International Journal of Science and Research (IJSR)
ISSN (Online): 2319-7064
Index Copernicus Value (2015): 78.96 | Impact Factor (2015): 6.391

Design, Development & Analysis of Hydraulic Noise Suppressor

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Abstract: ***Hydraulic pump is the main source of pulsations and vibrations. While pump manufacturers have made noise reduction a design goal, every pump still produces some ripple - the pump manufacturers' term for pulsations. Ripple causes noise generation in pumps.To get reduction of noise in pumps hydraulic conductors should be reviewed. Somewhat surprisingly, one factor that can contribute much to the noise level is improper use of hydraulic hose. Recent research shows that they could take an average of 5 dB(A) out of a standard power unit merely by changing the configuration of the hydraulic hose.Introduction of compressible medium with incompressible medium of hydraulic fluid will show reduction in hydraulic pulsations.The main challenge is to get the fluid to interact with the nitrogen so the nitrogen compresses and the fluid merely loses its pulsation.To absorb the pulsations nitrogen-charged accumulators have been installed in various hydraulic units. At first, accumulators were used as appendage devices - teed off the hydraulic line. Majority of the pulsations bypassed the line leading to the accumulator. Various designs then evolved in which the full flow was diverted into the accumulator. Correctly sizing this type of accumulator is complicated and is expensive.***

Keywords: Pump, Pulsations, Hydraulic hose & Vibrations.

1. Introduction

Many countries have noise regulations at their work stations. Due to high noise emissions from hydraulic line, efforts are made to control noise.

The pump is the dominant source of noise in hydraulic systems. It transmits structure-borne and fluid-borne noise into the system and radiates air-borne noise. All positive-displacement pumps have a specific number of pumping chambers, which operate in a cycle of opening to be filled, closing to prevent back flow, opening to expel contents and closing to prevent back flow. These separate, superimposed flows result in a pulsating delivery, resulting in a corresponding sequence of pressure pulsations. These pulsations create fluid-borne noise, which cause downstream components to vibrate. The pump generates structure-borne noise by producing vibration in any component it is mechanically linked to, for example, the tank lid. The transfer of fluid- and structure-induced vibration to the adjacent air mass results in air-borne noise.

Pump pressure and pump sizes have about equal effects on hydraulic noise levels. However the pump speed has about 300% greater effect on pump noise than either pressure or pump size. This is the reason some pump manufacturers recommend slower electric motor speeds. Fixed pumps are usually quieter then variable displacement pumps. It is difficult to judge how much additional noise is being generated by hydraulic line and the surrounding structure. This is the main reason, many power units are enclosed after they have been manufactured and installed. Slight adjustments to the nitrogen pre-charge of the suppressor will show variations in the noisecontrol. This is easier than wrapping the piping in sound absorbing tape, or enclosing the entire power unit as an afterthought.

Lab tests show that pump noise levels are increased by 2 to 3 dB (A) just by adding 12 feet of outlet and return lines. The lines do not generate noise; instead they radiate noise when they respond to pulsations or vibrations. Pump usually generates the pulsations and the vibrations are transmitted by large flat machine surfaces. So not only do hydraulic lines radiate noise but also they frequently provide the primary path for propagatingnoise from the pump to components. This is the reason for pump manufacturers to show low pump rating, but when the pump is installed on a power unit the sound rating is much higher.

2. Present Theories & Practices

Reducing Fluid borne Noise:
While fluid-borne noise caused by pressure pulsation can be minimized through hydraulic pump design, it cannot be completely eliminated. Fluid borne noise can be reduced by introduction of silencer. The simplest type of silencer is the reflection silencer, which eliminates sound waves by superimposing a second sound wave of the same amplitude and frequency at a 180-degree phase angle to the first.

Reducing Structure-Borne Noise:
Elimination of sound bridges between the power unit and tank, and power unit and valves, can cause total elimination of structure borne noise which is caused by vibrating mass. Reduction of structure borne noise is achieved by use of flexible connections such as rubber mounting blocks and hoses. However, it is necessary to introduce additional mass in certain situations, where the inertia reduces the transmission of vibration at bridging points.

Reducing Air-borne Noise:
The magnitude of noise radiating from an object is proportional to its area and inversely proportional to its mass. Reduction in objects surface area can reduce noise radiation. Use of thicker plates for construction of hydraulic reservoir

will increase its mass which in turn will reduce its noise radiation. Introduction of hydraulic pump inside the tank will reduce the air borne noise. To get better results and effect, clearance between pump and sides of tank should be half a meter.Insulation against structure-borne noise can be done by incorporating decoupling between power unit and tank. The obvious disadvantage to this is the access for maintenance and adjustment is restricted.

