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Design Analysis and Testing of Silencer

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***Abstract*: This paper describes predicted results of the Acoustic Transmission Loss, Insertion Loss & Back Pressure. Noise emitted from the automobiles Engines need to be controlled due to environmental concerns. Hence good design of the muffler should give the best noise reduction and offer optimum backpressure for the engine. Transmission Loss, IL & Back pressure are the important performance parameters for optimization of muffler. Design of mufflers is a complex function that affects noise characteristics, emission and fuel efficiency of engine. Therefore muffler design becomes more and more important for noise reduction. Traditionally, muffler design has been an iterative process by trial and error. However, the theories and science that has undergone development in recent years has given a way for an engineer to cut short number of iteration.**

The muffler geometry can be optimized consequently, to attenuate or remark certain spectral components of the engine noise, according to the results expected. Then modify the muffler design by increasing the no. of holes on the baffle plate or by some other means. In particularly 1-D GT-Power Simulation tool has been applied to predict the muffler behaviour in time & frequency domain. In this process very efficient muffler is taken for bench marking & tested for transmission loss, Insertion loss & Back pressure. These results are validated in the GT-power. Depending on the performance of this muffler the targets are set for the new muffler.

Keywords: **Silencer, Insertion Loss, Engine Noise, Backpressure.**

I. INTRODUCTION

Generally speaking there is no technical distinction between Silencer & muffler, and the terms are frequently used are interchangeable. Silencer has been the traditional name for the attenuating device, while a muffler is smaller, mass produced device to reduce the engine exhaust noise. A muffler is a device for reducing the amount of noise emitted by a machine (I C ENGINE). As the noise norms becoming more stringent, it is necessary for the entire automotive manufacturer to give more attention in the design of mufflers. Designing mufflers have been a challenging task for the designer for many years, as it is not only reducing the noise, but it also creates back pressure, which reduces the overall efficiency of engine.

II. MUFFLER USED IN TESTING

Reactive mufflers are usually composed of several chambers of different volumes and shapes connected together with pipes, and tend to reflect the sound energy back to the source, they are essentially sound filters and are mostly useful when the noise source to be reduce contains pure tones at fixed frequencies or when there is a hot, dirty, high-speed gas flow. Reactive muffler for such purpose can be made quite inexpensively and require little maintenance.

2.1 ACOUSTICAL PERFORMANCE:

2.1.1 Insertion loss:

Insertion loss is reported in units of dB. It is a measure of the true attenuation or noise reduction of a silencer. Insertion loss can be directly subtracted from the noise levels of a fan or other noise maker that the silencer is attached to achieve the resultant, quieted noise levels.

2.1.2Transmission loss:

It is defined as the difference between the power incident on the muffler and that transmitted downstream into an anechoic termination .It is independent of source and presumes an anechoic termination at downstream end. It describes the performance of muffler.

2.1.3Back Pressure:

This represents the extra static pressure exerted by muffler on engine through restriction in flow of exhaust gases. Higher Back pressure can cause decrease in engine efficiency or increase in fuel consumption, overheating, and may result in a complete shutdown of engine.

III. MUFFLER DESIGN METHODOLOGY

***Step 1: Benchmarking*: -**The first step in any design and development activity is to set a target by doing benchmarking exercise of same kind of models. The same will be applicable for the silencer here, to set a target in terms of transmission loss of same engine power models of competitor benchmarking vehicles. Based on the provided engine input data and bench mark study target for back pressure and noise are range decided.

