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# Design Analysis and Testing of Diverter mechanism based noise suppressor for single piston pump system for minimum quantity lubrication application.

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**Abstract -** *Minimum quantity lubrication is a new concept in lubrication methods where in a metered quantity of lubricant is delivered by the MQL system to the machine / process under consideration. These systems normally employ piston pumps for application due to accuracy of the piston pump in delivering exact quantity of fluid. But noise generated from this pump is the main problem in industries. Pump noise can be categorized into two basic classes namely the audible noise that can be heard and needs to be controlled to maintain comfort level in the industry / workshop where this device is used and secondly the pump noise in form of pulsations of flow which is more significant because it one of the major cause of inaccuracies in the metered quantity of fluid. The proposed design is developed for R-11 pumping element to be used in one such MQL pumping unit. The purpose of paper is to discuss the design and analysis of two critical components namely the neo-polymer membrane (Eartlon-66) and the diverter that play a significant role in noise reduction. The paper also discusses the effect of change in discharge from pump on the audible noise from the system.*

***Key Words*: Diverter, Minimum quantity lubrication, neo-polymer membrane, Piston pump.**

## 1. INTRODUCTION

Minimum quantity lubrication (MQL) has increasingly found its way into the area of metal cutting machining and, in many areas, has already been established as an alternative to conventional wet processing. In contrast to flood lubrication, minimum quantity lubrication uses only a few drops of lubrication (approx. 50 ml to 500 ml per hour) in machining. [1] Today, the enormous cost-saving potential resulting from doing almost entirely without metalworking fluids in machining production is recognized and implemented by many companies, primarily in the automotive industry. While in the early 1990s small applications (sawing, drilling) were done "dry", today we are able to produce cylinder heads, crankcases, camshafts and numerous other components made of common materials – such as steel, cast iron and aluminum – using MQL in the framework of highly automated large volume production. The advantages of this new technology are clear. With respect to occupational safety, MQL offers reduction in permissible exposure to mist in work area, [2] and numerous advantages over water-mixed metalworking fluids.

Minimum quantity lubrication is a total-loss lubrication method rather than the circulated lubrication method used with emulsions. This means using new, clean lubricants that are fatty-alcohol or ester based.

Minimum quantity lubrication is a new concept in lubrication methods where in a metered quantity of lubricant is delivered by the MQL system to the machine / process under consideration. These systems normally employ piston pumps for application due to accuracy of the piston pump in delivering exact quantity of fluid. Pump noise can be categorized into two basic classes namely the audible noise that can be heard and needs to be controlled to maintain comfort level in the industry / workshop where this device is used and secondly the pump noise in form of pulsations of flow which is more significant because it one of the major cause of inaccuracies in the metered quantity of fluid. The variable forces inside the pump mainly depend on variations of pressure within the pump. They change periodically with the change of the load at the displacement elements. [3]

## 2. LITERATURE REVIEW

**Anurag goyal, Jasvir S. Tiwana, Amrit Pal [1]** has studied the Minimum Quantity Lubrication in machining. minimum quantity of lubrication (MQL) is newly developed economic and environmental friendly alternative to completely dry or flood lubrication. MQL refers to the use of a small amount of cutting fluid, typically in order of 500 ml/hr or less, which are about three to four orders of magnitudes lower than that used in flooded lubricating conditions, MQL technique consists in atomizing a very small quantity of lubricant in an airflow directed towards the cutting zone [1].

**D.V. Lohar and C.R. Nanavaty [2]** have explained in his paper about advantages of Minimum Quantity lubrication (MQL) in maintaining the regulations of occupational Health and Safety (OSHA). MQL offers least exposure to mist within a plant [2].

**Wieslaw Fiebig [3]** has explained that noise generated by power units cannot be sufficiently decreased with primary approaches towards single components. Guidelines are provided for the design of power units regarding noise reduction. Study shows that noise emitted by pumps depends on their mounting, i.e., the application and the layout of the piping. Practical experience also shows that a pump considered silent in an anechoic room can cause high noise emission when built into a real system. Their study gives conclusion that successful noise reduction of hydraulic systems can only be achieved when the design at the loudest noise sources is changed. Therefore, detection of the loudest noise sources in a power unit is most important.

**Binghui and Moore [4]** explained about noise control in fluid power systems. Their study shows that Pressure pulsations which are created by the operation of pumps in hydraulic system, is one of the primary causes of noise issues from hydraulic machinery. Energy resulting from such pulsation propagates in both the wall and the fluid of the flow pipes associated with the fluid power systems, inducing fluid borne vibration of the pipes and the consequent noise radiated from the pipes. They have presented a case study of noise control for a series of marine hydraulic mooring winch systems installed on a marine barge, which emit excessive noise levels during operation. Also the installation of passive pulsation suppressors was proposed as the most practical solution to control pulsation from the fluid power.

