Vibrational Analysis of Muffler

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***Abstract*: The component that reduces the intensity of the sound or decrease the intensity of the pressure pulse is called a muffler. There are various designs that are available today in market. However there are two major types of the design in mufflers. Reactive type or Absorptive two main types of mufflers that are in employed in major day to day applications. In this study we've considered the various geometries of the mufflers that have been designed using Genetic Algorithm and would study their behavior at varying frequency of 10-600HZT. In the low-frequency range, reactive damping prevails. Therefore, resistive damping is not included in the model and would suggest the best configuration in use today. The geometry is modeled Catia and the effect would be studied using the processor Ansys and Hypermesh would be used as pre and post processor and suggest the optimal design conditions and suited materials for the muffler designs.**

Introduction:

The major task of an efficient muffler is to reduce the noise emitted by the emission of the exhaust valves repeatedly opens and high-pressure waves is introduced into the exhaust system of the engine. These pressure pulses are the sound that we hear when the engine is running. The pulse repeats at the firing frequency of the engine which is defined by f = (engine rpm x number of cylinders)/120 for a four stroke engine. The frequency content of exhaust noise is dominated by a pulse at the firing frequency, but it also has a broadband component to its spectrum which extends to higher frequencies.

In general, sound waves propagating along a pipe can be attenuated using either a **dissipative** or a **reactive** muffler.

Reactive muffler basically reflects the sound waves back towards the source and prevent sound from being transmitted along the pipe.

Dissipative muffler uses sound absorbing material to take energy out of the acoustic motion in the wave, as it propagates through the muffler.

Genetic Algorithm Method (GA): A condensed description about Genetic Algorithms method is available in Charbonneau [01], and the right reference about him is mentioned in reference section as well. Hypothesize that there is a group of design parameters ν and a model that explains the parameters ν to measure a function $F(\vartheta)$ for a specific design. Now, a set of variable which maximizes the function has to be found by the optimization algorithm. The GA works as follows: at first, initialize the population fortuitously and estimate the fitness of its members, reproduce chosen members of present population to harvest offspring population, substitute present population by offspring population, estimate fitness of novel population members and reiterate until the most appropriated member of the present population is supposed suitable enough.

The general procedures of this method starts with defining a counter (K=K+1). Secondly the population of the l chromosome ϑ^1. Thirdly, compute the objective function amounts of l chromosomes F^l. Fourth step is to produce novel chromosomes by implementing competence scaling to the chromosomes, and rejoining fit parent encryptings. Fifth is deleting elements of the population to make more space for the new generations. Sixth step is estimating each novel chromosome as in step 3, and enter it into the population. Seventhly, if the ceasing criterion has been satisfied, cease and return the chromosome with the best competence, otherwise keep on with step 4.

For this particular study we've considered number of population as 500 and the number of variables as 6.

Model Building:

The model thus derived from the Genetic algorithm is modeled in Catia V5. CAD model of the present muffler which will be examined in this paper as shown in Fig. 1 the muffler consists of perforated inlet and outlet pipes and two perforated baffles. The perforate rates of inlet and outlet pipes are approximately 30% and 12%, respectively. Furthermore, the muffler has three expansion chambers. Perforated parts of inlet and outlet pipes create a cross flow inside the muffler.

Then it is meshed in Hypermesh to get the Hexa mesh. The element type assigned is Solid 45 in Ansys profile. The Element length assigned in 2.8mm, to approximate it with the real time thic ness of the muffler. . The element is defined by eight nodes having three degrees of freedom at each node: translations in the nodal x, y, and z directions.

