PERFORMANCE EVALUATION OF SILENCER BY SYSNOISE

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ABSTRACT

Internal combustion engine is a main source of noise pollution. These engines are used for various purposes such as, in power plants, automobiles, locomotives, and in various manufacturing machineries. Noise level of more than 80 dB is injurious for human being. The main sources of noise in an engine are the exhaust noise and the noise produced due to friction of various parts of the engine to reduce this noise, various kinds of silencer are usually used. The level of exhaust noise reduction depends upon the construction and the working procedure of silencer. For the present study is to investigate acoustic behavior of reactive silencer by FEM and BEM. First, the acoustic performance of simple and concentric resonator chamber is explored with FEA. Computational results obtained are compared with the experimental results available in the literature. Once these result shows good agreement with each other then this finite element analysis procedure can be used for performance analysis of silencer with perforated tubes and baffles.

Keywords: *- Silencer, Perforated tubes, Baffles, TL, FEM, BEM, SYSNOISE software.*

1. INTRODUCTION

The main sources of sound in an engine are the exhaust sound and the sound produced due to friction of various parts of the engine. The exhaust noise is the most dominant. To reduce this noise, various kinds of silencer are usually used. The level of exhaust noise Reduction depends upon the construction and the working procedure of silencer. Engine makers have been making silencer for more than 100 years. As the name implies the primary purpose of the silencers to reduce or muffle the noise emitted by the internal combustion engine. Muffler technology has not changed very much over the last 100 years. The exhaust is passed through chambers in reactive type silencer or straight through a perforated pipe wrapped with sound deadening material in an absorptive type silencer. Both types have strengths and weaknesses. The reactive type silencer is usually restrictive and prevents even the good engine sounds from coming through, but does a good job of reducing noise

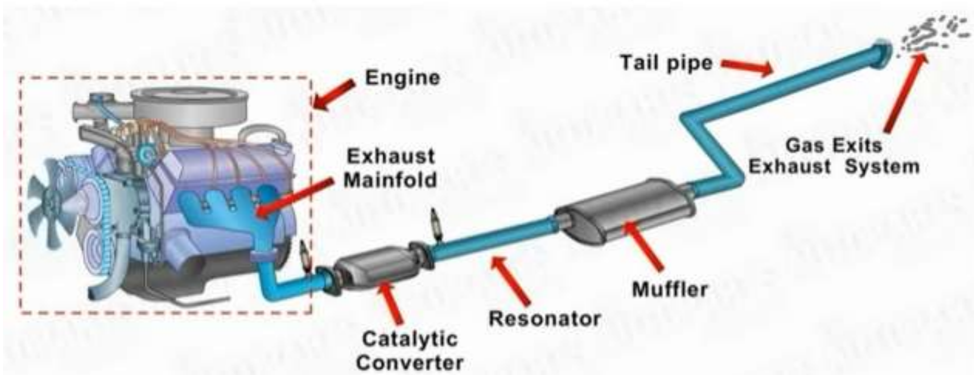

Fig-1: Exhaust System with its Components

2. MUFFLER TERMINOLOGY

1. Insertion Loss

It is defined as difference between acoustic powers radiated without any muffler and with muffler.

$$IL = L_{w1} - L_{w2}$$

$$IL = 10*\log (W_1/W_2)$$

Where, subscripts 1 and 2 denote systems without filter and with filter.

W: Acoustic Power Flux.

L_W: Acoustic Power Level.

2. Transmission Loss

It is defined as difference between power incident on muffler and that transmitted downstream into an anechoic termination.

$$TL = 20\log_{10}\left(\frac{p_{1^+}}{p_{2^+}}\right)_{p_{2^-}=0}$$

3. LITERATURE REVIEW

Advancements in the analysis and design of complex mufflers for commercial automotive exhaust system, incorporating 3D or high order mode effects which have long been anticipated by Sahasrabudhe et al.[1]

Masson et al., worked on optimize the acoustic performance of low cost, simple geometry mufflers by using micro-perforated panels (MPP) in their expansion chambers. The Transmission Loss (TL) given by a computational model is compared with laboratory measurements, both for the mufflers containing the micro-perforated panels and without them. [2]

The acoustic behavior of perforated dissipative circular mufflers with empty extended inlet/outlet is investigated in detail by means of a two-dimensional (2D) ax symmetrical analytical approach that matches the acoustic pressure and velocity across the geometrical discontinuities, and the finite element method (FEM) presented by Denia et al. [3]

A new method based on the Matrizant theory is developed for acoustic analysis of perforated pipe muffler components put forward by Dokumaci. [4]

A time domain computational approach is applied to predict the acoustic performance of multiple pass silencers with perforated tube sections performed by Dickey et al. [5].