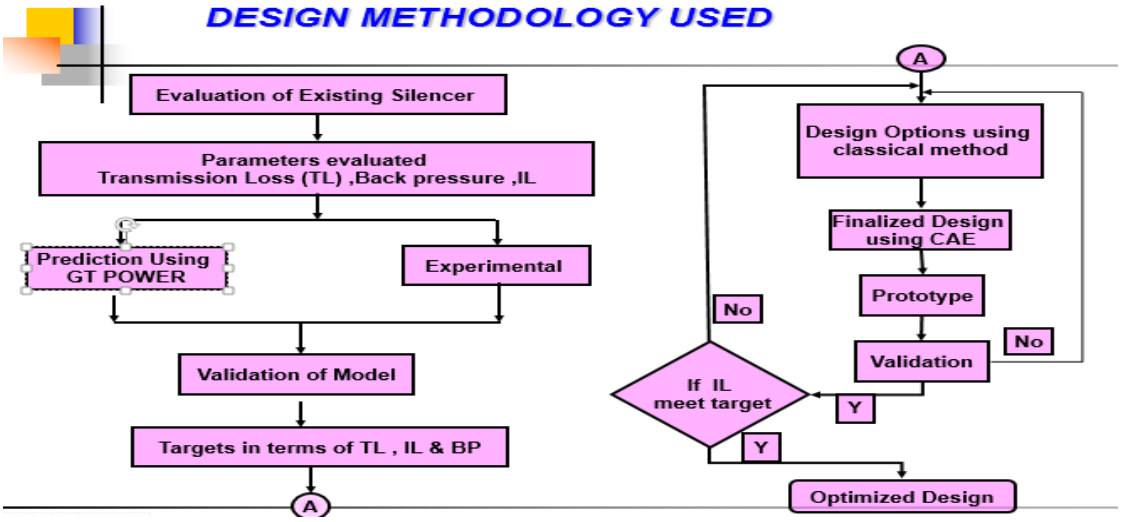

Fig 1: Design Methodology

Step 2: Target Frequencies:-After benchmarking exercise, one needs to calculate the target frequencies to give more concentration ofhigher transmission loss.

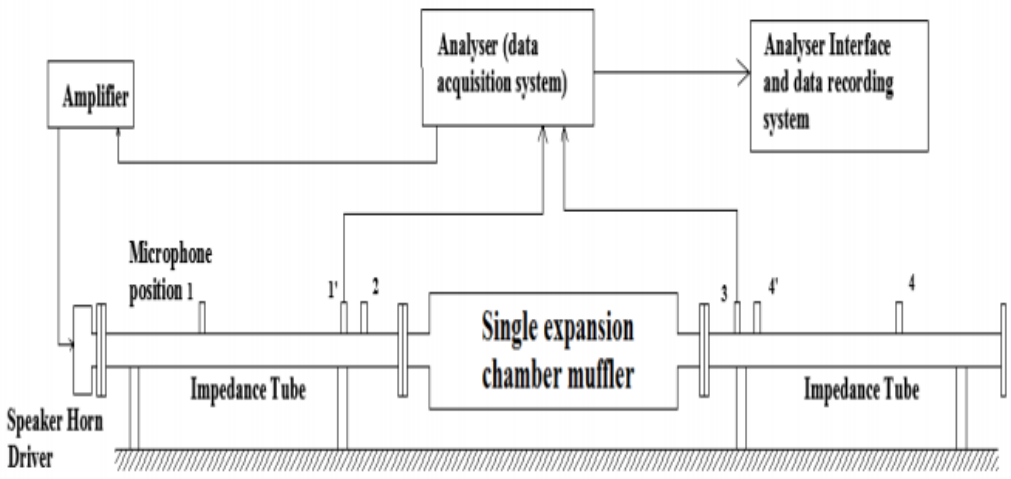

Fig 2: Experimental Setup

Step 3: Evaluation of Transmission loss & Back Pressure Experimentally:- The experimental set up consists of a speaker connected to the silencer at one end. The speaker excites the silencer cavity using a random noise generator. Two microphones were placed at the upstream and downstream tubes of the silencer. The microphones are used to convert acoustic signal into electrical signal. A multi-channel data acquisition system was used to acquire the acoustic transfer functions between the two microphones. The noise signal is amplified by the amplifier & then given to muffler. At the downstream end of muffler the noise signal is terminated anechoic ally so that no reflection of pressure takes place as shown in Fig.2.

***Step 4: Virtual Simulation, Building Gem3d Muffler*: -** Modelling the geometry in GEM3D Different objects are available in GEM3D like pipe, shell, baffles, orifice, which help in creating the muffler geometry

***Step 5: Transmission Loss Analysis*:-** Prediction of transmission loss virtually is an important analysis required for the development of muffler at an initial design stage. There are different software packages available in market for predicting the transmission loss. We have used virtual lab for Transmission loss measurements. It is also to be noted the limitations of the CAE tools, as the co-relation at higher frequencies is difficult since the plane wave theory holds good only up to 3000Hz beyond which the wave is no more 2 dimensional but 3 dimensional for which the computations are far complex to match the practical results.

***Step 6: Prototype Manufacturing*:-** All the above stages combined with the packaging of the engine evolve the design of the prototype muffler and those; can be taken up for manufacturing.

Following are some of the important manufacturing considerations summarized based on experience: There should not be any leakage of gas from one chamber to another.

