-48. This TF 47-48 is modulated as pressure output p_0

Finally the exhaust gas is going to the atmosphere. The atmospheric pressure is considered as a source of effort SE 46. SE 46 is taken as zero, as atmospheric pressure is negligible compare to the exhaust gas pressure of the engine.

RESULTS AND DISCUSSION

The bond graph model of Resonative muffler is prepared and simulated on COSMO-Kgp Package. The Fig.5 shows graph of magnitude of flow output VS frequency. The graph shows sudden rise in flow output. This is due to the natural frequency at zero modes, and then the flow output decreases smoothly. Thus the muffler has smoothened the flow.

Fig.5: Flow Output of Resonative Muffler



The Fig.6 shows FFT of impulse response of the Resonative muffler. This is a graph of magnitude flow output Vs Frequency. The attenuation at the location of the muffler is calculated by using mathematical model. This attenuation at 63 Hz, 125Hz, 250 Hz and 500 Hz are 18.025 dB, 18.025 dB, 16.47 dB, and 16.4 dB respectively.

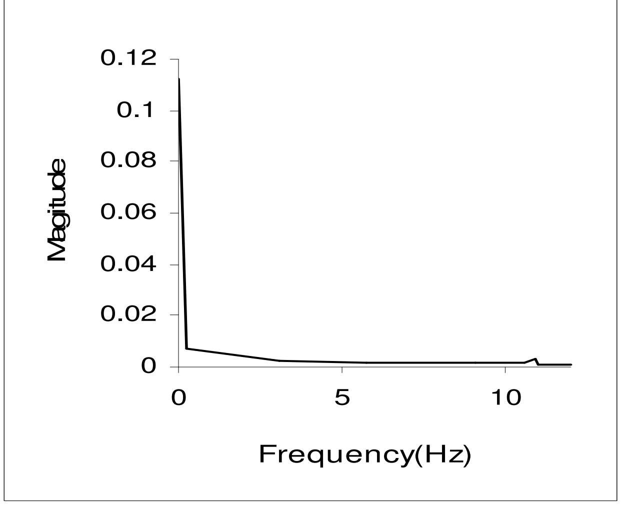


Fig.6: FFT of Resonative Muffler

Fig.7 shows the graph of Brake Thermal Efficiency Vs B.H.P. The Brake Thermal Efficiency is 26%, which is 1.5% less compared to that of the existing Resonative muffler. This is due to the complex configuration of the existing Resonative muffler.

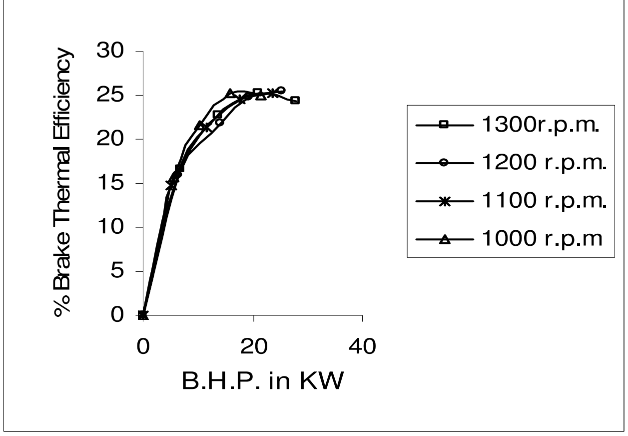


Fig.7: Brake Thermal efficiency Vs B.H.P

Fig.8 shows the graph of B.S.F.C Vs B.H.P. There is increase in fuel consumptions due to reason mentioned above. The B.S.F.C 0.24 Kg/BHP-hr. It is 5.5 % more as compare to the existing muffler. The fuel consumption increases as there is increase in resistances.

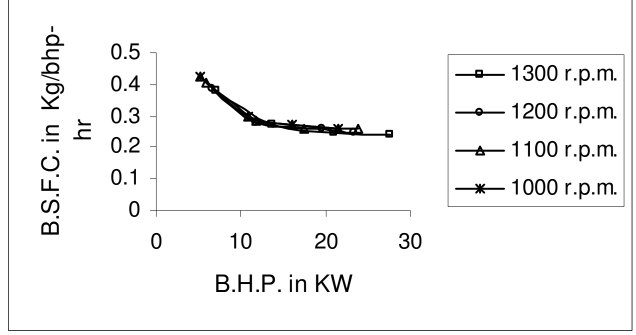


Fig.8:B.S.F.C Vs B.H.P. with Resonative Muffler

Fig.9 shows the graph of drop of pressure Vs load. As the torque increases the pressure drop increases. The increase in pressure drop affects the performances of the engine. The pressure drop increases with the increasing speed of the engine.

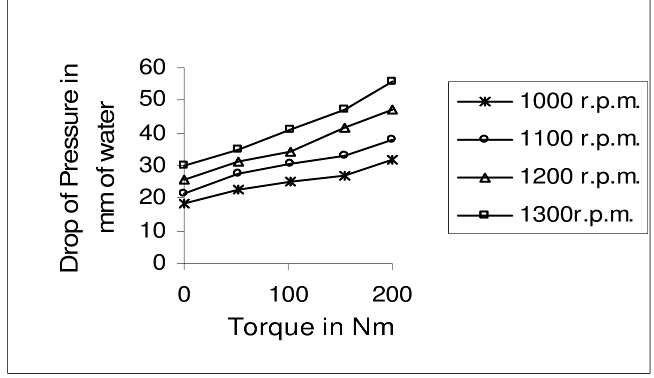


Fig.9:Drop of Pressure Vs Torque with Resonative Muffler

CONCLUSION

From results and discussion the conclusion are drawn

1. The Resonative muffler is effective at all frequencies.
2. The back pressure exerted on the engine is lower as compared to existing muffler.
3. The Brake Thermal Efficiency of the engine is somewhat low for Resonative muffler as compared to existing muffler.
4. Brake Specific Fuel Consumption is comparable with existing muffler.
5. Bond graph model of Resonative muffler is simple for simulation. the analytical results show that the muffler is more effective at higher frequencies than lower frequencies.
6. Considering the reduction in SPL and performance characteristic of the engine the designed and fabricated Resonative muffler is superior to Reactive muffler.
7. Design and fabrication of Resonative muffler is simple and cheaper than those of existing

muffler, the performance characteristic and noise level are almost comparable with existing muffler.

8. The designed and fabricated Resonative muffler can compete the existing muffler for commercial application.

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