PREDICTION OF TRANSMISSION LOSS IN MUFFLER ON VARYING THE FLOW RESISTIVITY OF ABSORPTION MATERIAL

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Abstract: Now a day's noise and pollution free environment is the most important aspect as the number of vehicles is increasing day by day. Noise control is the most important criteria as it will lead to friendly environment. It can be achieved by various techniques of which absorbing the sound coming out of the exhaust system of vehicles by using muffler is the most important technique. Porous and fibrous materials are widely used as sound absorbing materials. In this paper the different sound absorbing materials that are used are light weight acoustic absorber with silicon carbide fibers, polyester, Rockwool are used and the amount of transmission loss occurring because of the absorption materials are compared. Air flow resistivity which is one of the physical properties of absorption material is taken for the transmission loss calculation in muffler. In this paper the different mufflers are modeled in Solidworks and these are analyzed in Comsol Multiphysics where the transmission loss is determined at various frequencies. From the analysis it is found that increase in air flow resistivity and increases in thickness of absorptive lining increases the transmission loss and light weight ceramic acoustic absorber is favorable and could be used in muffler for sound attenuation. This paper also reveals one of the effective designs of muffler that could be fitted in automobile industry.

Keywords: Muffler, transmission loss, light weight ceramic acoustic absorber (SiC fibers), Analysis in Comsol

I. INTRODUCTION: Day by day noise and pollution is increasing because of the increasing in vehicles. The amount of noise produce by the exhaust is almost ten times more than the structural noise. Muffler plays an important role in reducing the exhaust and intake system noise. It is a device for reducing the amount of noise emitted by the exhaust of an internal combustion engine. It is generally placed at the exhaust system of the engine. So a great deal of research and development is going on over the years on muffler performances and the effects on which these mufflers depend. M L Munjal's classical book on ducts and acoustics (1) has told us about the different aspects of muffler. With the advancement of computer use and function there has been a great deal of limitations for predicting muffler performance and properties. But with the invention of different simulation software and solvers like Finite Element Method (FEM) and Boundary Element Method (BEM) it has become easy for predicting these muffler performances. These mufflers consist of different acoustic filters for reducing the noise from the exhaust. Absorption material is one such filter which is taken for study in this paper in the muffler.The different absorption materials that are used in this paper for study are polyester, Rockwool and light weight ceramic acoustic absorber (patented by Tsutomu Oishi Et. Al in June, 2006) (2).

Light weight ceramic acoustic absorber: This is a ceramic acoustic absorber with Silicon carbide whiskers or fibers which is light in weight and it has excellent resistance to thermal stresses. It has excellent sound absorbing characteristics. Silicon carbide fibers can resist high temperature of about 1800^o – 2300^o C. These materials also act as a perforated body as it is having a void ratio in the range of 80-92%. The mean diameter of the material is 50- 450µm near the front surface and 500- 3400 µm near the rear surface of the taken body. In the taken perforated body the thickness of the dense layer is 1000 μm and the voids present in it are having a mean diameter of 10 to 50 μm (2). These material is having air flow resistivity of about 4 to 60 Pa.sec/m(cgs Rayls/cm).

The air flow resistivity is the main physical properties that are taken for determining the transmission loss of muffler which is performed in the Comsol simulation software. Comsol Multiphysics is a simulation software package for analyzing different physical and engineering applications. This software allows using of coupled system of partial differential equations. It is having different modules for solving different structural system. Acoustic module of the software is used for the transmission loss calculation. In this module the model is analyzed using the harmonic pressure acoustic interface in the frequency domain. The modified Helmholtz equation for acoustic pressure is considered.

$$\nabla\left(-\frac{\nabla p}{\rho}\right)-\frac{\omega^2 p}{{c_s}^2\rho}=0$$

Acoustical Characteristic performance parameters of muffler: Transmission loss, Insertion loss and Level Difference are three acoustical performance parameters.

II.LITERATURE SURVEY: Most of the research on mufflers was based upon accurately predicting the transmission loss of muffler features using both Numerical and Analytical techniques.

M L Munjal in his book titled “acoustics of ducts and mufflers with application to exhaust and ventilation system” (1) described about the different aspects of muffler. Selamet Et Al. and Munjal(1999) together performed work on this transmission loss in mufflers. On their works further studies were made by different scientists by considering different geometric features such as using sudden expansion chambers, extended tubes, resonators, and perforated materials. Selamet along with some other scientist worked on the Fem and CFD technique.