Srinivasan et al. developed fully automatic 3D analysis tool for expansion chamber mufflers. [6]

According to S.Bilawchuk the use of the finite element method and the boundary element method to aid in acoustical engineering design is increasing rapidly. [7]

4. OBJECTIVE

The objective of the present study is to investigate acoustic behavior of reactive muffler by FEM and BEM Validation of the standard procedure for the use of SYSNOISE software. First, the acoustic performance of simple and concentric resonator chamber is explored with FEA. Computational results obtained are compared with the experimental results available in the literature. Once these result shows good agreement with each other then this finite element analysis procedure can be used for performance analysis of silencer with perforated tubes and baffles.

5. COMPUTATIONAL METHODS (FEM / BEM)

To decide whether BEM or FEM solution is more suitable for a particular problem, three factors must be taken into consideration:

1. The type of problem (linear, non-linear, shell analysis, etc.)
2. The degree of accuracy required
3. The amount of time to be spent in preparing and interpreting data.

5.1 Acoustic Analysis in Sysnoise by FEM

- Purpose of FEM Acoustics module
  - Solve the Helmholtz equation inside internal Fluid domains
- Method suited for interior noise
- Radiation application can be handled with Infinite Elements
- Acoustic modes of the fluid volume can be easily computed
- Acoustic modal response can be quickly performed when modes are present
- In FEM fluid the boundary conditions are always applied on the *FACES* of an element.
- Solvers
  - classical skyline solver
  - Krylov iterative solver (fast)
- Vibrating panels, pressure BC's, sources& FEA BC's can be defined

Principle Steps of Finite Element Application

- Model Definition:
  - Model Type
  - Meshes
  - Materials & Properties
  - Field Point Mesh
  - BC: source, vibrating panels
- Use of FEM solvers
- FEM applications
- Post processing

5.2 Acoustic Analyses in Sysnoise by BEM

- Mesh on surface only
  - field-point mesh for other results
- Direct BEM solver
  - closed geometry
  - fluid on one side: interior or exterior
- Indirect BEM solver
  - no restriction on geometry
    - open
    - ribbed
  - fluid on both sides: interior and exterior
- Surface absorbers

Principle Steps of Boundary Element Application

- Model Definition
  - Meshes

   - Model Type
   - Acoustic Properties
   - BC: source, vibrating panels
   - Advanced Boundary Conditions
- Use of BEM solvers
- BEM applications
- Post processing.

5.3 Geometry of Simple Expansion Chamber

The three-dimensional simple expansion chamber muffler is modeled in the CATIA V5R17. The muffler is subjected to a harmonic input velocity and boundary conditions were set. The acoustic performance of the muffler is then obtained using the transmission loss equation.

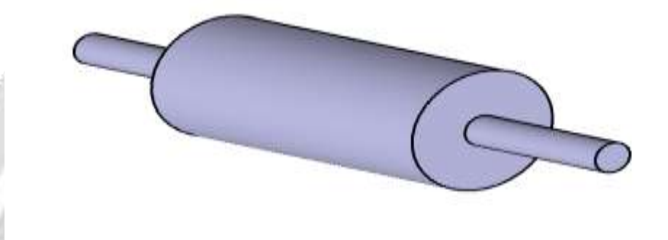

Fig-2: 3-D model of simple expansion chamber

The transmission loss of simple expansion chamber whose dimensions are (d1=d2=50 mm D=150 mm L=250 mm) is investigated by using,

a) Building the FEM and BEM Model

Following fig. show the FEM mesh created for the geometry as used by SYSNOISE and example of a BEM mesh where each dot represents a node while the lines in between the dots represent elements.