***Step 7: Experimental Testing and Design Finalization*:-** The experimental determination of backpressure on engine and transmission loss on two source method for different concepts of verified.

IV. SIMULATION IN GT-POWER

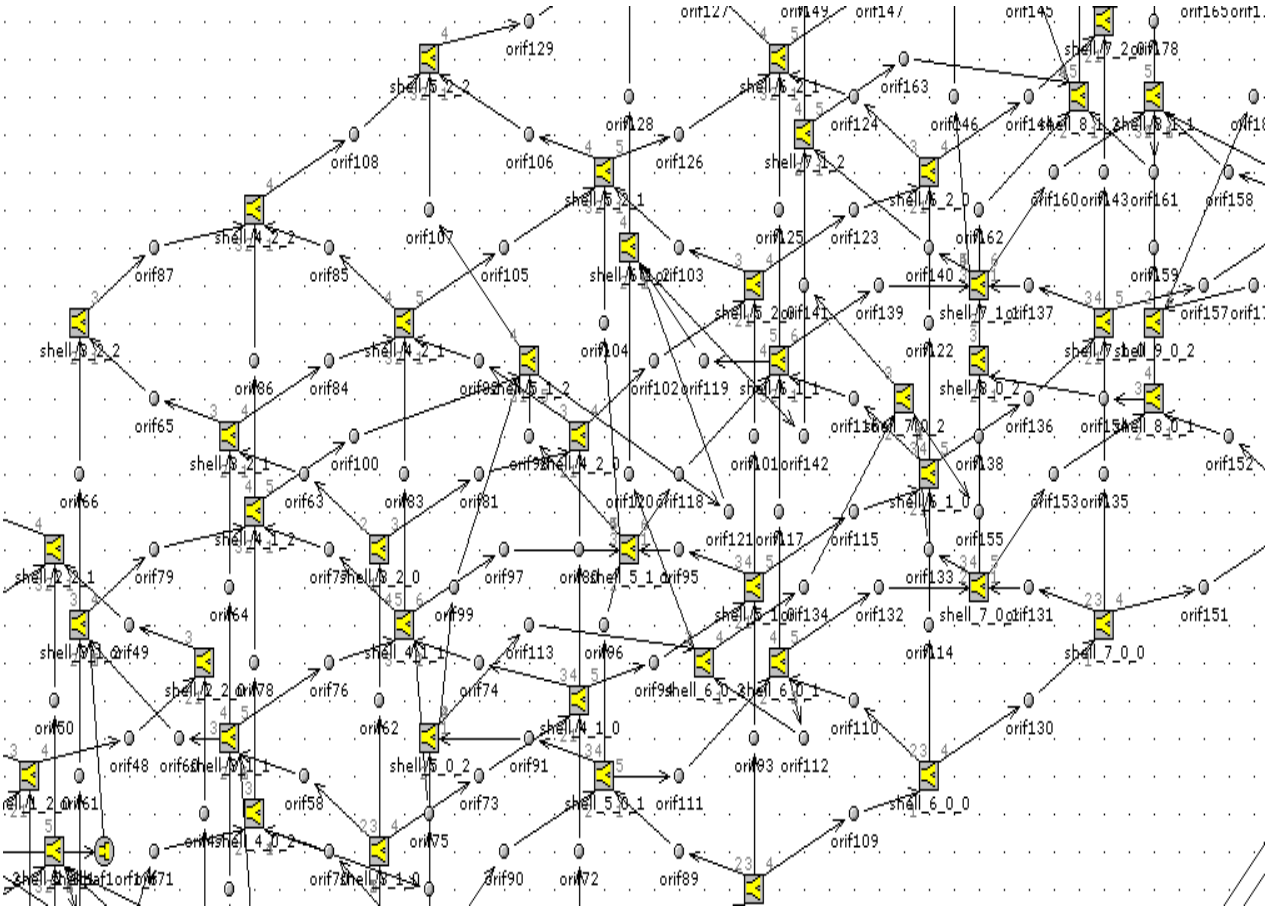

Fig 3: Line Diagram of Muffler in GT Power

The Existing bench marked Muffler has been simulated ‘in GT-POWER as per the procedure

Table 1 Comparison Of Experimental Vs Simulated in Existing Muffler

	Parameter		Existing Muffler
Muffler			
	Avg. T.L (dB)	Experimental	14.34
		Simulation	18.93
	Back Pressure (mm hg)	Experimental	75 @ 230 kg/hr
		Simulation	70 @ 230 kg/hr
	Insertion Loss (dB)	Experimental	8
		Simulation	10

There is difference of 4 dB in Transmission loss & around 2 dB insertion loss in experimental v/s GT Power results. So for improve the performance of muffler we have to design the muffler in such a way that it should consider this difference between the experimental & simulation. For getting the optimized design, now we are going to change the geometry (internal construction) of muffler.