Energy Storage in Hydraulic Fluid:
Storage and release of energy in the hydraulic fluid also generates noise in hydraulic systems. Hydraulic fluid is not perfectly rigid, and the compression of the fluid results in energy storage, similar to the potential energy stored in a compressed spring. Compressed fluid has the ability to perform the beneficial work. If decompression is not controlled, the stored energy dissipates instantaneously. This sudden release of energy accelerates the fluid, which affects anything in its path. The decompressions which are not controlled create noise and stresses conductors, which causes pressure transients which damage the system.

3. Literature Review

NingChenxiao, Zhang Xushe [1], Study on Vibration and Noise for the HydraulicSystem of Hydraulic hoist.By analysis on all kinds of the vibration source andnoise mechanism, this paper points out the vibration and noise harm, cause and source of the hydraulic hoist hydraulic system.

Furthermore it puts forward to effective and specific measures to reduce the vibration and noise of the hydraulic hoist hydraulic system which can also be widely applied to vibration and noise control of other hydraulic system.

Binghui Li, Simon Moore[2], Pressure pulsation, created by the operation of hydraulic pumps in a fluid power system, is one ofthe primary causes of noise issues from hydraulic machinery. The pulsations generates wave energy which propagates in wall and fluid flow of pipes of fluid power systems, inducing fluid borne vibration of the pipes and the consequent noise radiated from the pipes. The pressure pulsation can be controlled using many available techniques, including the design of quiet fluid power pumps, active control and passive control treatments (e.g. by installing pulsation suppressor/dampener). It presents a case study of noise control for marine hydraulic mooring winch systems installed on a marine barge, which emit excessive noise levels during operation. The installation of passive pulsation suppressors is proposed as the most practical and beneficial solution to control pulsation from the fluid power units and the consequent excessive noise radiation from the flow pipes, considering a number of factors such as cost, implementation schedule and complexity, as well as intrusion to the system.

SripriyaRamamoorthy and Karl Grosh[3],Theoretical studies show that the introduction of an in-line structural acoustic silencer into ahydraulic system can achieve broadband quieting ~i.e., high transmission loss!. Strategies for using structural acoustic filters for simultaneously reducing reflection and transmission by tailoring the material properties are studied. A structural acoustic silencer consists of a flexible layer inserted into nominally rigid hydraulic piping. Transmission loss is achieved by two mechanisms—reflection of energy due to an impedance mismatch, and coupling of the incoming acoustic fluctuations to structural vibrations thereby allowing for the extraction of energy through losses in the structure. Structural acoustic finite element simulations are used to determine the transmission loss and evaluate designs. Results based on the interaction of orthotropic and isotropic plates with variable geometry, operating in heavy fluids like water and oil, are presented.

4. Objectives of Project

1) Design and fabrication of Resonator chamber and rubber bladder in inline hydraulic suppressor.
2) Design of test rig to test the hydraulic suppressor using Ansys.
3) Comparative analysis of the results of discharge, noise and pressure at the outlet of silencer.

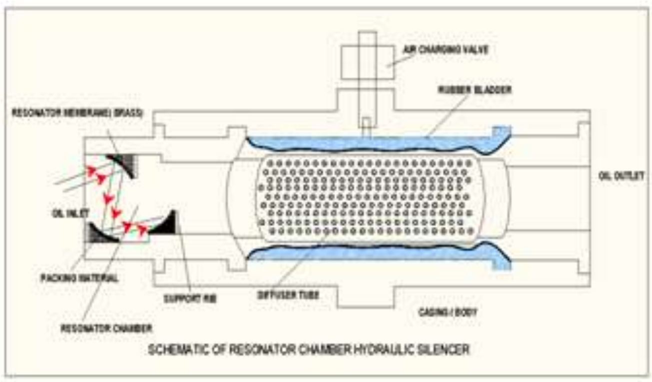
5. System Components

Pumping element

Technical Specifications
Designation - Pumping element for 11R/12R
Design - Plunger type, valve controlled
Mounting - Face Mounting
Speed range – 300 to 2000rpm
Hydraulic Medium – Mineral oil
Viscosity range – 10 to 100 CST
Mass – 0.7kg

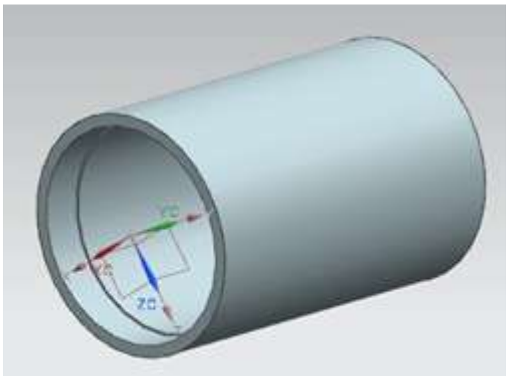
The operation pressure is between minimum of 3bar to maximum of 5bar. Hence the maximum design pressure for the analysis purpose is taken to be 5bar.