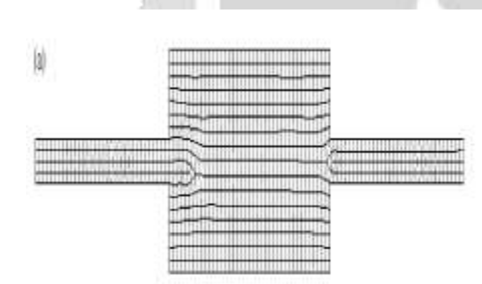

Fig-3: FE Mesh for Simple Expansion chamber

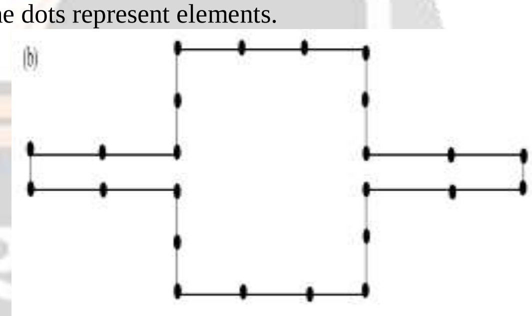

Fig-4: BE Mesh for Simple Expansion chamber

b) Boundary Conditions

To calculate the acoustic performance of the muffler using the transmission loss equation, two boundary condition cases need to be satisfied as per TMM. In SYSNOISE boundary conditions apply at inlet and outlet. At inlet we apply velocity in m/s and at outlet impedance in kg-s/m2.Transmission losses are indirectly calculated via the calculation of the transfer matrix coefficients. Calculation requires two runs with different BC.

In SYSNOISE transmission losses calculated in one step by applying following boundary condition.

1) Impose boundary conditions U1=1 , Z0=0
2) Calculate P0 and P1
3) Calculate TL from given formula

Advantage – Shorter calculation time

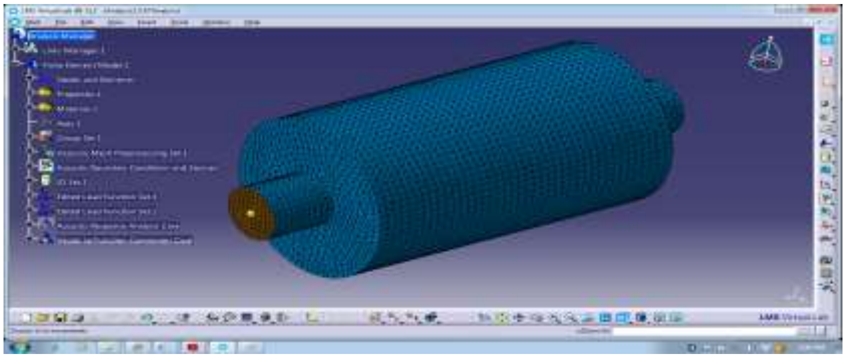

Fig-5: View of model after apply of Boundary Condition in SYSNOISE

6. VALIDATION OF COMPUTATIONAL RESULTS

1 .Comparison with A.Selamet and P.M.Randavich

This paper investigates in the details effect of the length on the acoustics attenuation performance of concentric expansion chamber.

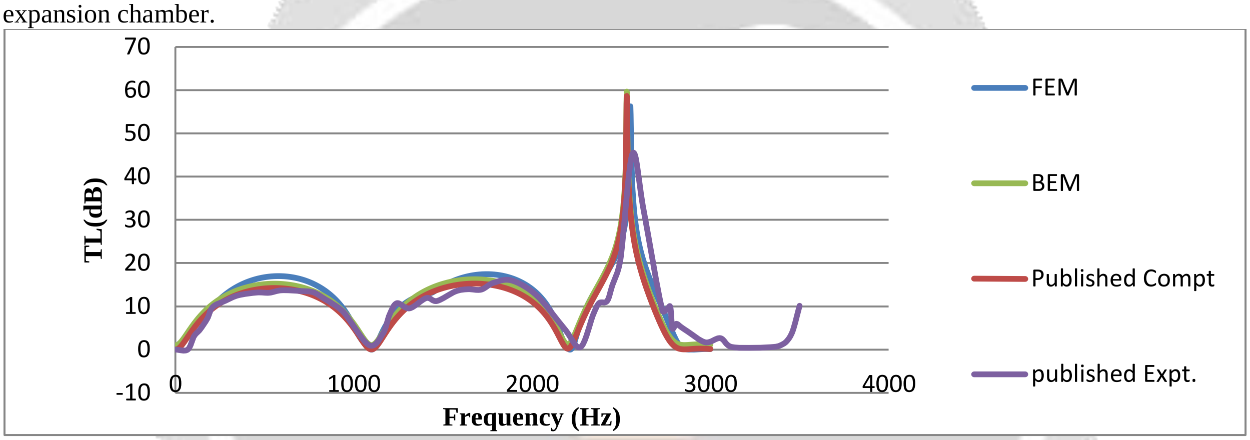

Fig-6: Comparison with published Compt. and Exp. Results (d1= 48.59mm, d2=153.18mm L= 156.89) [3]