V. OPTIMIZATION OF EXISTING MUFFLER

These are the target set for the new muffler in terms of Transmission loss. Insertion loss, Back pressure

5.1 OPIMIZATION:

1) ***Muffler (A):*** The Proposed model geometry is drawn in GEM3D Pre-processor and analysis for transmission loss, Insertion loss, Back Pressure. In this model geometry consist of three baffles like the existing one, except changing the distance of two baffles.

2) **Muffler (B):** The second model was checked by changing the orifice diameter of the baffles. But the baffle distance is same as above. Increase the diameter of the orifice baffles.

3) ***Muffler (C):*** The following changes have been made in this model. Changing the orifice locations; Hole at the centre in the first & third Baffle, second baffle remain unchanged

4) ***Muffler (D):*** In this Geometry Perforations have been done in all three baffles. Perforation Of 8mm of 30 holes in all three baffles .Perforation is decided from the literature survey during the project. But the Baffles distance is same as existing muffler.

5) ***Muffler (E):-***In this geometry, pipes are used in place of baffles. Perforation is done in pipes. The main aim of this geometry is to reduce the back pressure. The overall length & thickness of the pipe & shell are same.

Transmission loss values are good, Back pressure, Insertion loss is also meeting the target. From the above Results it is clear that in Muffler E, we are getting the higher Transmission loss and optimum Back Pressure as compared to all other models simulated in GT-POWER. Therefore we choses it as a optimized design

VI. TRANSMISSION LOSS RESULTS

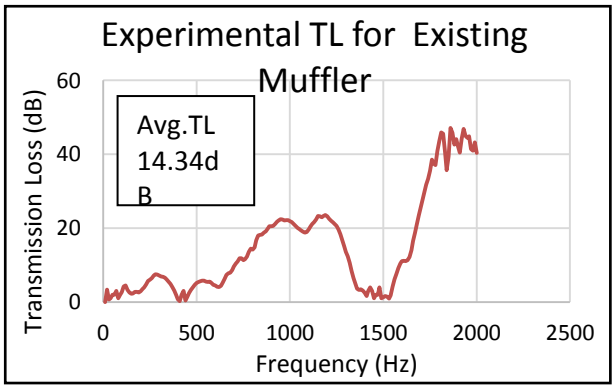

Fig 4: TL in Existing Muffler Exp.

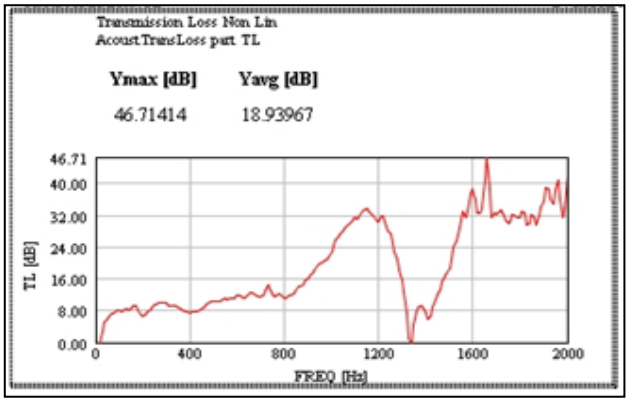

Fig 5: TL in Existing Muffler GT

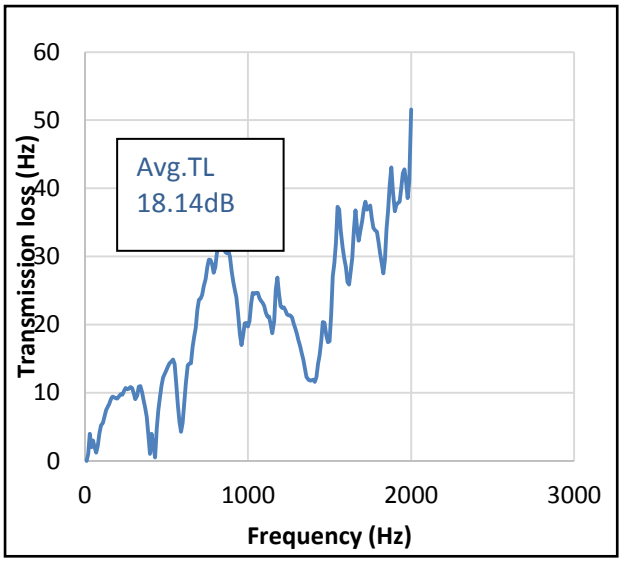

Fig 6: T L of Modified Muffler E Exp.