Arrangement of components in the noise suppressor is as shown below:



System consists of following elements:-

1) **Resonator chamber**

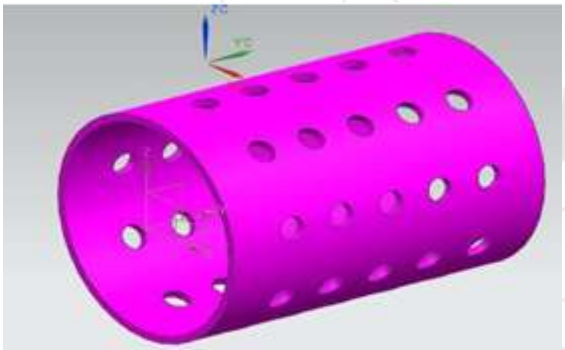


3D MODEL

2) **Diverter tube**

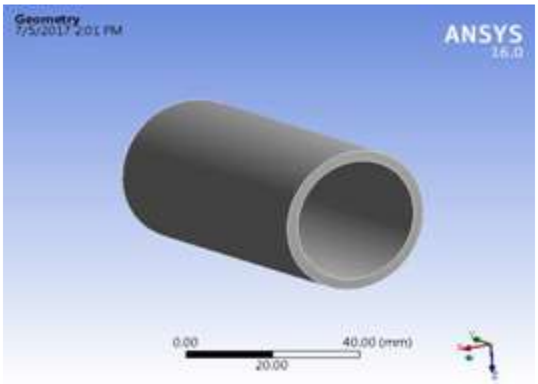
3D MODEL

3) **Inlet Diffuser tube**

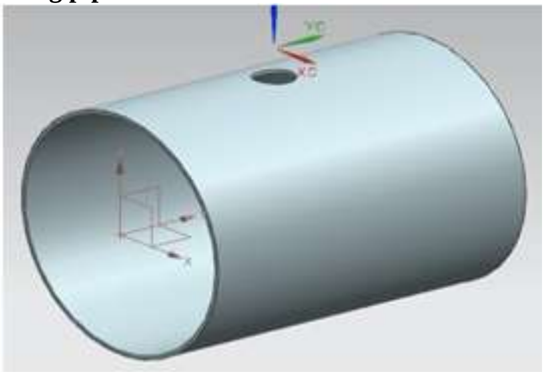


3D MODEL

4) **Membrane**



5) **Casing pipe**



6. Numerical Analysis

The procedure of Static structural analysis using ANSYS Workbench is deliberated below:

1) Definition of Material properties
2) Creation of model
3) Import of Solid Model in ANSYS workbench
4) Mesh Generation of Solid model
5) Application of Boundary conditions and loading conditions
6) Solving the analysis
7) Generation of desired results

The mesh model, boundary conditions and results of analysis for different parts are given below:

Analysis of Resonator chamber-

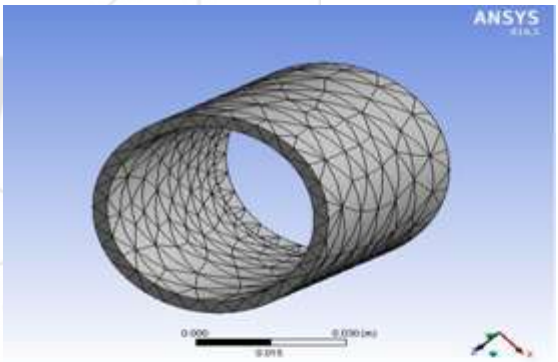


Figure: Meshed model of resonator chamber

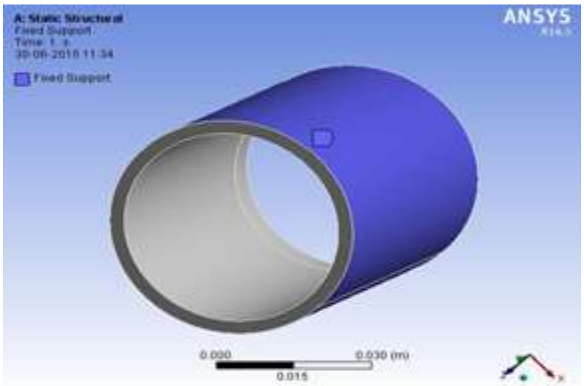


Figure: Boundary cond 1 for resonator chamber (Fixed sup)

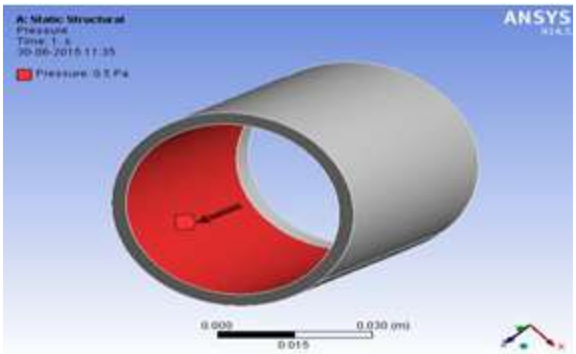


Figure: Boundary cond 2 for resonator chamber (Int press)