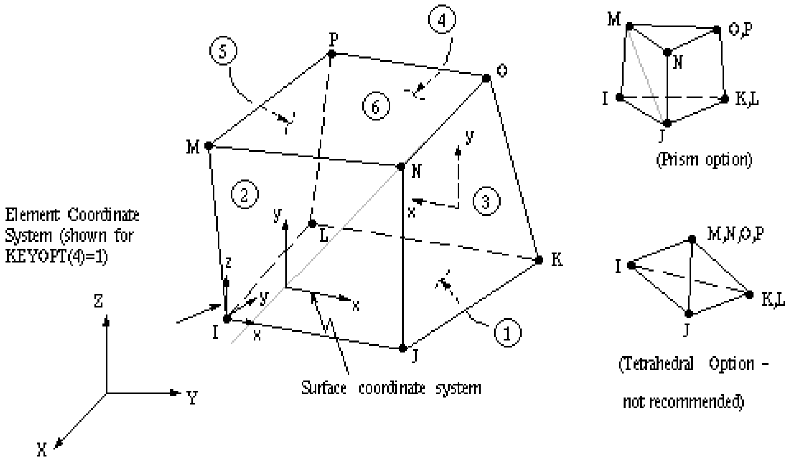
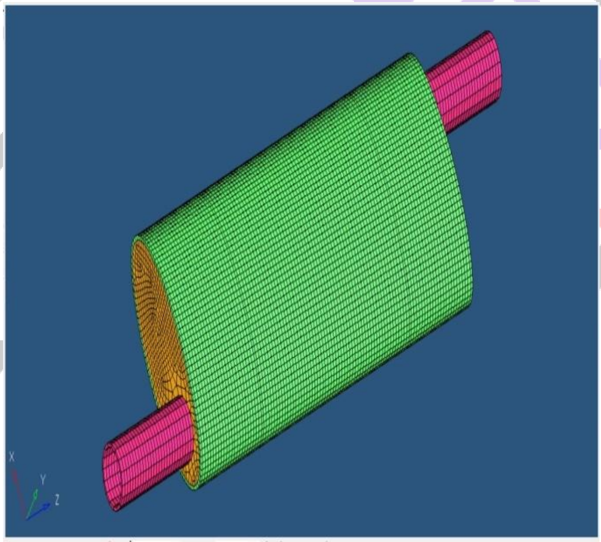
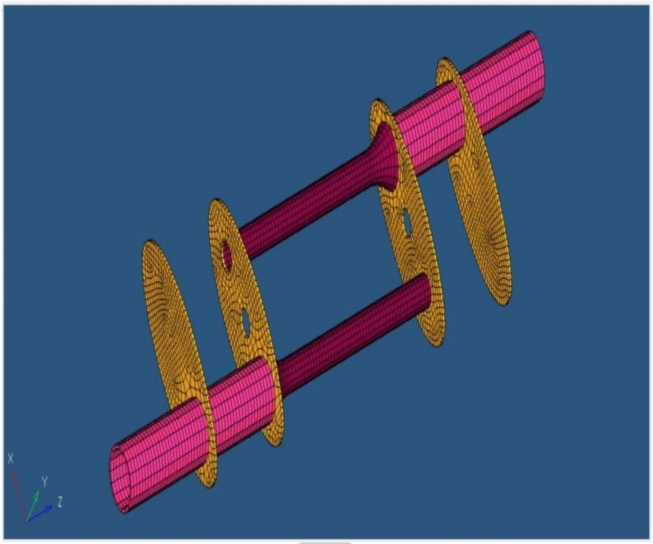


Fig 4.2: Geometry of the SOLID 45 Element.

The final meshed model in Hyper Mesh is shown. In order to minimize the complexity of the geometry the profanations in the middle of the Muffler is approximated by the filling with the Solid 45 elements so that the connectivity of the elements aren't missed.



1.3: Complete Mesh model



. 1.4: The inner Mesh of the Muffler.

For this analysis we've considered the Steel as our material for this analysis. We can see the Material properties in the below table.

Table 1. Material Properties

Properties	**VALUE**
YOUNG'S MODULUS [E]	2.1E5 n/mm2
POISSON'S RATIO	**0.3**
Density (Rho)	**7.9E-09TONNE/MM**
Mass	1.721E-3 TONNE

Results and discussion: Before we investigate or look into the modal analysis, let us see the optimum values that are derived from the Genetic Algorithm, based on which our Geometric model is molded.

Table 2: Optimized values derived from the GA.

	Inlet Length (mm)	Silencer length(mm)	Outer Length(mm)	Inlet Diameter(mm)	Silencer Dia(mm)	Outlet Dia(mm)
Optimum Values	9.98	187.68	9.98	132.94	55.24	24.94

The frequency of the muffler is taken from the range of 100 Hz to 600 Hz. We get 6 modes of vibrations in this range.

The following table gives the displacement at the following frequencies.

Table 3: Frequencies of vibrations

1	26.519	1	1
2	135.30	1	3
3	306.87	1	4
4	442.19	1	6

The above table shows 5 modes of vibrations at which the frequencies would occur. The displacements can be seen in the figure below.

Table 4 Frequencies and displacements.