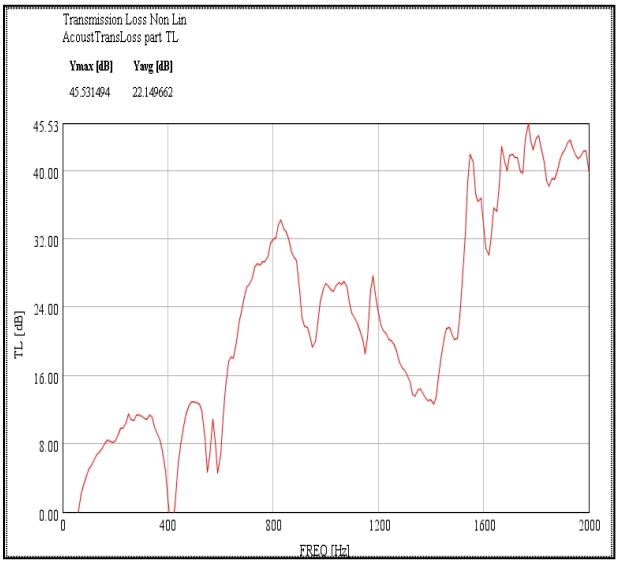

Fig 7: T L of Modified Muffler E in GT

The experimental results of modified muffler are showing good results as compare to the existing muffler. Transmission Loss in modified muffler is 18.14 dB .So Transmission loss is increased 3.8dB as compared to the existing muffler.

Table 2: Comparison of TL Of Existing Vs. Modified Muffler

Transmission Loss	Existing	Modified
Experimental	14.3	18.14
GT Power	18.93	22.14

VII. INSERTION LOSS RESULTS

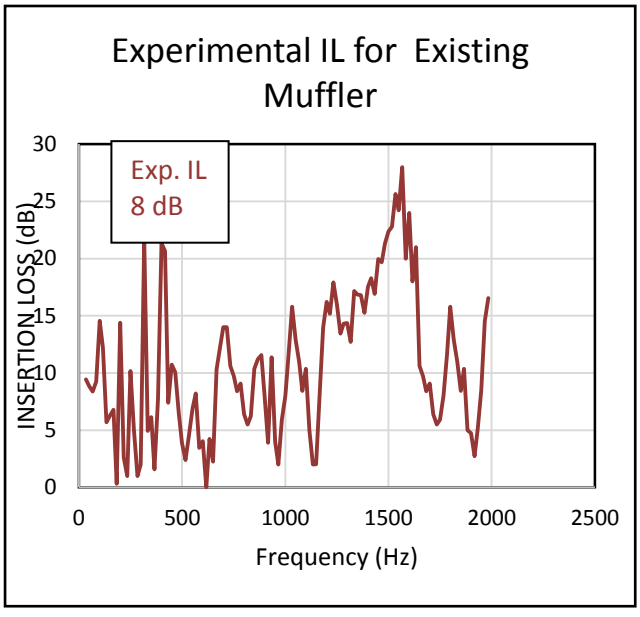

Fig 8: IL in Existing Muffler Exp.

