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A REVIEW ON DESIGN OF ABSORPTIVE MUFFLER WITH AMMONIA PULSATOR FOR IC ENGINE

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ABSTRACT

In these review paper, we discuss about the absorptive muffler. There are various types of engines exhaust noise pollutes harmful in environment. The main principle of this paper is on reducing the noise and emission of engine. Any type of engine exhaust noise is controlled by using silencers/mufflers. By attaching of muffler in the exhaust pipe is the most effective means of reducing the noise, but muffler requires specific design and construction by considering various noise parameters which produced by the engine. The analysis and design work for the absorptive muffler has been going on since the early 1920s. Here we are taking different design parameters and improving the efficiency of the absorptive muffler. The formulated muffler traditional design problem will be solved by new design and optimization.

Keywords: Internal combustion Engine, Absorptive Muffler, Engine Exhaust Noise and Emission Reduction.

I. INTRODUCTION

Internal combustion engine is a major source of noise pollution. These engines are used for various purposes such as, in power plants, automobiles, locomotives, and in various manufacturing machinery. Noise pollution created by engines becomes a vital concern when used in residential areas or areas where noise creates hazard. Generally, 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. The exhaust noise is the most dominant. To reduce this noise, various kinds of mufflers are usually used. The level of exhaust noise reduction depends upon the construction and the working procedure of mufflers.

The exhaust is passed through a series of chambers in reactive type mufflers or straight through a perforated pipe wrapped with sound deadening material in an absorptive type muffler. Both types have strengths and weaknesses. The reactive type muffler is usually restrictive and prevents even the good engine sounds from coming through, but does a good job of reducing noise. On the other hand, most absorptive type mufflers are less restrictive, but allow too much engine noise to come through. Regardless of the packing material, absorptive type mufflers tend to get noisier with age.

An Absorptive Muffler is used to control the noise and emission in IC engines. The reason why we go for Absorptive Muffler is, in today life the air pollution causes physical ill effects to the human beings and also the environment. The main contribution of the air pollution is automobiles releasing the gases like carbon dioxide, unburned hydrocarbons etc. In order to avoid this type of gases by introducing this Absorptive Muffler. It is fitted to the exhaust pipe of the engine; Sound produced under water is less hearable than it produced in atmosphere.

1.1 Typical Muffler Designs

There are two typical muffler designs are shown in Fig.1.1 and Fig.1.2. The first design, shown in Fig.1.1, is frequently chosen because of its low cost and because it causes a lower back pressure. The second design shown in Fig.1.2 which provides more attenuation and is typical of the design recommended by muffler manufacturers. However there is no direct connection between the inlet and the outlet so back pressure is generated that can effect engine performance. This is sometimes referred to as a baffled muffler design.

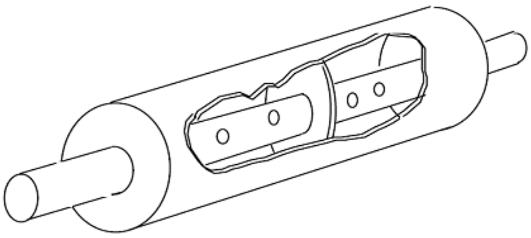

Fig.1.1 Sketch of typical muffler with two cavities and no flow restriction

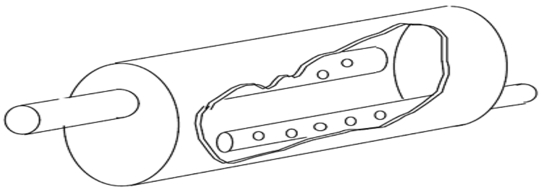

Fig.1.2 Sketch of typical muffler in which there is no direct passage between the inlet and exit

II. LITERATURE REVIEW

The literature review focuses on the literature study done on the review of related journal papers, articles available as open literature.

Vijay M Mundhe et al which depicts, muffler is an important part of an engine system used in exhaust system to reduce exhaust gas noise level. The literature review reveals that the exhaust gas noise level depends upon various factors. Muffler geometry, extension in inlet and outlet valves, number of whole perforations and its diameter are the factors which affects noise from engines. The objective of this study is to reduce exhaust gas noise level [1].

Ujjal Kalita et al represent a bibliographical review of the muffler used in automobile industry. Use of sound absorption material in an exhaust system dissipates the energy of the acoustic waves into heat and also store heat energy from the exhaust stream. Using an absorptive material can greatly increase the transmission loss of an exhaust system in the mid to high frequency ranges [2].