From his book we get an idea about the muffler properties which is used by different researchers for the development of the muffler. Mehdizadeh Et Al. (2005) used a packed muffler lined with polyester lining in his work where it was found that it produced high transmission loss of about 55 dB at around 1800 Hz (3).**H**aluk Erol, Özcan Ahmetoglu (2006**)** applied finite element approach for predicting the 4 pole parameters for the various different combinations of mufflers to receive the transmission loss characteristics. In this the transmission loss for the muffler with and without the use of perforated plates and absorption material are determined. It shows a good transmission loss of around 60- 80 dB in both numerical and experimental method (4).

Kirby (2009) presented the two-dimensional finite element eigenvalue calculation in combination with a point collocation matching scheme in the inlet/outlet ducts for mufflers with the effect of mean flow and perforated pipe. Here two automotive dissipative silencers are of elliptical cross sections. Fiber glass and basalt wool were used the absorptive material used here. The average fiber diameter of fiber glass was around 5- 13μm and for basalt it was around 6-13 μm and it showed good attenuation at around 1500Hz.Jorge P. Arenas, Malcolm J. Crocker (2010) studied about the different sound absorption materials that could be used in mufflers. According to them all materials absorb incident sound but the term “acoustical material” is used to only those materials which absorb most of the sound waves transmitting only a little. They said that the materials have absorption properties depending upon frequency, composition, thickness, surface finish and the method of mounting and the materials with high sound absorption coefficient are usually more porous (5). In their work they described about the different absorption materials available and said that the recent evolution of new materials will help in sound absorption to a great amount. According to them rockwool, glass wool, SiC ceramics and some foam materials could be used as sound absorption materials.

A.G. Antebas, F.D. Denia, A.M. Pedrosa, F.J. Fuenmayor (2013) in their work no perforated duct was considered and the fibrous material was directly exposed to the gases in the central airway. Segmentation method was used in their work. From the comparison of experimental and numerical calculation the amount of transmission loss found is around 50-60 dB at about 1000-1500 Hz (6).

III.RESEARCH PURPOSE: In this paper transmission loss is the main parameter which is required. From the earlier studies we found that acoustic filters of the muffler such as perforated tubes, absorption materials, resonators could be used for reducing the noise in muffler. As these filters are used the weight of the system increases which affects the performance of the engine also. The fuel consumption also increases. So we have the scope of finding such a type of absorption material which is lighter in weight and which is also effective in reducing the sound pressure level. By these the fuel consumption would be reduced which would be helpful for common people. Here absorption material is used as the acoustic filter inside the muffler for attenuation and thus the amount of transmission loss in the muffler is calculated.

IV.RESULTS: The dimension of the muffler used in this study is as follows: Design 1: The length of the chamber is 45.72 cm (18 in) and the diameter of the chamber is 20.32 cm (8 in). The inlet and outlet tube are of length 15 cm and diameter 5.08 cm (2 in) respectively. The thickness of the absorptive lining is 2.54 cm (1 in).

Design 2: Here the length of the chamber is 500 mm and the diameter of the chamber is 200 mm. the inlet and outlet tube are of length 96 mm and diameter 51 mm respectively. The thickness of the absorptive lining is 2.54 cm. The materials that are taken for study in this work are light weight ceramic acoustic absorber, polyester and Rockwool. The analysis are performed in Comsol for frequency range of 100 to 3000 Hz. These analyses would give us a complete overview of the amount of sound absorption produced in the muffler on application of absorbing material and from these analyses we could justify that light weight ceramic acoustic absorber could also be used in muffler for automobiles.

1. Effect of Air flow resistivity

   Here the resistivity values are: Polyester: 16000[Rayls/m], ceramic acoustic absorber (SiC): 60.6[cgs rayls/cm] and Rockwool: 13813[Rayls/m]

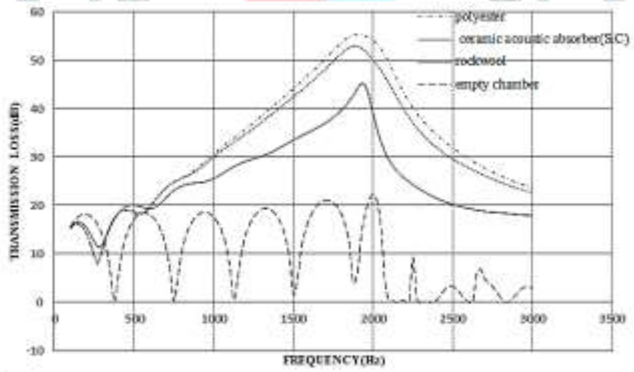

Figure 1: Transmission loss in muffler wrt the resistivity of each material for design 1