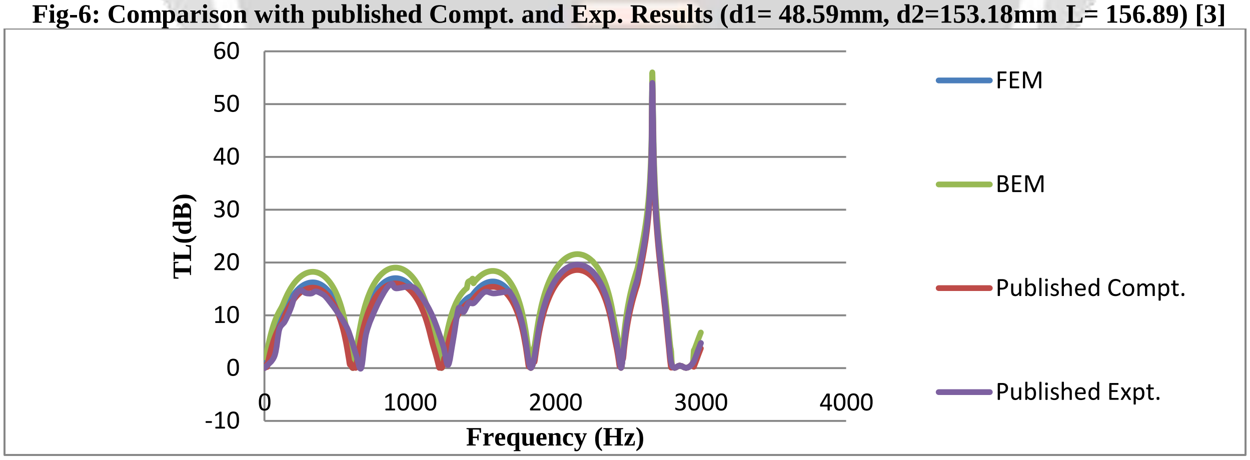

Fig-7: Comparison with published Compt. and Exp. Result (d1= 48.59mm, d2=153.18mm L=282.30mm) [3]

From the above all results it is concluded that if the length of expansion chamber increase then transmission loss also increases.

2. Comparisons with A.J.Besa

This paper investigates in details effect of the baffle radius. Three different values of the radius and two total chamber lengths are considered [3]

The FEM and BEM results show good agreement with the published FEM results of A.J.Besa.

Dual chamber muffler geometry, Radius of chamber=766mm, Radius of inlet and outlet resp.R1 and R2 =243mm, Thickness of Baffle= 1mm.