**Lin Wang [5]** explained in his thesis about effective active control methods of noise control. Various active control methods like online noise control algorithm, frequency domain noise control, described. All these methods are complicated and also required lot of computation.

## 3. OBJECTIVES

- Design and fabrication of Air charged hydraulic noise suppressor.
- Design and fabrication of test rig to test the hydraulic suppressor system.
- Compare the noise generation of hydraulic system without suppressor and with suppressor unit.
- Study of % reduction in noise according to changes in flow rate of fluid.

## 4. SYSTEM COMPONENTS

Considering that the heart of the MQL system is the dispensing unit i.e. the pump used to supply the fluid to the lubricant system, the pump element used in the system is as follows:

The proposed design is developed for R-11 pumping element to be used in one such MQL pumping unit.


**Fig -1**: Pumping Element [6]

**Table -1:** Technical Specification [6]

| **Technical Specification of Piston Pump** | |
|---|---|
| Designation | Pumping element for 11R / 12R |
| Design | Plunger type valve control |
| Mounting | Face Mounting |
| Speed range | 300 to 2000 rpm |
| Hydraulic medium | Mineral oil |
| Viscosity Range | 10 to 100cSt |
| Optimum Viscosity range | 16 to 32 CSt |
| Temperature range | -10°C to +80°C |
| Mass | 0.7Kg |

In case of the MQL system the operating pressure is between minimum of 3bar to maximum of 5 bar. Hence the maximum design pressure for the analysis purpose of diverter and neo-polymer eartlon-66 material is taken to be 5 bar.

The arrangement of components in the noise suppressor is as shown below figure 2:

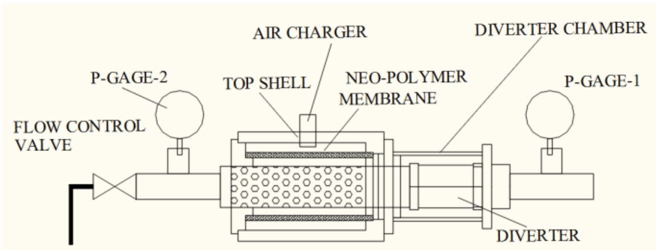


**Fig -2**: Components of Noise suppressor system

System consists of following Elements:-

- Pressure gauge 1:- 1st pressure gauge is used for the measurement of incoming fluid pressure.
- Diverter Chamber: - Diverter chamber is used for diverting the path of the fluid.
- Resonating Chamber: - Resonating chamber Covered with Top shell. Air bladder of Neo- polymer membrane is located inside the chamber. Bladder is charged by compressed air through air charger.
- Pressure gauge 2: - 2nd pressure gauge is used for the measurement of outgoing fluid pressure.
- Flow control Valve: - The valve is used for controlling the flow of fluid.

## 5. MODAL ANALYSIS

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### 1.1 Diverter

Figure 4 shows geometry which is developed in UG-Nx 8 and step file is used as input to Ansys Workbench-16.0.Diverter is made of Copper with OD 23 mm & ID 22 mm.Meshing type is free mesh with tetrahedral elements, 8134 nodes and 3792 elements