Dr. Suresh P. M. et al whose paper deals with the experimental modal analysis, also known as modal analysis or modal testing, deals with the determination of natural frequencies, damping ratios, and mode shapes through vibration testing. The exhaust muffler in an automobile plays an integral role in reducing the sound of the automobile, as well as the ride itself. In order to maintain a desired noise and comfortable ride, the modes of a muffler need to be analyzed [3].

Jigar H. Chaudhari et al which represent the review on different types of mufflers and design of exhaust system belonging engine has been studied. The object of this study is deciding muffler design which one reduces a large amount of noise level and back pressure of engine. In designing, there is different parameter which has to taken in to the consideration. These parameters affect the muffler efficiency. Absorptive muffler design uses only absorption of the sound wave to reduce the noise level without messing with the exhaust gas pressure [4].

Rahul D. Nazirkar et al whose paper explain an automotive exhaust system the noise level, transmission loss & back pressure are the most important parameters for the driver & engine performance. In order to improve the design efficiency of muffler, resonating of the exhaust muffler should be avoided by its natural frequency. The design of muffler becomes more and more important for noise reduction. The solid modeling of exhaust muffler is created by CATIA-V5 and modal analysis is carried out by ANSYS to study the vibration and natural frequency of muffler. So as to differentiate between the working frequencies from natural frequency and avoid resonating [5].

M. Rahman et al which describes the absorptive muffler is the classic dissipative design, deriving its noise control properties from the basic fact that noise energy is effectively "absorbed" by various types of fibrous packing materials. That is, as the sound waves pass through the spaces between the tightly packed, small diameter fibers of the absorptive material, the resulting viscous friction dissipates the sound energy as small amounts of heat [6].

III. METHODOLOGY

In order to select a suitable muffler type, some basic information are necessary regarding how industrial mufflers work. Industrial mufflers, (and mufflers in general), attenuate noise by two fundamentally different methods. The first method, called reactive attenuation - reflects the sound energy back towards the noise source. The second method, absorptive attenuation – absorbs sound by converting sound energy into small amounts of heat. There are three basic industrial muffler types that use these methods to attenuate facility noise – reactive silencers, absorptive silencers and anyone or both of them combined with resonator. The proper selection of a muffler is performed by matching the attenuation characteristics of the muffler to the noise characteristics of the source, while still achieving the allowable muffler power consumption caused by muffler pressure drop.

A muffler have been designed which is of super critical grade type and includes all the three attenuation principles i.e., reactive, followed by absorptive type muffler, and a side branch resonator. The interesting events of the design are continuous volume reduction of chambers in the reactive part; the flow pipe cross-sectional area is maintained constant throughout, a layer of insulation outside the reactive part, the placing of side branch resonator compactly, option for tuning the resonator using a screw and cylinder.

3.1 Design Data

For the experiment, an existing petrol engine has been used. Calculations are done on the basis of data collected from the engine; Specifications of the engine available for testing are as follows:

Specification of Engine

Make: Crompton Greaves Model: IK-35

Engine is two stroke spark ignition engine with following specifications

Bore 'diameter: 35 mm

Stroke: 35 mm

Capacity: 34 cc

Power output: 1.2 BHP at 5500 rpm

Torque: 2.72 N-m @ 5000 rpm

Dry weigh: 4.3 kg

Ignition: Flywheel magneto

Direction of rotation: Clockwise looking from driving end

Carburetor: 'B' type

Cooling: Air Cooled engine

Lubrication: Mist –via petrol

However, some data are applicable to all engines. For designing, the following data are required.

3.1.1 Sound characteristics (Without silencer)

Rpm of the engine= 5500

Load Sound level

Without any load 9.2 kg 104.5 dbA

50% load 15 kg 106.5dbA

100% load 24 kg 107dbA

3.1.2 Sound analysis with frequency analyzer (to obtain the dominating frequency)

Two dominating frequencies, the low level and the high level have been obtained. These are Frequency Level Frequency (Hz): Low 270 and High 40000

3.1.3 Diameter of exhaust pipe of engine/inlet pipe of muffler

The Exhaust Pipe diameter: 1.0 inch (25.4 mm)-this is in accordance to the standard mounting flange on the engine exhaust.

3.1.4 The theoretical exhaust noise frequency range

From various experiments is has been found that the theoretical exhaust noise frequency is 200-500Hz.

3.2 Muffler Part Design

S1 = Exhaust pipe diameter = 1.0 inch

The dimensions to determine are that of the chamber length L and the body diameter S2.