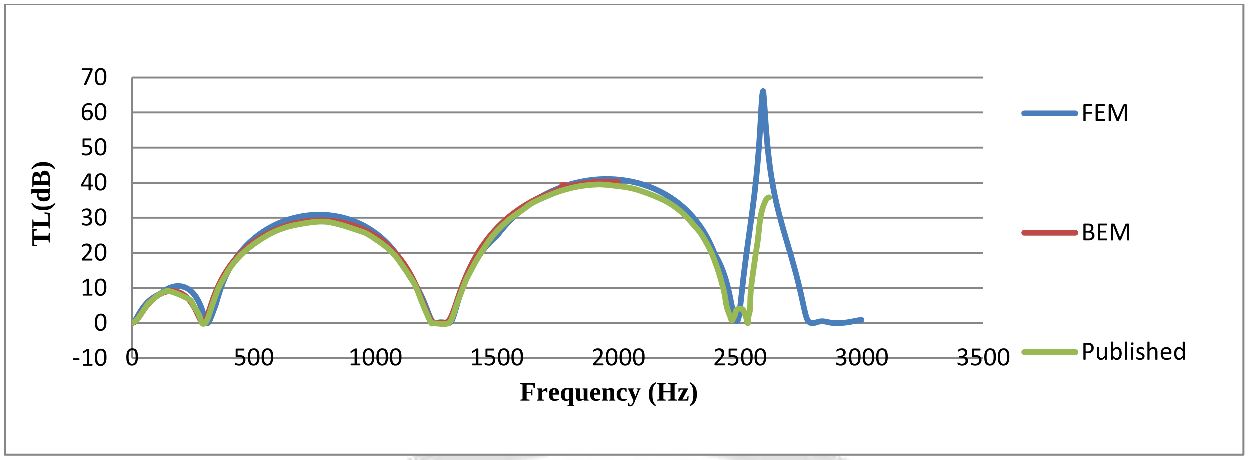

Fig-8: Comparisons with A.J. Besa for L=280mm & BR=175mm

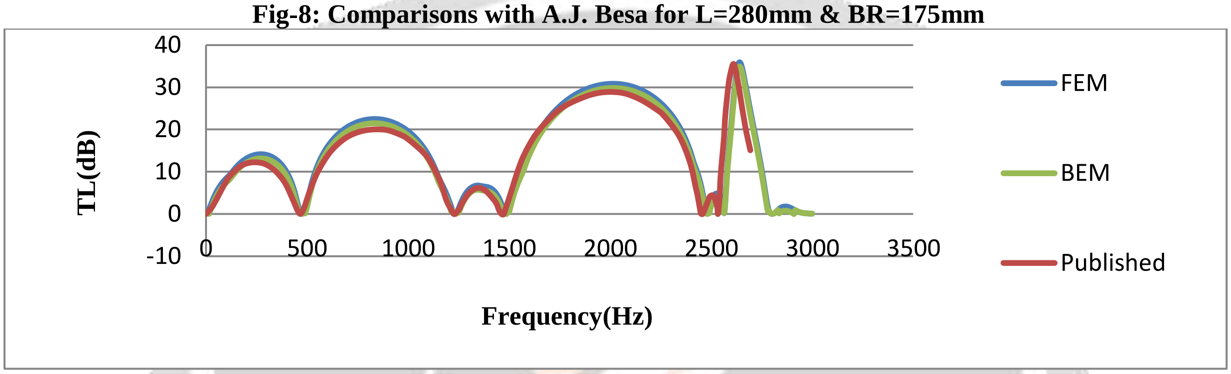

Fig-9: Comparisons with A.J.Besa for L=280mm & BR=375mm

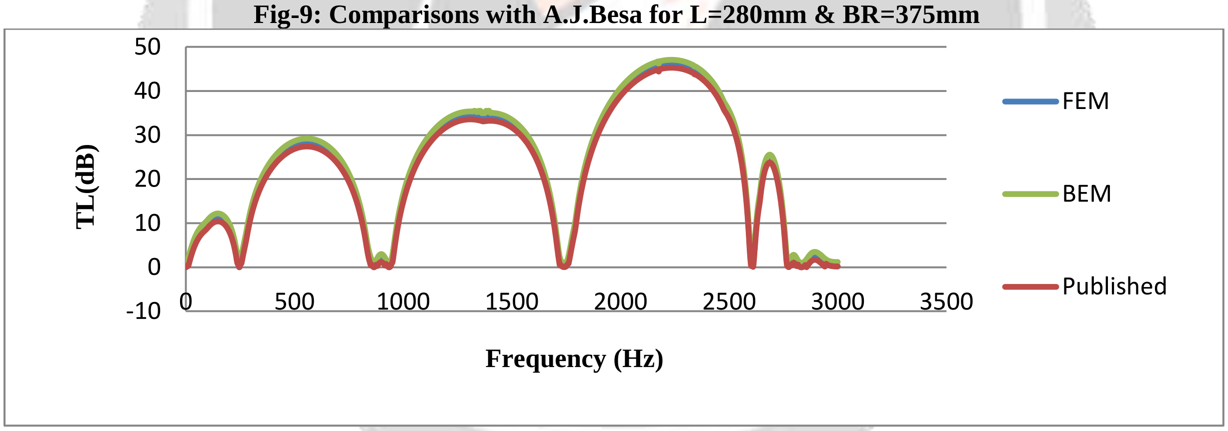

Fig-10: Comparisons with A.J.Besa for L=400mm & BR=175mm

7. RESULT AND DISCUSSION

The objective of this study is to investigate the acoustic behavior of simple expansion chamber with perforated tubes and baffle.