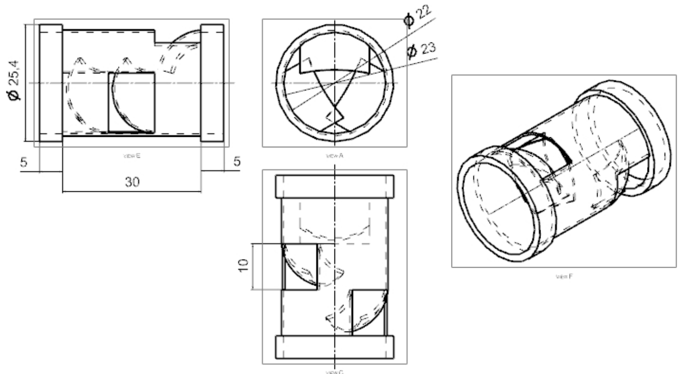


**Fig -3**: CAD Drawing of Diverter

**Fig -4**: Geometry of Diverter

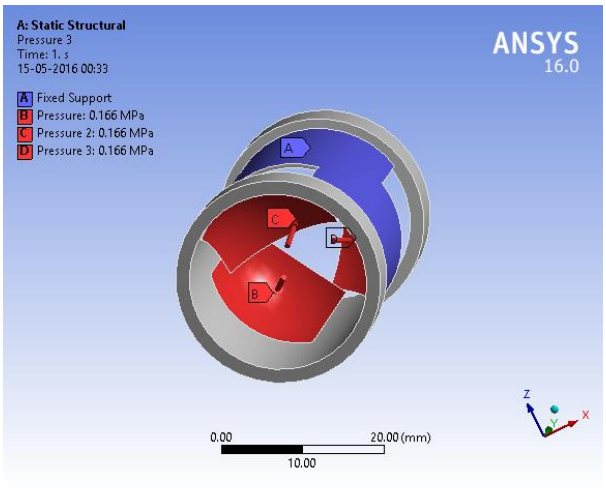


**Fig -5**: Boundary conditions & Pressure intensity

Fixed support A provided over Dia 22 mm as shown in figure 5.Pressure of 0.166 MPa is applied at 3 diverting faces to determine the equivalent stress.

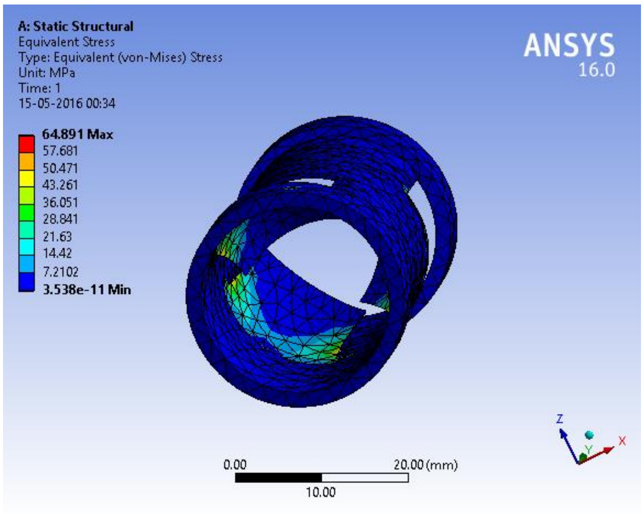


**Fig- 6**: Stress induced in Diverter

Figure 6 shows that maximum stress induced 64.9 N/mm2 <allowable stress 150 N/mm2 for the given component material hence the diverter element is safe.

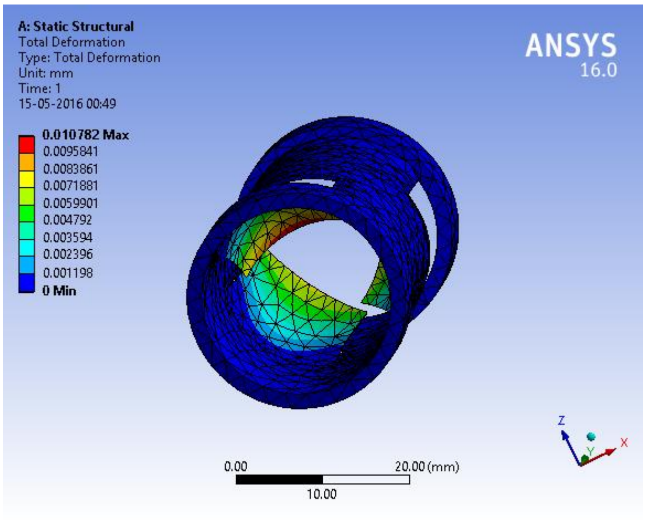


**Fig- 7:** Total Deformation

Figure 7 shows that Maximum deformation of the component is 0.0107 mm

### 1.2 Neo- Polymer EARTLON membrane

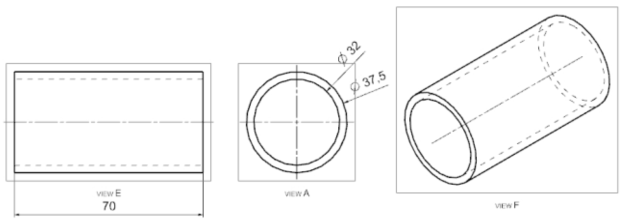


**Fig- 8:** CAD Drawing of Neo polymer membrane

Figure 9 shows geometry is developed in UG-Nx 8 and step file is used as input to Ansys Workbench-16.0 Bladder is designed of neo polymer, 70mm length & 37.5 mm OD & 32 mm ID. Meshing type is free mesh with tetrahedral elements, 3207 nodes and 476 elements.