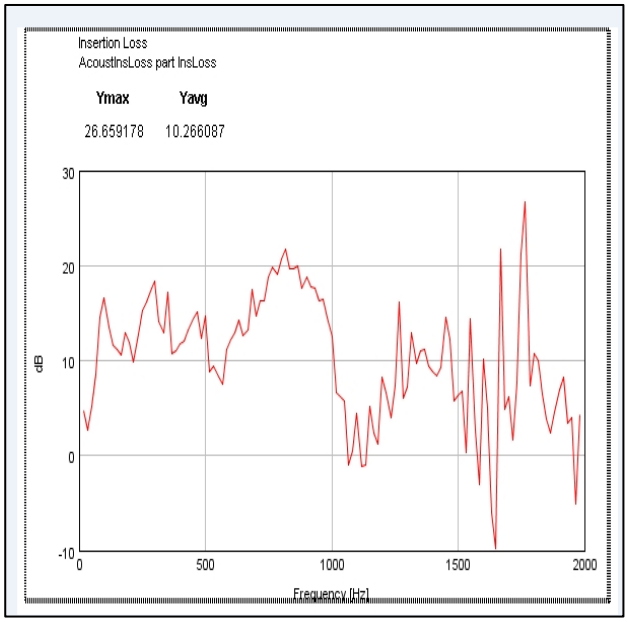

Fig 9: IL in Existing Muffler GT

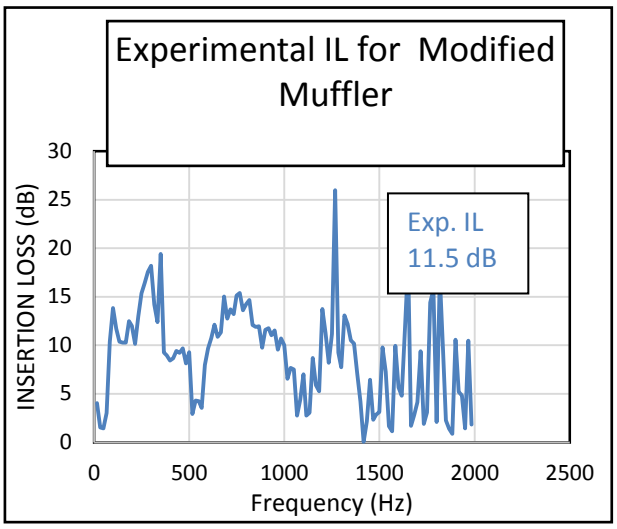

Fig 10: IL in Modified muffler Exp.

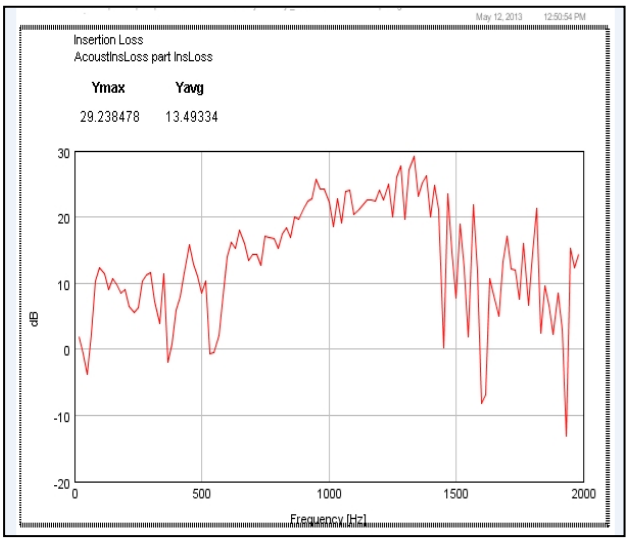

Fig 11: IL in Modified muffler GT

The experimental results of modified muffler are also showing good results as compare to the existing muffler. Insertion Loss in modified muffler is 11.5 dB .So Insertion loss is increased 3.5 dB as compared to the existing muffler.

Table 3: Comparison of Insertion Loss

Insertion Loss			Existing	Modified
Experimental			8 (dB)	11.5(dB)
GT Power	10 (dB)	13(dB)		