Fig-11: 3D View of Simple Expansion Chamber (A)

This is the base model for comparison after modification by keeping same inlet, outlet pipe diameter and length of expansion chamber.

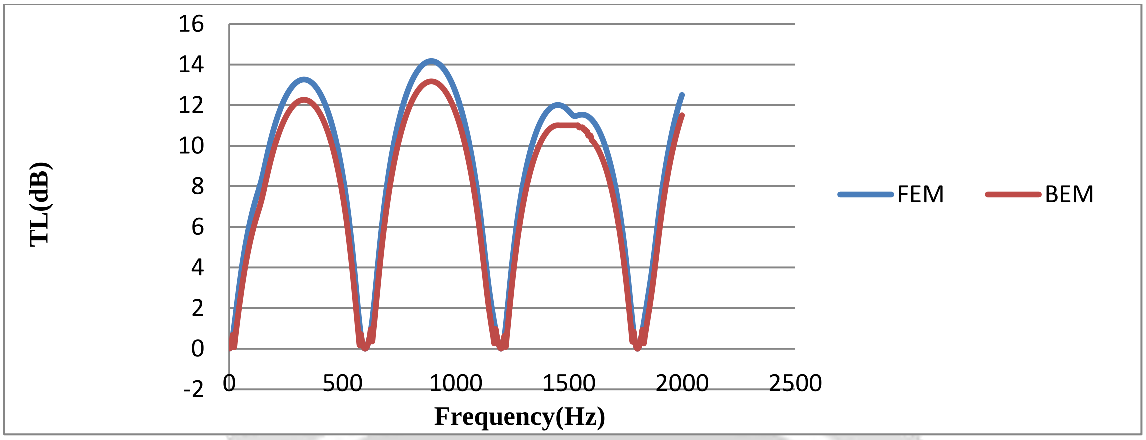

Fig-12: Comparison of Simple expansion chamber by FE and BE Method

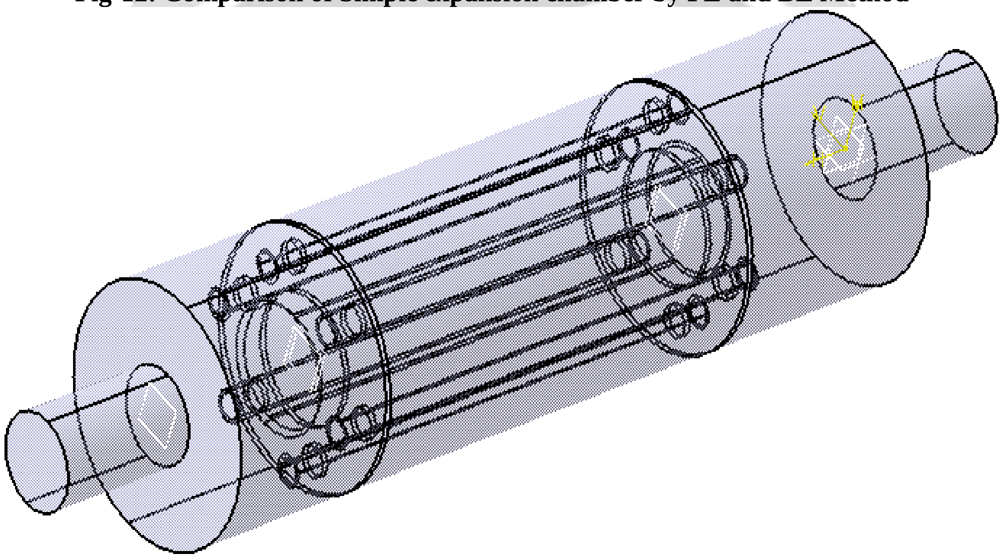

Fig-13: 3D view of modified muffler with 2 baffles and 6 pipes& 1 pipe at centre supported by baffle (B)