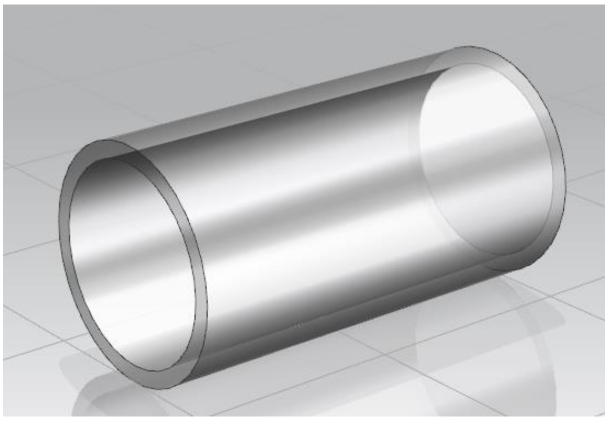

**Fig- 8:** Neo polymer membrane Geometry

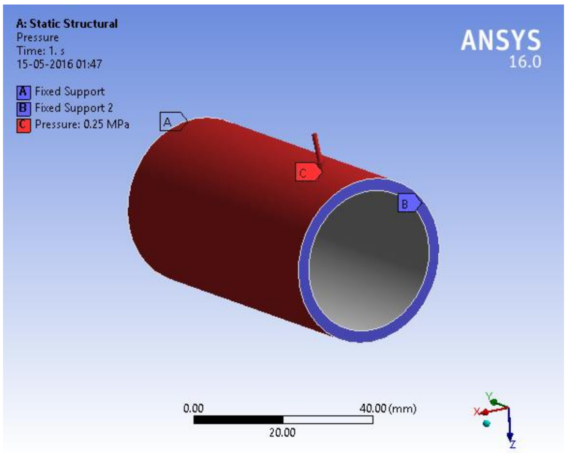


**Fig- 9:** Boundary conditions & Pressure intensity

Fixed support A provided over one end face of bladder as shown in figure 9 .Pressure of 0.25 MPa is applied over OD to determine the equivalent stress.

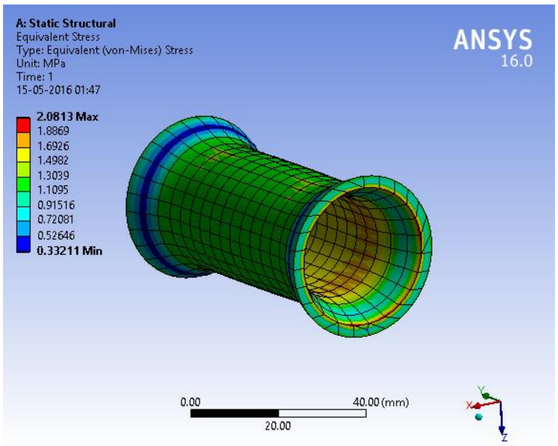


**Fig- 10:** Stress Analysis

Figure 10 shows Maximum stress induced 2.08 N/mm2 <allowable stress 32N/mm2 for the given component material (EARTLON -66) hence the NEO-POLYMER EARTLON MEMBRANE is safe.

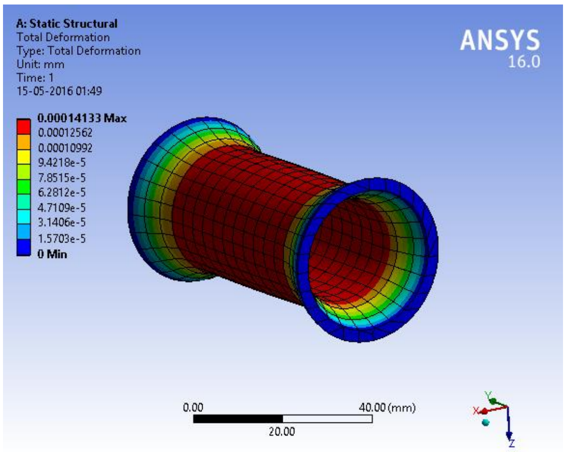


**Fig- 11:** Total deformation

Maximum deformation of the NEO-POLYMER MEMBRANE is 0.0107 mm as shown in figure 11.

## 6. TESTING

Test and trial on the Diverter mechanism based noise suppressor for single piston pump system for minimum quantity lubrication application is as shown below:

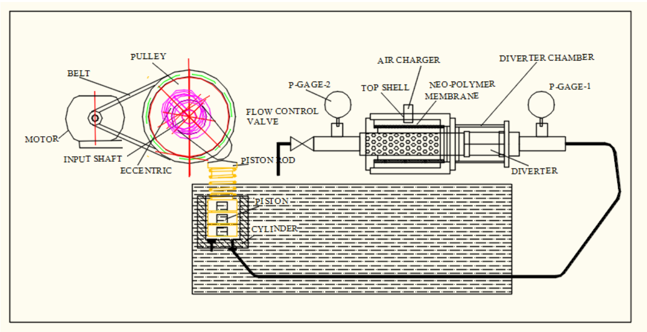


**Fig- 12:** Working of Hydraulic Noise Suppressor

### 6.1 Procedure:

The tank is filled with the lubricating Oil- SAE 20 W 60 with specific gravity 0.985.