VIII. BACK PRESSURE

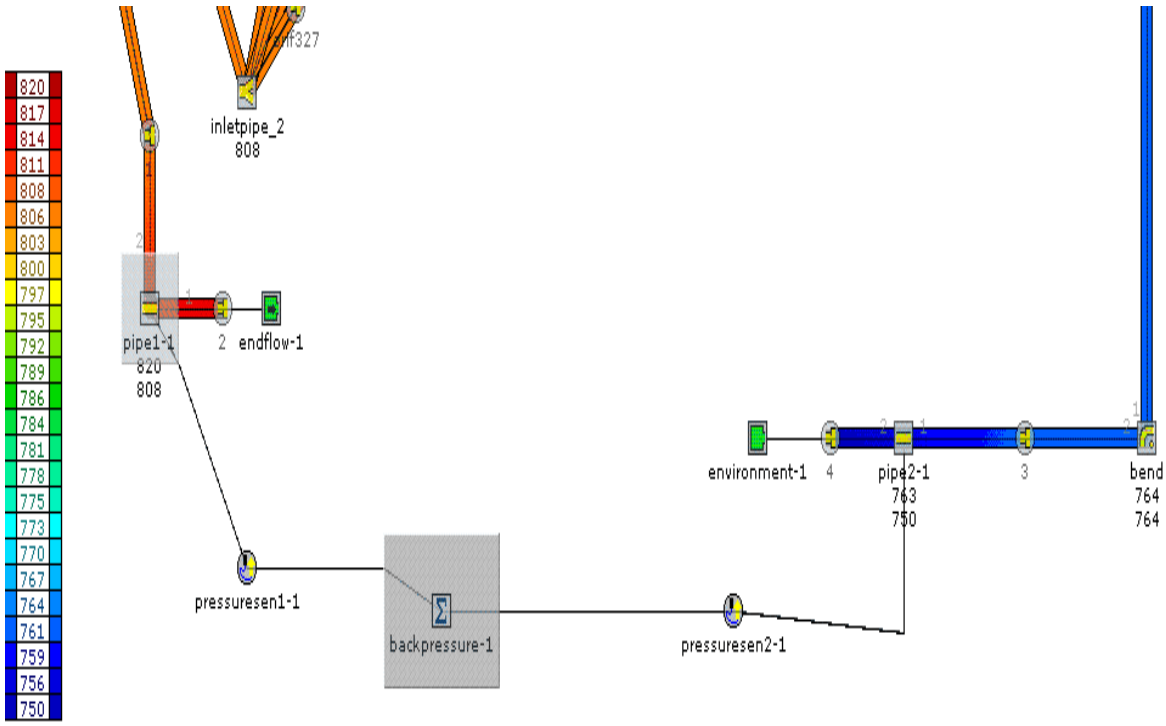

Fig 12: Back Pressure Evaluation In GT Power

This is how we compute the back pressure in GT-Power. We can vary the mass flow rate & compute the back pressure.

Table 4: Comparison of back Pressure

Back Pressure In GT Power	Existing	Modified
At 230 kg/hr	70 mm of Hg	56 mm of Hg

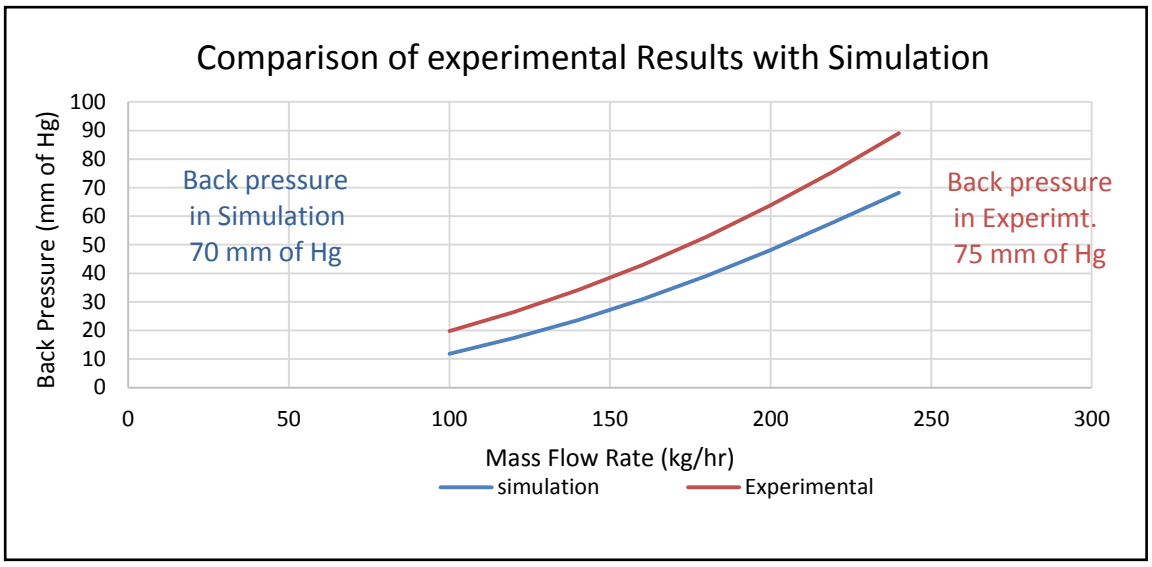

Fig 13: Back Pressure Comparison of Existing vs. Modified Muffler

Table 5: Comparison of back Pressure

Back Pressure	Existing	Modified
Experimental	70 mm of Hg	60 mm of Hg
GT Power	75 mm of Hg	56 mm of Hg