To determine L, three methods have been used.

They are as follows:

3.2.1 First method used to determine L

Maximum attenuation occurs when $L = n\lambda/4$

Where, λ = wavelength of sound (m or ft), n = 1, 3, 5… (Odd integers)

Since λ is related to frequency by the speed of sound, one can say that the peak attenuation occurs at frequencies which correspond to a chamber length.

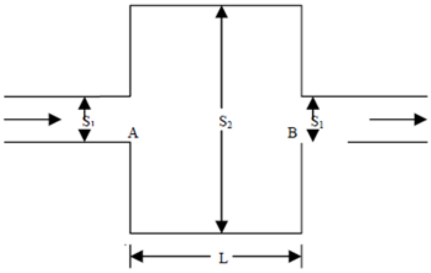

Fig.3.1 Schematic of muffler

Frequency	λ=c/f (m)	λ (Inch)	N=odd integer	L=Nλ/4(inch)
N(Min)	0.5	19.6	1	4.9
200HZ	(Max)	(Max)	-	14.7
N(Max)	0.6	23.6	1	5.9
500	(Min)	(Min)	3	17.7

Table 3.1 Calculated Wavelength from frequency

From table above we can determine the length for the engine exhaust specifications length is within the range of minimum 4.9 inches to maximum of 17.7 inches as maximum conditions as never achieved because engine is always operated under load…hence length of the muffler smaller section is considered to be 5 inches and length of the overall section can be considered to be 17.7 inches or 450 mm.

3.2.2 Range of chamber length considering the temperature of exhaust gas

Another factor which must be considered in expansion chamber design is the effect of high temperature of exhaust gases. This factor can easily be included in the design by using the following equation:

$$0.5(49.03\sqrt{°R})/2\pi f \leq L \leq 2.6\,(49.03\sqrt{°R})/2\pi f \qquad (1)$$

Where, $\sqrt{°R}$=absolute temperature of the exhaust gas f = frequency of sound (Hz)

Let the temperature of exhaust is assumed to be 300° F or 759.7° R

Putting this value in equation (1), one obtains,

$$0.5(49.03\sqrt{759.7})/2\pi 270 \leq L \leq 2.6\,(49.03\sqrt{759.7})/\,2\pi 270$$ (Here, f =270Hz for low frequency absorptive muffler)

$$0.4 \text{ ft} \leq L \leq 2.04 \text{ ft}$$

From the 1st method, L = 17.7 inch = 1.47 ft.

So the condition of $0.4 \text{ ft} \leq 1.47 \leq 2.04$ ft is satisfied.

3.3 Other parts of absorptive muffler design

It has always been considered that the flow path diameter does not reduce at any point. Otherwise, there would be a possibility of back pressure. That is why; the following equation has been used to determine the diameter of the smaller pipes, which are at the outlet of the first two chambers.

$$\pi S1^2/4 = \pi d1^2/4 + \pi d2^2/4$$ Where, d1 and d2 are smaller pipe diameters.

As both pipes are of the same diameter, one gets,

$$d1 = d2 = 1.06 \text{ inch} \approx 1 \text{ inch.}$$

Now, the total length L has been divided into three small chamber lengths L1, L2, and L3. As the pressure is dropping from the first chamber to the next, we reduced the length slightly from the first to the third.

3.4 Tailpipe Design

According to equation (1), resonance occurs when L = nλ/2. So, for an economical construction, the value of n may be taken as 1. Then the tailpipe must be less than λ/2 i.e., 3"

IV. DESIGN & CONSTRUCTION

Basically an Absorptive muffler consists of a perforated tube which is installed at the end of the exhaust pipe. The perforated tube may have holes of different diameters. The very purpose of providing different diameter hole is to break up gas mass to form smaller gas bubbles the perforated tube of different diameter .Generally 4 sets of holes are drilled on the perforated tube. The other end of the perforated tube is closed by plug.

Around the circumference of the perforated tube a layer of activated charcoal is provided and further a metallic mesh covers it. The whole unit is then placed in a water container. A small opening is provided at the Top of the container to remove the exhaust gases and a drain plug is provided at the bottom of the container for periodically cleaning of the container. Also a filler plug is mounted at the top of the container. At the inlet of the exhaust pipe a non-return valve is provided which prevents the back flow of gases and water as well.