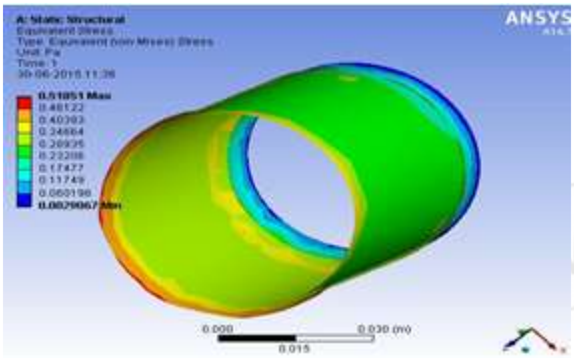


Figure: von-Misses stress results of resonator chamber

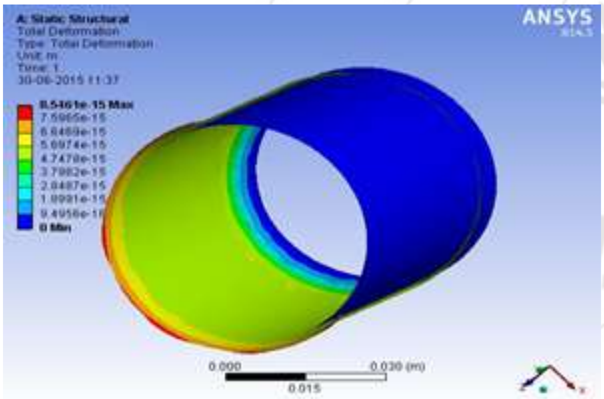


Figure: Total deformation of resonator chamber

Analysis of Diverter Tube-

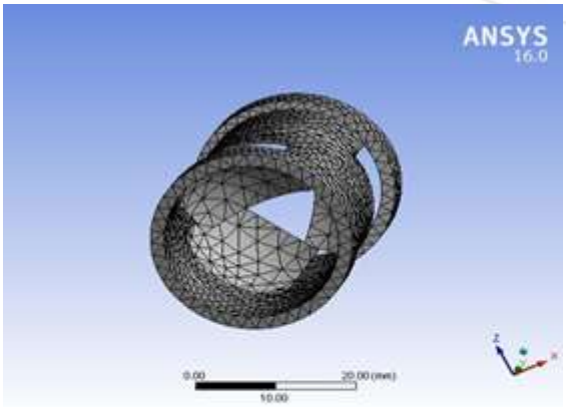


Figure: Meshed model of diverter tube

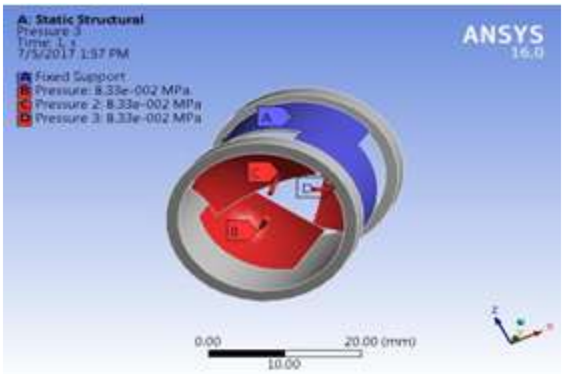


Figure: Boundary cond 1 & 2 for diverter tube

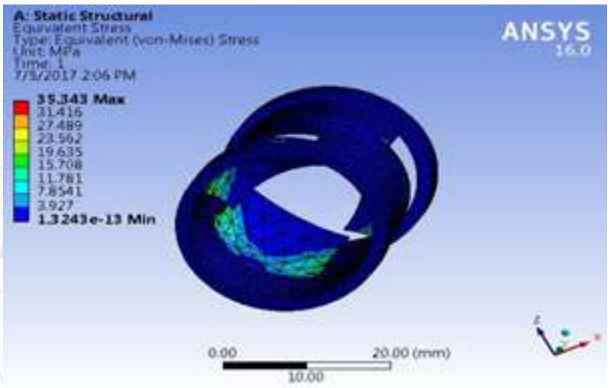