Mode	Frequency	Displacement
1	26.519Hz	1.47mm
2	135.30Hz	1.605mm
3	306.87Hz	1.511mm
4	442.19 Hz	1.462mm

For 26.519 Hz the displacement is 1.47mm. The deformed shape is given in the figure below.

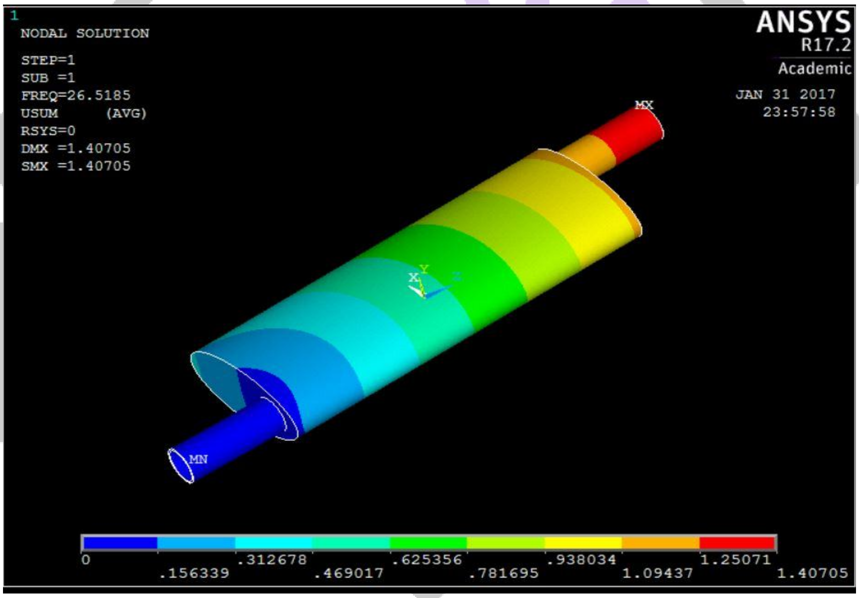


Fig 1.6 Displacement at 26.5185

The second frequency captured is at 135.30 Hz, where the displacement is 1.605 mm, deformation is shown in below figure.

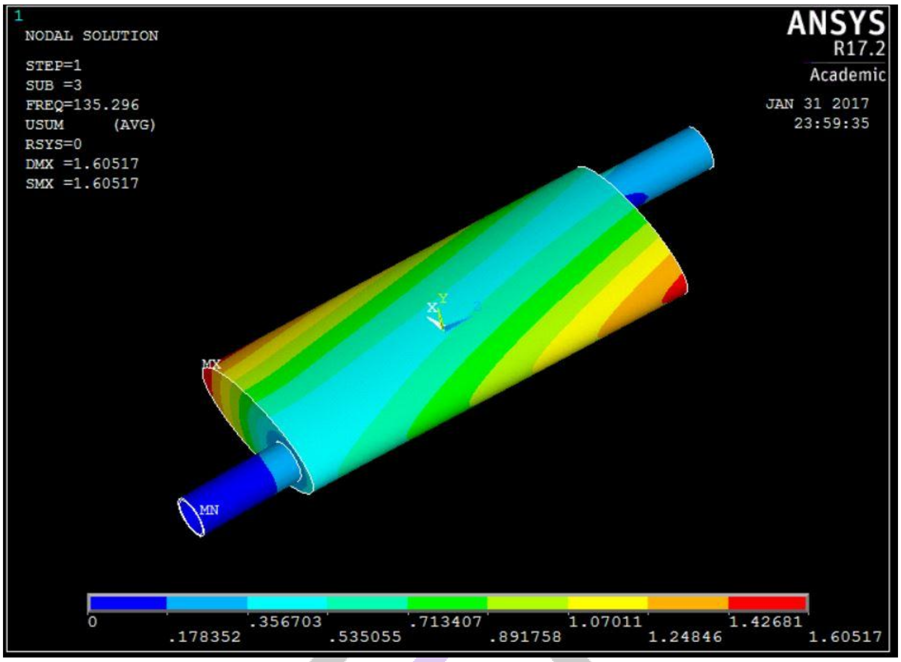


Fig 1.7 Displacement at 135.296

Third mode of vibration is at 306.866 Hz and its displacement is 1.511mm and mode of vibration is shown in the image below.