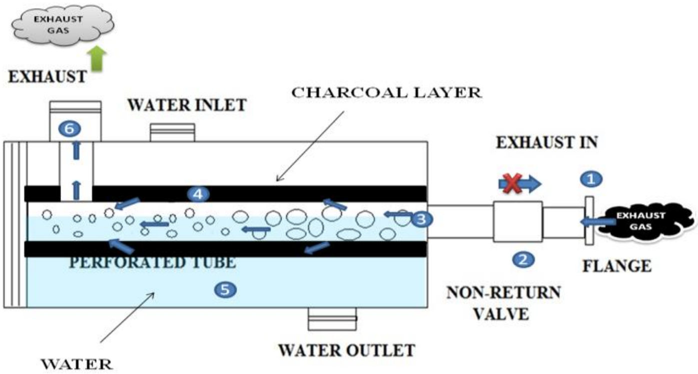

Fig. 4.1 Absorptive Muffler

4.1 Basic designs of absorptive muffler

4.1.1 Design of CASING PIPE

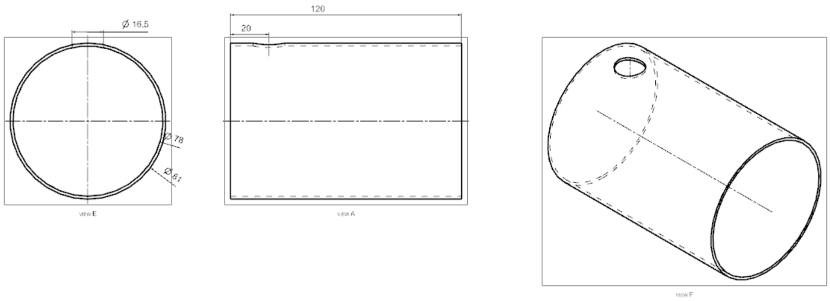

Fig. 4.2 Geometry of Casing Pipe

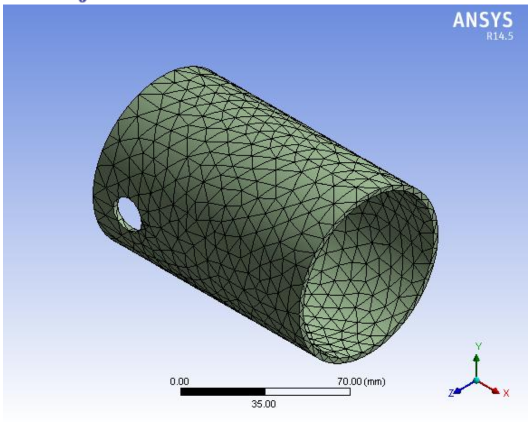

Fig.4.3 Meshing of Casing Pipe

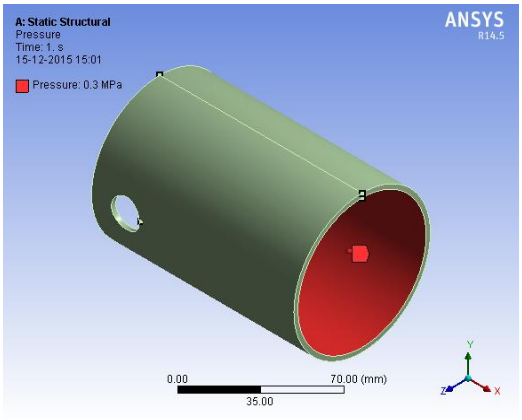

Fig.4.4 Static structure with pressure of Casing Pipe

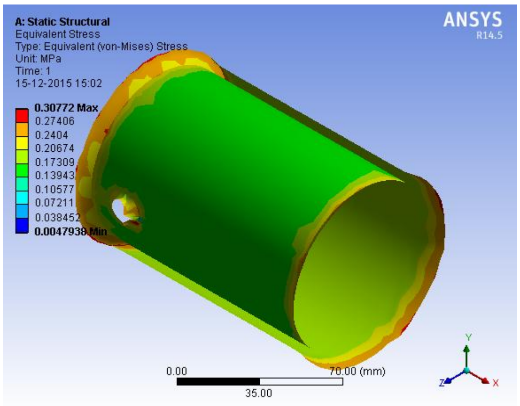

Fig. 4.5 Static structure with equivalent stress (von-mises) of Casing Pipe

Hoope's stress due to exhaust gas pressure

Maximum pressure induced in system due to exhaust gases=3 bar= 0.3 Mpa

fc_h =

fc_{act} = (0.3 x 81) / (2 x1.5)