Figure: von-Misses stress results of diverter tube

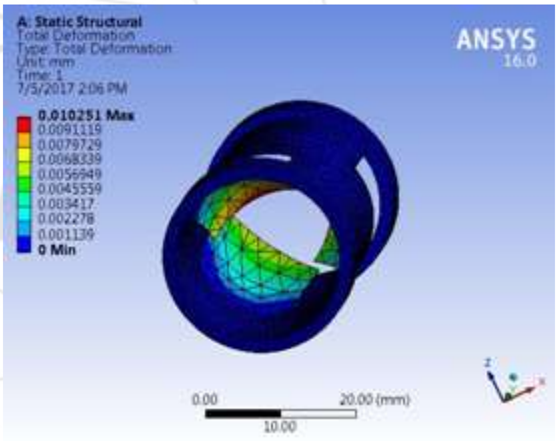


Figure: Total deformation of diverter tube

Analysis of Inlet Diffuser tube-

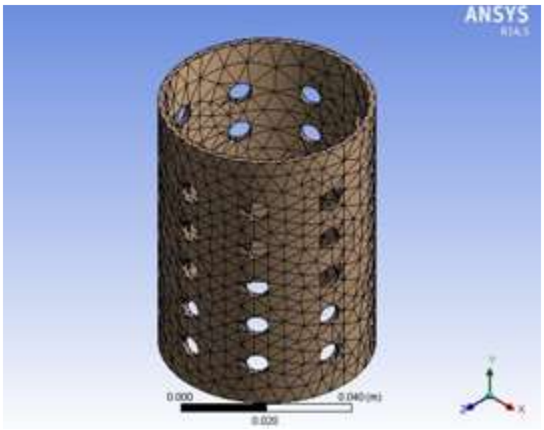


Figure: Meshed model of Inlet diffuser tube

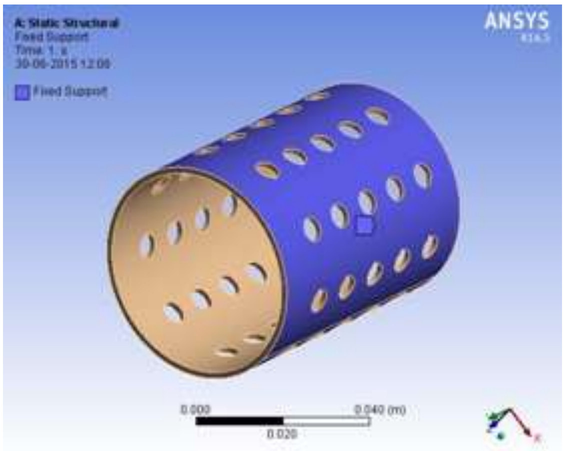


Figure: Boundary cond 1 of Inlet diffuser tube (Fixed sup)

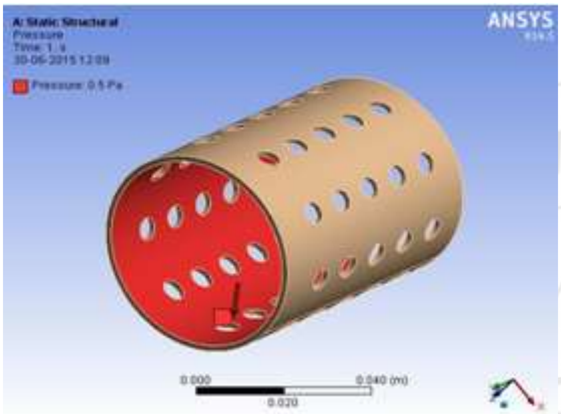


Figure: Boundary cond 2 of inlet diffuser tube (int press)