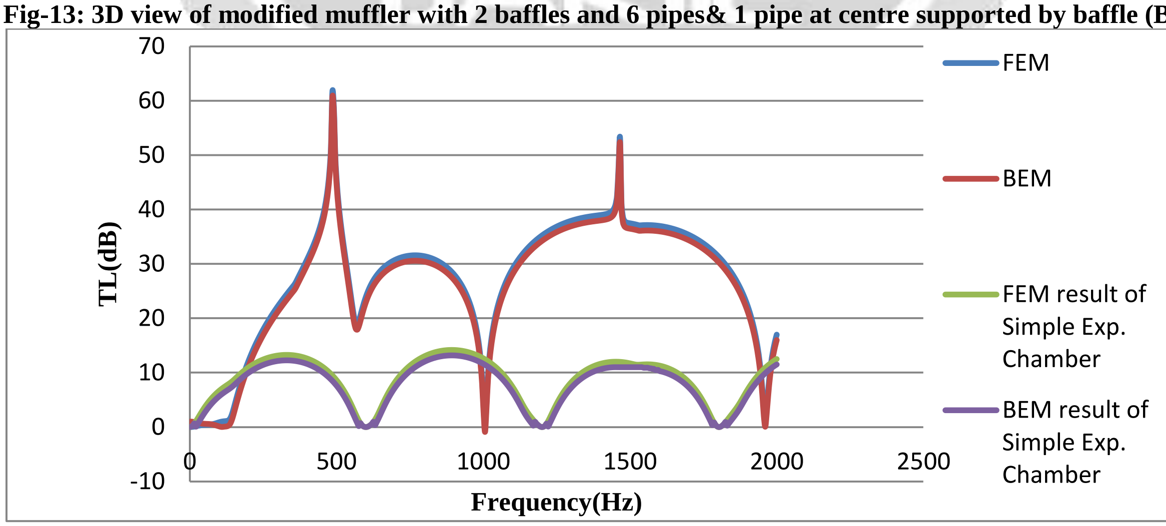

Fig-14: Comparison of model with simple expansion chamber

From the result of modified model it is concluded that if we used number of restriction in expansion chamber then Transmission loss will higher than the simple expansion chamber.

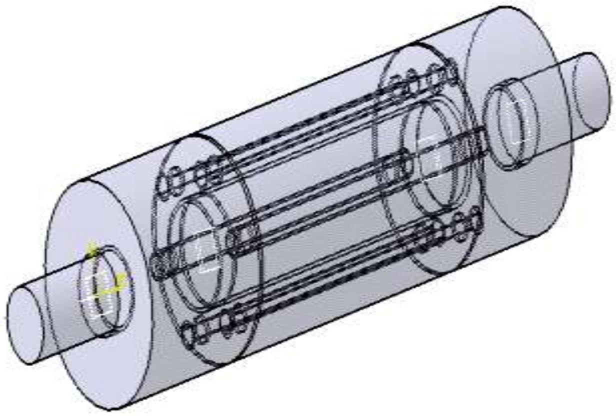

Fig-15: 3DView of modified extended inlet and outlet pipe with 2 baffles, 6 pipes and 1 pipe at centrally supported by baffles (C)

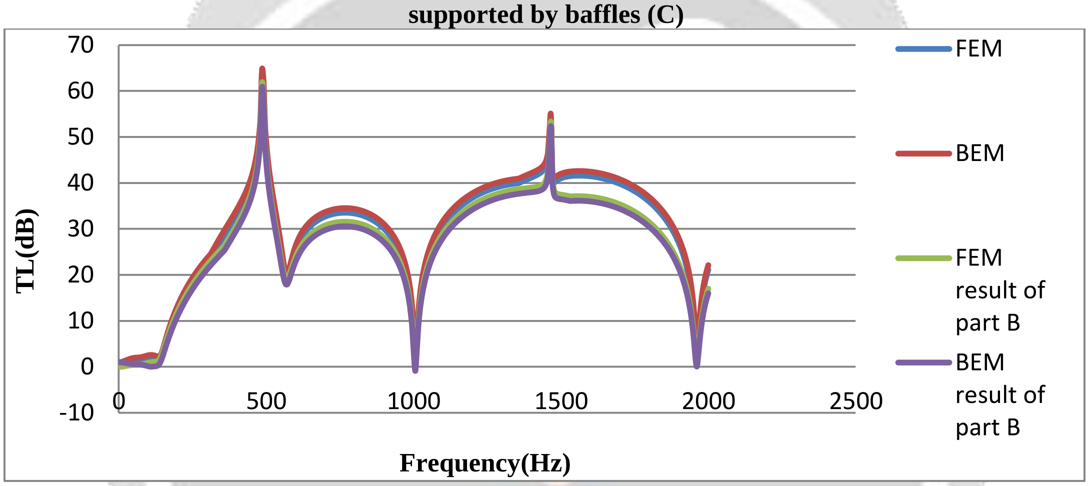

Fig-16: Comparison between parts B

From the result it is concluded that if we use extend inlet and outlet pipe then the transmission loss is slightly higher than previous model.