fc_{act} = 8.1 N/mm2/mm^2

As $fc_h < fc_{all}$; casing pipe is safe

Longitudinal stress due to exhaust gas pressure

Maximum pressure induced in system due to exhaust gases = 3 bar= 0.3 Mpa

fc_l =

fcl_{act} = (0.3 x 81) / (4 x1.5)

fcl_{act} = 4.0.5N/mm^2

As $fc_l < fc_{all}$; casing pipe is safe

4.1.2 Design of Charcoal Pipe – 1

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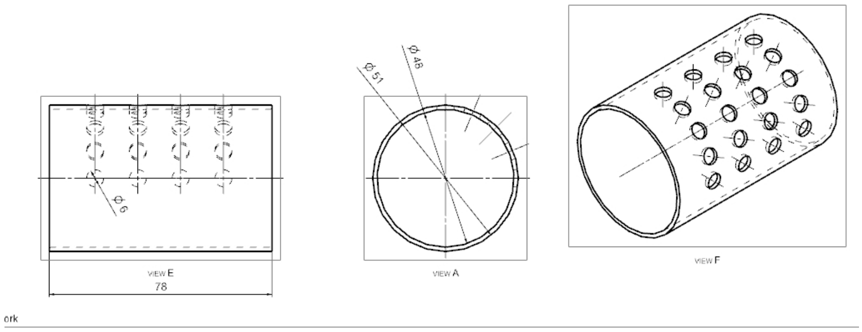