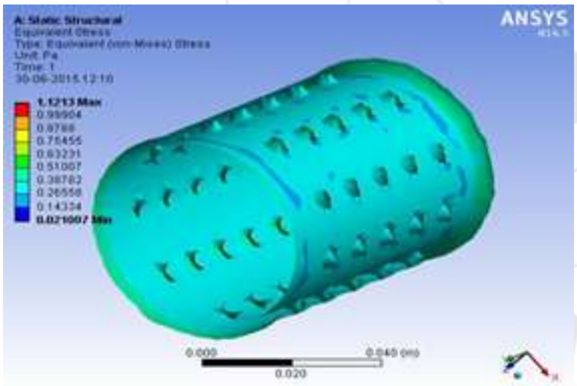


Figure: von-Misses stress result of inlet diffuser tube

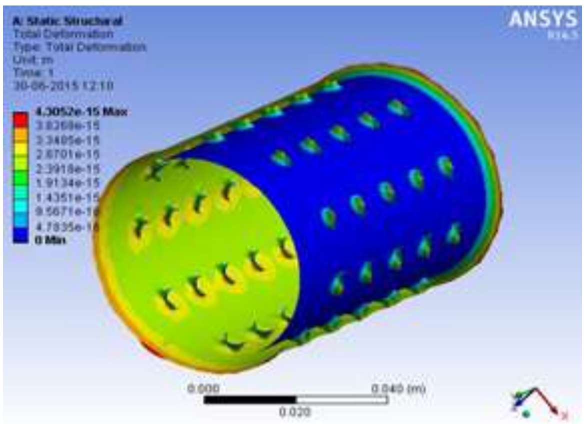


Figure: Total deformation of inlet diffuser tube

Analysis of Membrane-

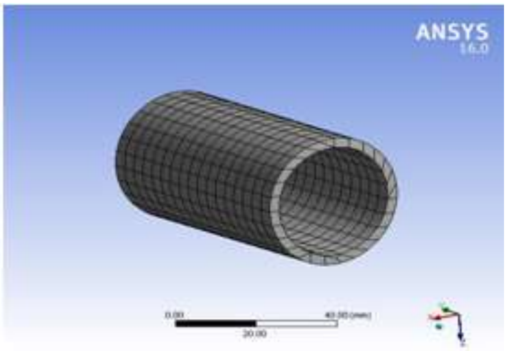


Figure: Meshed model of Membrane

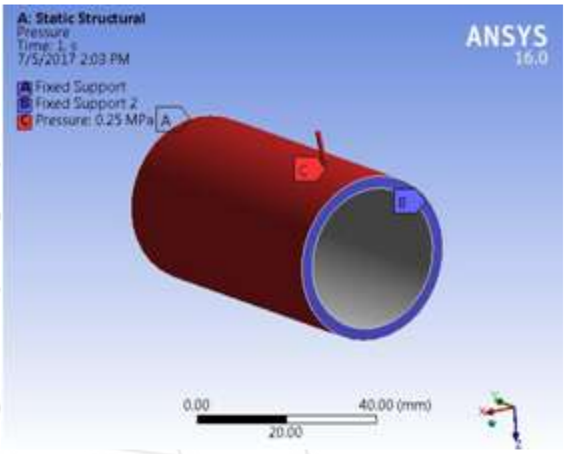


Figure: Boundary cond 1 & 2 of membrane (Fixed sup &Int press)

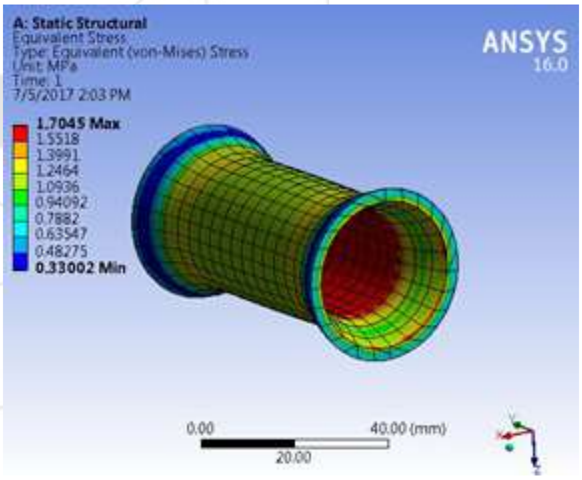


Figure: von-Misses stress result of membrane

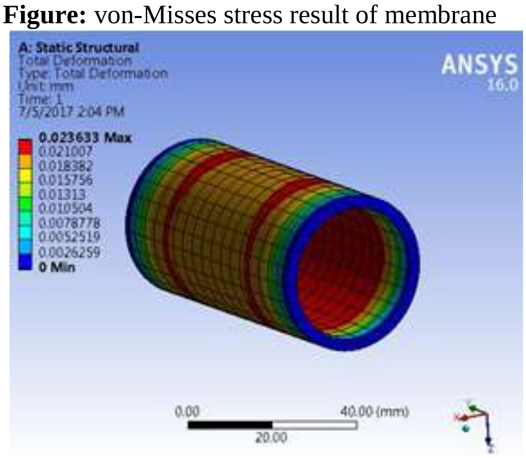


Figure: Total deformation of membrane

Analysis of casing pipe-

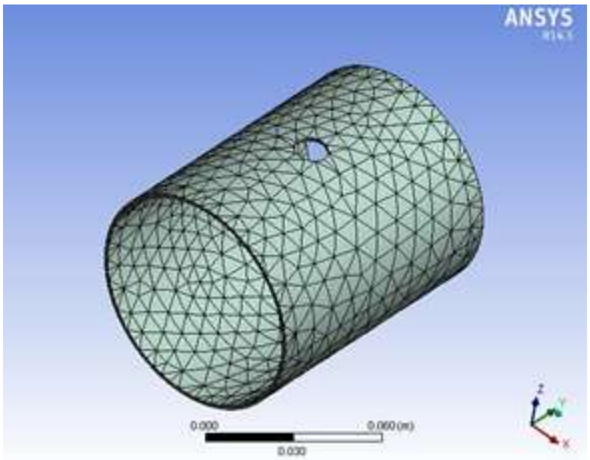


Figure: Meshed model of casing pipe

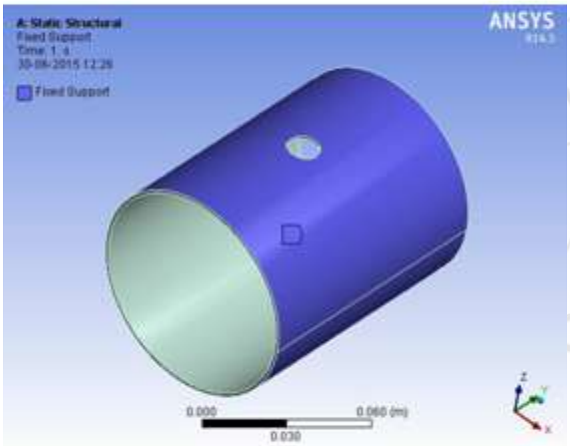


Figure: Boundary cond 1 of casing pipe (Fixed support)