1. **Existing Muffler Drawing:**

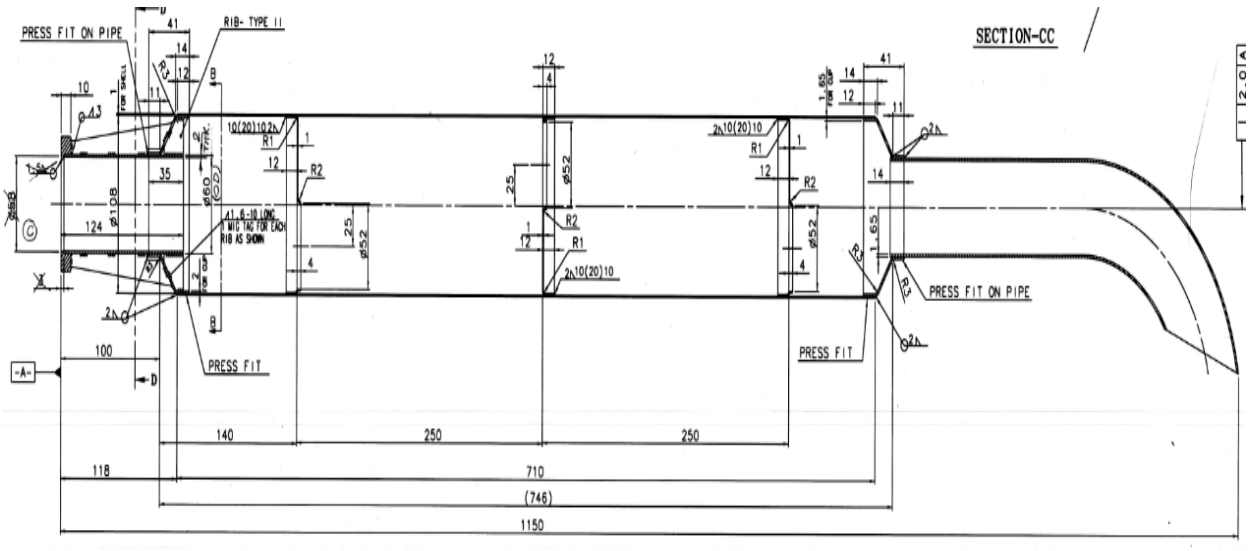

Fig 14 Existing Muffler Drawing

2. Modified Muffler E Drawing:

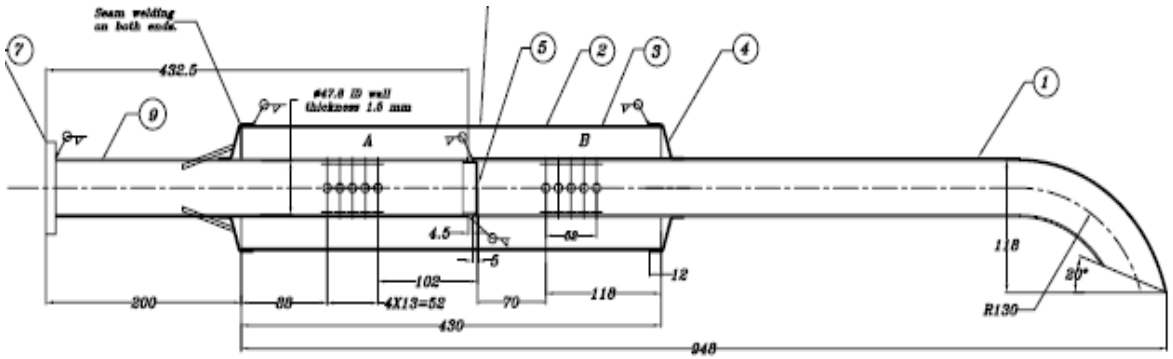

Fig 15: Modified Muffler Drawing

IX. CONCLUSION

This study emphasizes the importance of the design methodology –a practical approach from the concept design to proto manufacturing and validation of exhaust muffler. This approach serves the purpose of reducing the number of iterations, product development time and cost with Better design.

- The transmission loss in existing muffler is 14.34dB and in modified muffler is 18.14 dB Transmission loss is Increased by 3.8 dB in modified muffler.
- The insertion loss in existing muffler is 8 dB and in modified muffler, it is 11.5dB .Insertion loss is increased by 3.5dB in modified muffler E.
- Back pressure in existing muffler is 75 mm of Hg and in modified muffler it is 60 mm of Hg. BP is reduced by 15 mm of Hg

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