Fig.4.6 Geometry of Charcoal Pipe – 1

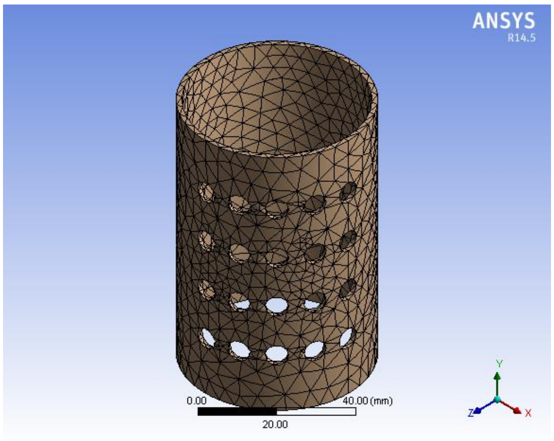

Fig. 4.7 Meshing of Charcoal Pipe – 1

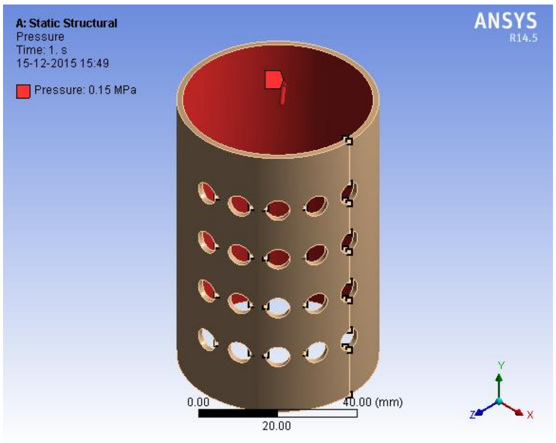

Fig.4.8 Static Structure with Charcoal Pipe - 1

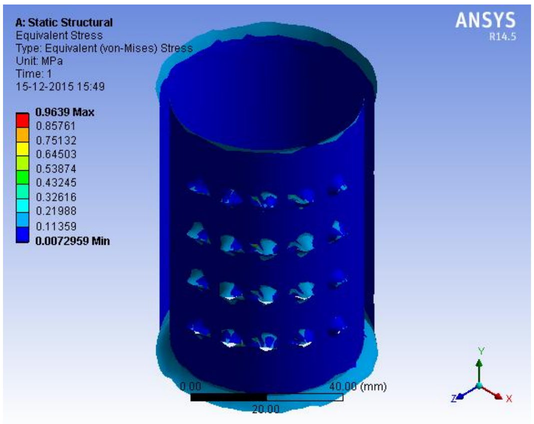

Fig.4.9 structure with equivalent stress (von-mises) of Charcoal Pipe - 1

Hoope's stress due to exhaust gas pressure

Maximum pressure induced in system due to exhaust gases=1.5 bar= 0.15 Mpa

Longitudinal stress due to exhaust gas pressure

Maximum pressure induced in system due to exhaust gases = 3 bar= 0.3 Mpa

4.1.3 Design of Charcoal Pipe - 2

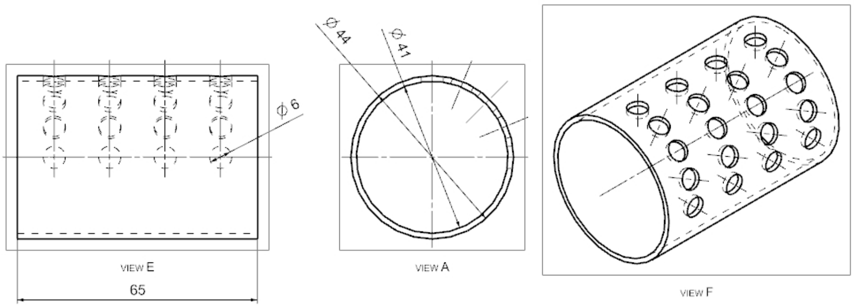

Fig.4.10 Geometry of Charcoal Pipe - 2

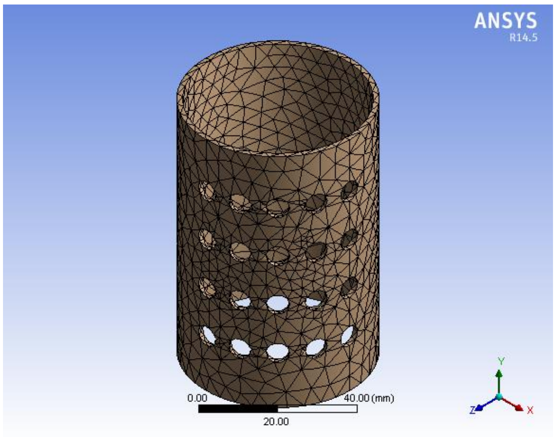

Fig. 4.11 Meshing of Charcoal Pipe - 2

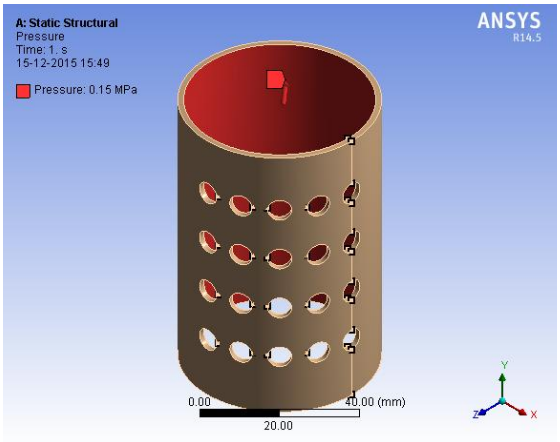

Fig.4.12 Static Structure with Charcoal Pipe - 2

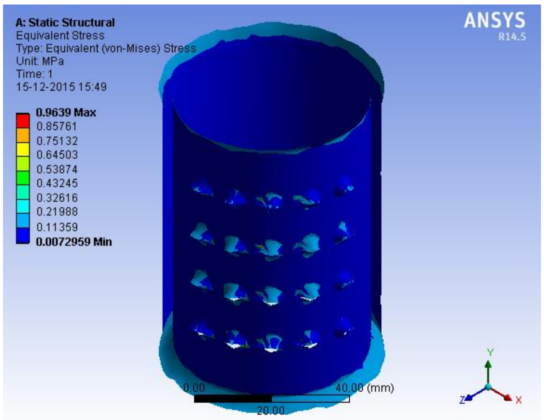

Fig.4.13 structure with equivalent stress (von-mises) of Charcoal Pipe - 2

Hoope's stress due to exhaust gas pressure

Maximum pressure induced in system due to exhaust gases=1.5 bar= 0.15 Mpa

Longitudinal stress due to exhaust gas pressure

Maximum pressure induced in system due to exhaust gases = 1.5 bar= 0.15 Mpa

Part Name	Maximum theoretical stress N/mm^2	Von-mises stress N/mm2	Maximum deformation mm	Result
Casing Pipe	8.1	0.307	2.12E-6	safe
Charcoal pipe-1	2.5	0.9	1.07E-7	safe
Charcoal pipe-2	2.5	0.9	1.07E-7	safe

Table.4.1 Results

V. CONCLUSION

In these review paper we outcomes about the various component of design absorptive muffler. We are finding the maximum theoretical stress result of casing pipe and charcoal pipes (i.e. 1 & 2). These results comparing with von-mises stress, maximum stress by theoretical method and von-mises are well below the allowable limits, means the design of casing pipe and charcoal pipes (i.e. 1 & 2) is safe design. Casing and charcoal pipe shows negligible deformation under the action of system of forces.

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