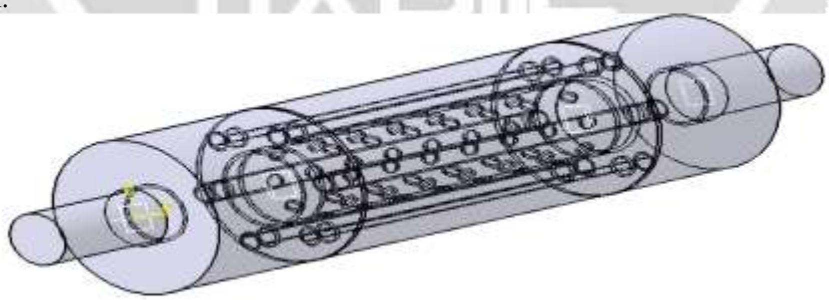

Fig-17: 3D view of muffler -Extended inlet and outlet pipe with 2 baffles, 6 pipes and 1 perforated pipe centrally supported by baffle (D)

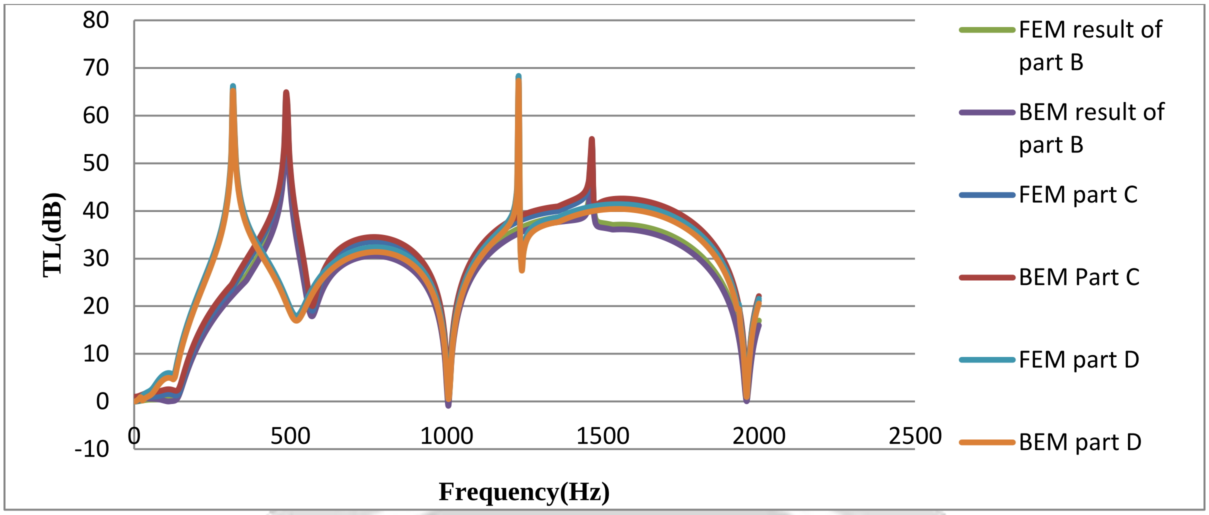

Fig-18: Comparison between part B, Part C and Part D

In the above muffler I have used perforated tube at the centre of expansion chamber also used another 6 tube of small diameter in align form and it is supported by two baffles then result check by FEM and BEM method in SYSNOISE. Result of that muffler compare with previous two mufflers (part B and part C). Fig.18 shows that if we used perforated tube then level of transmission loss as compare to other muffler is slightly higher.

8. CONCLUSION

Based on work carried out in this project, it can be concluded that the acoustic performance in terms of TL of reactive simple expansion chamber with various lengths of expansion chamber and baffle investigated computationally. The computational (FEM and BEM) result shows good agreement with experimental published results.

9. FUTURE SCOPE

For reducing computation time and storage, perforated tubes were modelled by using sub-structuring technique to facilitate the modelling of the complex perforate pattern. SYSNOISE may be used to predict the acoustic performance of mufflers with the inclusion of mean flow. Investigate the effect of backpressure on the engine due to the perforated pipes and baffles in the muffler.

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BIOGRAPHIES

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