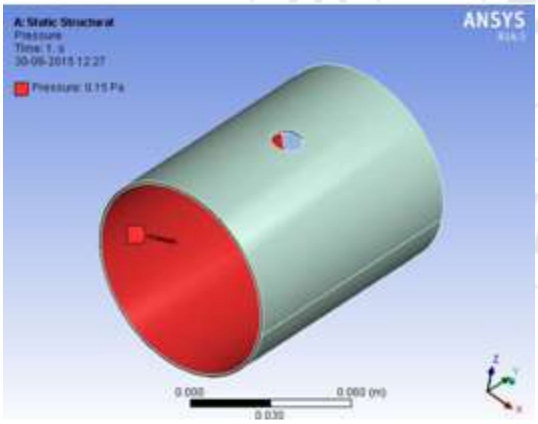


Figure: Boundary cond 2 of casing pipe (Internal pressure)

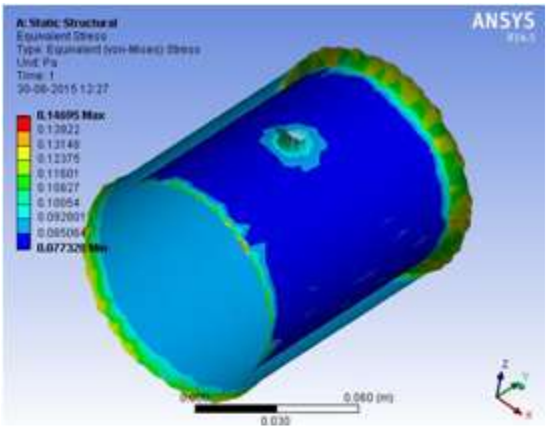


Figure: von-Misses stress result of casing pipe

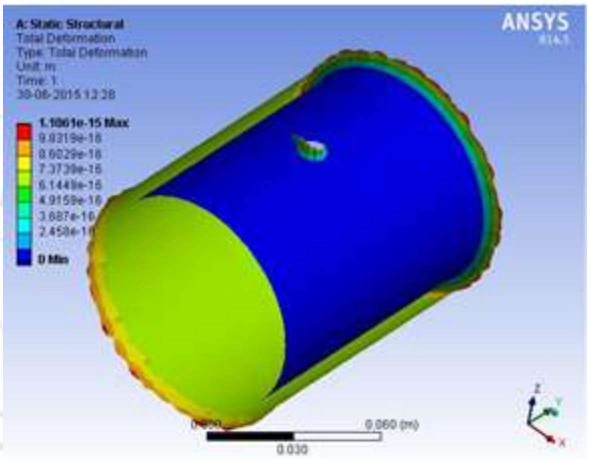


Figure: Total deformation of casing pipe

Analysis Result Summary:-

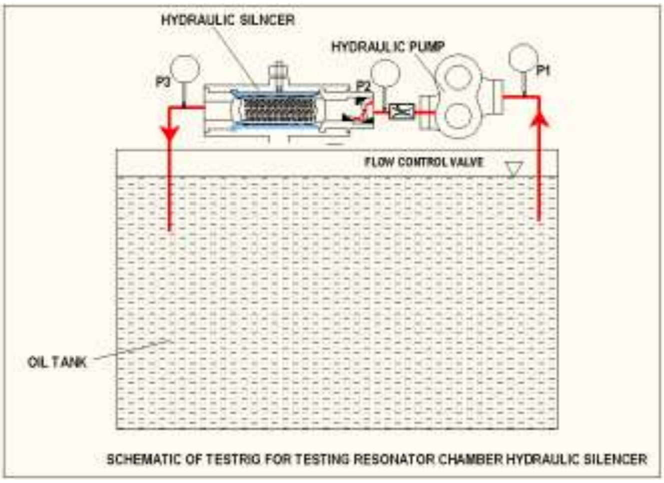
Part Name	Von-Misses stress (Mpa)	Total deformation (mm)
Resonator chamber	5.185 x 10-7	8.54 x 10-12
Diverter tube	35.343	0.0102
Inlet diffuser tube	1.12 x 10-6	4.3 x 10-12
Membrane	1.7045	0.023
Casing pipe	1.46 x 10-7	1.10 x 10-12

7. Procedure

The tank is filled with the lubricating oil-SAE20 W 60 with specific gravity of 0.985.