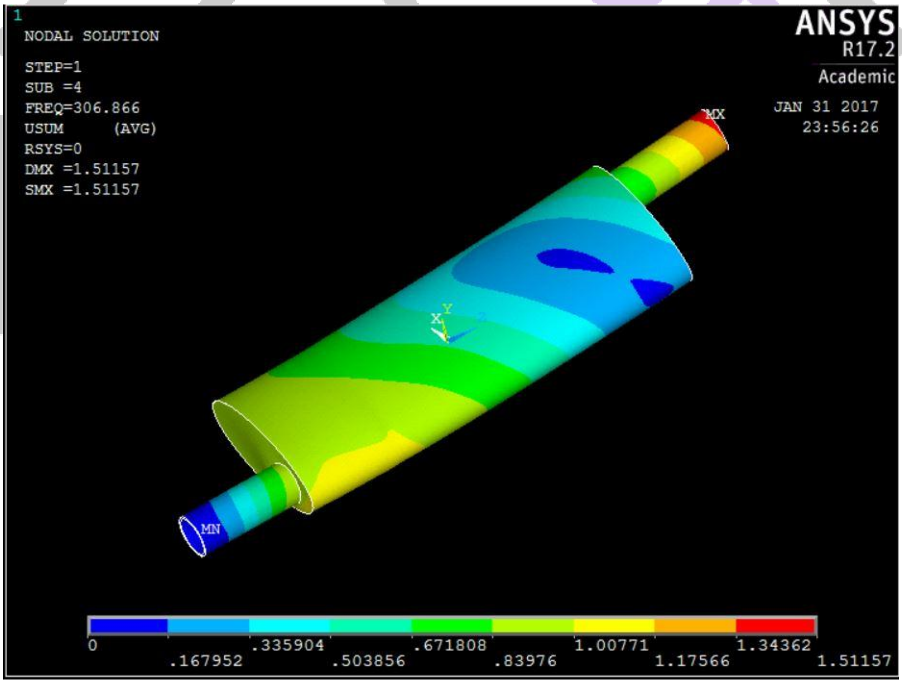


Fig 1.8 Displacement at 306.866

Fourth mode of vibration would occur at 442.193 Hz and its displacement would be 1.462mm.

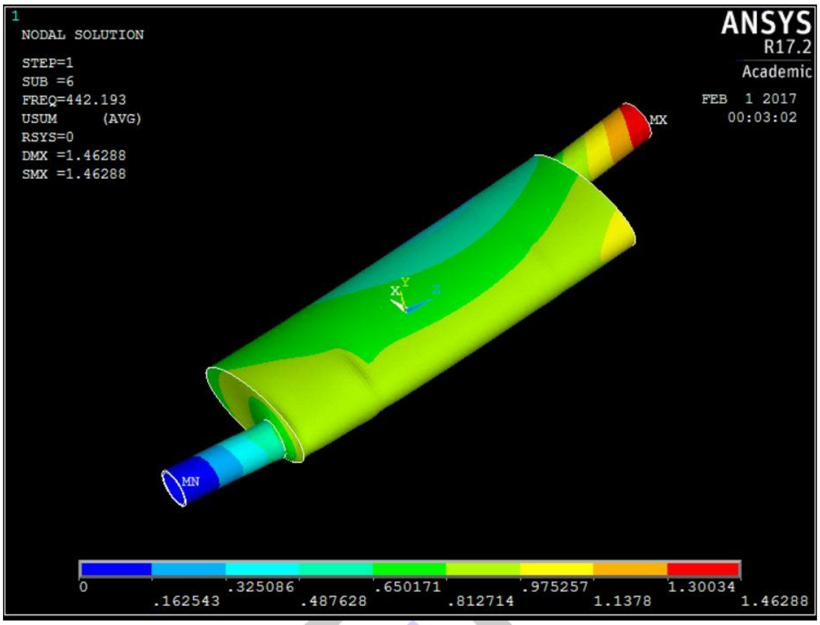


Fig 1.9 Displacement at 442.193

As we can see that the maximum displacement would occur at 135.30 Hz. Thus this frequency would be the natural frequency of this modal.

Often this scenario would occur at in engine idol cases. This can be avoided with the help of optimized muffler and better results.

Future Scope and Conclusion: In this paper we've seen how the genetic algorithm is employed to optimize the muffler model for better results. Although we've seen only the modal analysis in this paper, future, I will be implementing the Genetic algorithm to find the optimum TL (Total Loss) and Back Pressure of the muffler.

References:

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