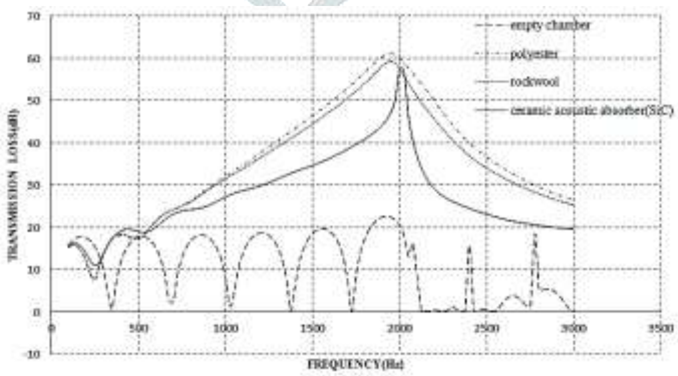

Figure 2: Transmission loss in muffler wrt the resistivity of each material for design 2

From the above it is found that the transmission loss in case of undamped condition is less than that of damped condition in both the design. It is found that as the air flow resistivity increases the transmission loss also increases.

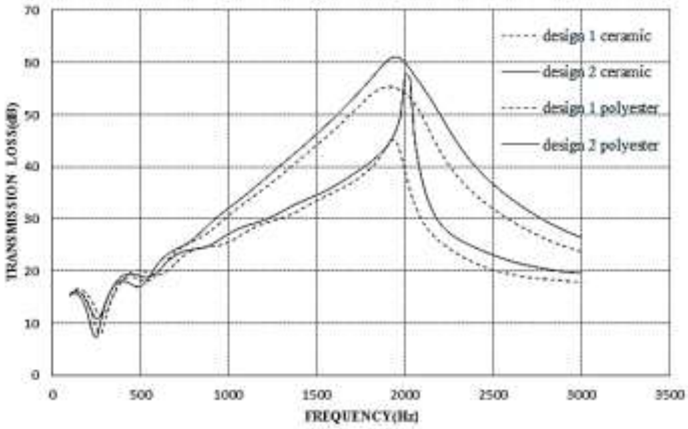

Figure 3: Comparison of TL in mufflers when ceramic acoustic absorber (sic fibers) and polyester absorption material are used

Here it is found that the design 2 is much effective as it produces more transmission loss.

2. Effect of thickness

For design 1

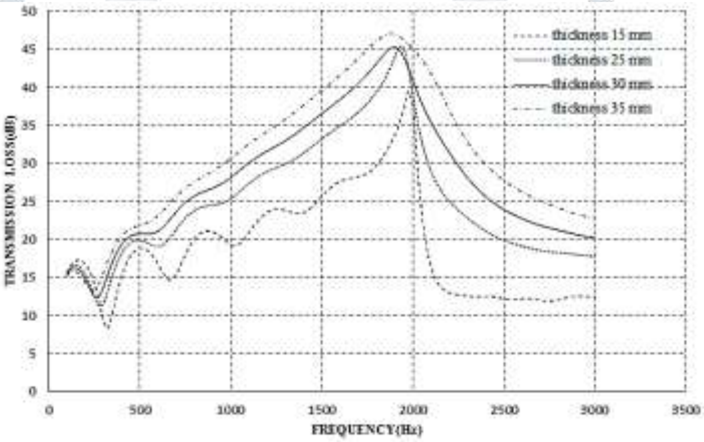

Figure 4: TL of muffler on varying the thickness of the absorption material (ceramic acoustic absorber) for design 1