- Proper electrical connections are made and motor started.
- By using regulator pump speed increased / decreased.
- As the pump speed increases, flow rate also increases.
- Noise level readings are taken for every 60ml of oil collected in jar by increasing flow rate every time.
- Sound level meter is used for the measurement of audible noise.

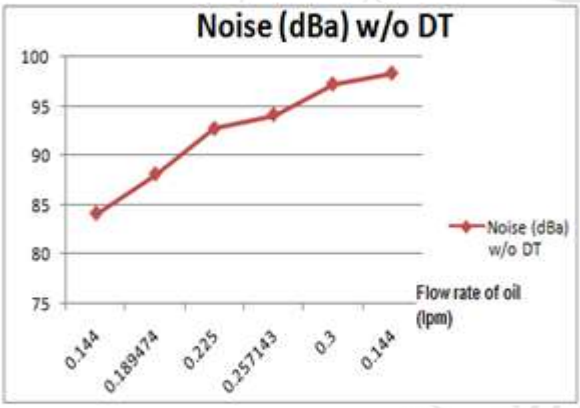
Test rig set-up:



8. Results

Observations:
<u>Without Diverter tube</u>

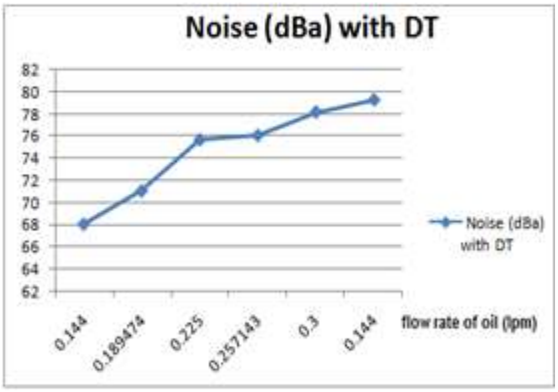
Sr. No	Volume (ml)	Time (sec)	Flow rate LPM	Noise (dBA)
01	60	30	0.144	84.1
02	60	25	0.189474	88.1
03	60	19	0.225	92.7
04	60	16	0.257143	94.1
05	60	14	0.3	97.2
06	60	12	0.144	98.3



Graph1. Noise vs Flow rate for suppressor without diverter tube

With Diverter Tube

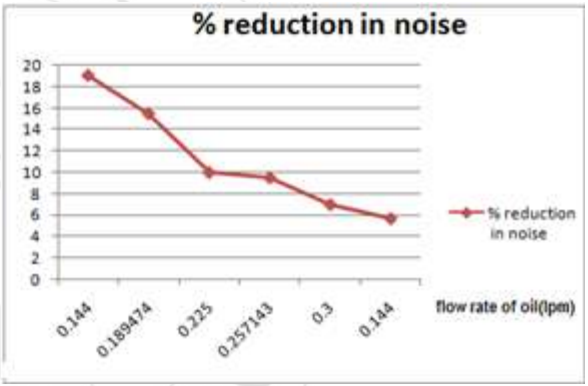
Sr. No	Volume (ml)	Time (sec)	Flow rate LPM	Noise (dBA)	% reduction In noise
01	60	30	0.144	68.1	19.02497
02	60	25	0.189474	71.1	15.45779
03	60	19	0.225	75.7	9.988109
04	60	16	0.257143	76.1	9.512485
05	60	14	0.3	78.2	7.015458
06	60	12	0.144	79.3	5.707491



Graph 2: Noise vs Flow rate with Diverter tube

Comparative results with and without Diverter tube

Flow rate	Noise (dBA) without diverter tube	Noise (dBA) with diverter tube
0.144	84.1	68.1
0.189474	88.1	71.1
0.225	92.7	75.7
0.257143	94.1	76.1
0.3	97.2	78.2
0.144	98.3	79.3



Graph 3: % reduction of noise vs Flow rate

Graph 1 shows Noise vs Flow rate for suppressor without diverter tube. Due to increase in pump speed, pressure pulsation increases hence graph shows increasing trend.

Graph 2. Shows noise vs Flow rate for suppressor with diverter tube.

Graph 3. Shows % noise reduction in suppressor.

9. Conclusion

1) The analysis of Diverter element shows that the diverter is safe under maximum operating pressure and shows negligible deformation under the operating conditions.
2) The analysis of membrane shows that it is safe under maximum operating pressure and shows negligible deformation under operating conditions.
3) The tests and trials indicate the noise increases with increase in flow rate with minimum noise of 84dBA and maximum of 98.3dBA. It is also clear that the noise suppressor successfully reduces noise.
4) The test and trial also shows that a maximum of 19% reduction in noise over conventional method is possible.

10. Acknowledgment

I acknowledge and express my profound sense of gratitude and thanks to everybody being a source of inspiration during the experimentation.

The consistent guidance and support provided by Prof. M.S. Ramgir is very thankfully acknowledged and appreciated for the key role played by him that enabled me in shaping the experimental work.

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