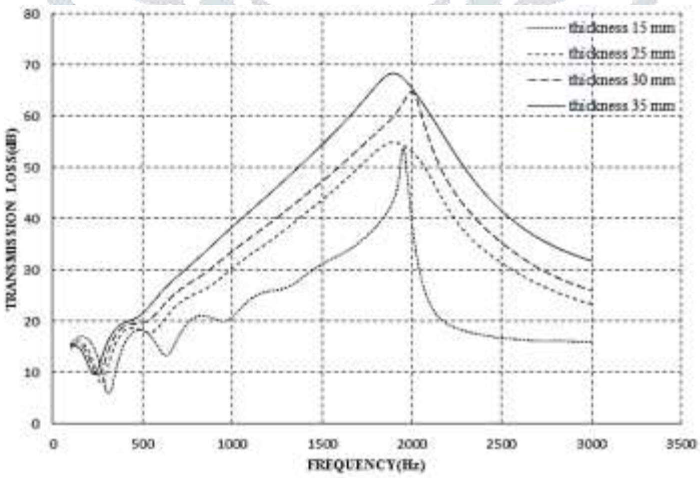

Figure 5: TL of muffler on varying the thickness of the absorption material (polyester) for design 1

From the above we can conclude that increase in thickness increases the transmission loss of the muffler.

For design 2

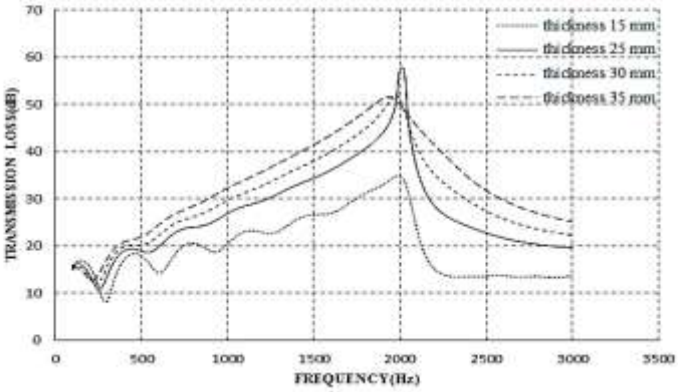

Figure 6: TL of muffler on varying the thickness of the absorption material (ceramic acoustic absorber) for design 2

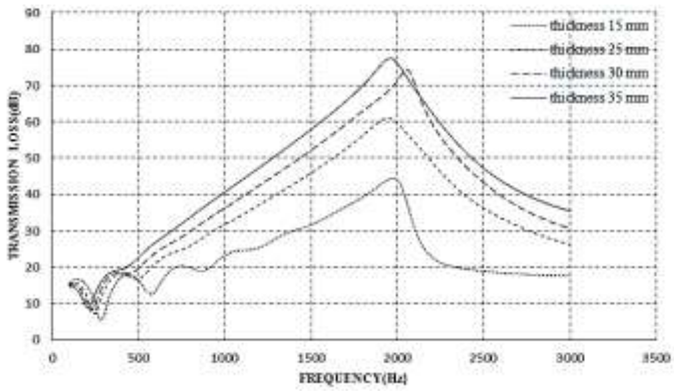

Figure 7:TL of muffler on varying the thickness of the absorption material (polyester) for design 2

From figure 9 it is found that the muffler with 25 mm thickness absorption lining of ceramic acoustic absorber contradicts the general theory produce high transmission loss on varying the thickness. Whereas figure 10 follows the general theory as other the mufflers are acting.

By changing the thickness of absorption material, transmission loss for the muffler is determined.

V.CONCLUSION: From the different analysis we found that the amount of transmission loss in an empty muffler is very low i.e. it occurs in the range of about 15 to 30 dB for respective frequency. But the damping is not uniform throughout the muffler. As we apply an absorptive lining inside the muffler the amount of transmission loss increases which is very efficient for the vehicles. It is found that there is not much difference in transmission loss because of polyester lining, Rockwool lining and ceramic acoustic absorber with SiC whiskers lining. But the melting point of polyester is 660^{o} C and that of Rockwool is 1000^{O} C. whereas melting point of light weight ceramic acoustic absorber is about 1800^{o}C to 2400^{o}C. Thus, the muffler with polyester, Rockwool lining could be replaced by light weight ceramic acoustic absorber lining as this material could be directly exposed to heat for long time. By this weight of the muffler would also be decreased as we don't have to use any other extra tube inside the muffler for resisting the direct contact of heat energy with the absorption material.

From the different analysis we can conclude that design 2 will be the most favorable muffler with an absorption lining of polyester of 35 mm thickness. But for high speed vehicles where the exhaust heat will be very high, the muffler with 25 mm absorption lining of ceramic acoustic absorbers with SiC fiber will be the most effective.

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