- Proper Electrical connections are done & Motor started.
- By using regulator pump speed increased/ decreased.
- As the pump speed increases, flow rate also increased.
- Noise level readings are taken for every 20 ml of oil collected in beaker by increasing the flow rate every time.
- DB Meter is used for the measurement of audible noise.

Noise of the system without noise suppressor with maximum discharge of 0.1 liter per minute is 108 dBA.


**Fig- 13:** dB Meter used for Noise measurement

Figure 13 shows Digital sound level meter GM 135.1 is used for the measurement of process audible noise.

## 7. RESULTS

**Table -2:** Result Table

| Sr. No | Volume (ml) | Time (sec) | Flow rate LPM | Noise (dBA) | % Reduction in noise |
|---|---|---|---|---|---|
| 01 | 20 | 30 | 0.04 | 84.1 | 22.12962963 |
| 02 | 20 | 25 | 0.048 | 88.1 | 18.42592593 |
| 03 | 20 | 19 | 0.063 158 | 92.7 | 14.16666667 |
| 04 | 20 | 16 | 0.075 | 94.1 | 12.87037037 |
| 05 | 20 | 14 | 0.085 714 | 97.2 | 10 |
| 06 | 20 | 12 | 0.1 | 98.3 | 8.981481481 |

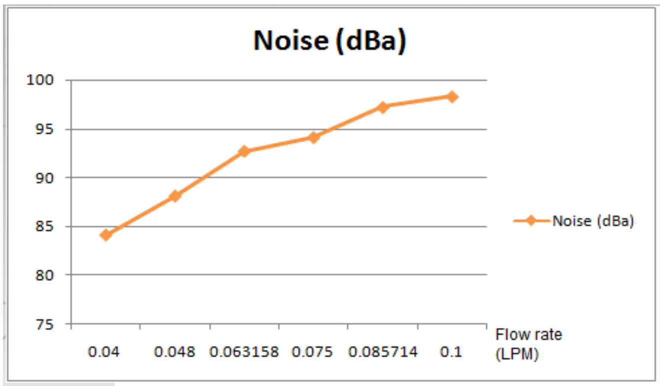


**Chart -2:** Graph of Noise Vs Flow rate

Chart 1 shows Graph of % Reduction Noise Vs Flow rate. Graph indicates the system noise increases with the increase in flow rate.

Due to increase in pump speed, pressure pulsation increases hence graph shows increasing trend.

But graph also shows that, for maximum flow rate of 0.1 LPM the noise rating is well below of 108 dBA which is noise level of pump unit without suppressor.

It shows the effectiveness of the noise suppressor.

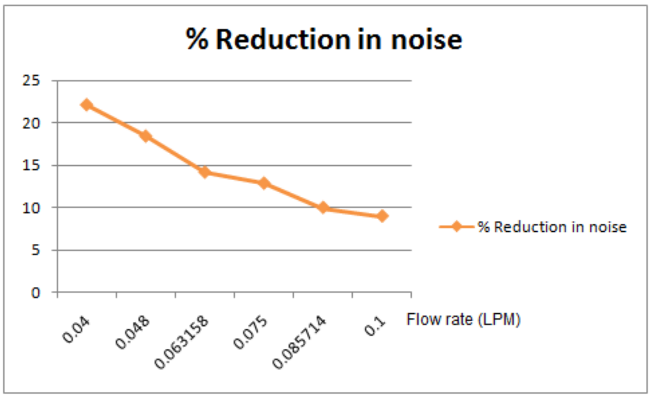


**Chart -2:** % Reduction in Noise Vs Flow rate

Chart 2 shows graph of % noise reduction Vs flow rate. Graph shows reducing trend that means % noise reduction also reduced as we are increasing flow rate of fluid.

## 8. CONCLUSION

- The analysis of the diverter element shows that the diverter is safe under maximum operating pressure and shows negligible deformation under the operating conditions.
- The analysis of the neo-polymer membrane shows that it is safe under maximum operating pressure and shows negligible deformation under the operating conditions.
- The Test and trial indicate that the noise increases with increase in flow rate with minimum noise of 84 dBA and maximum noise of 98.3 dBA. It is also clear that the noise reducer successfully reduces the noise level well below that without noise reducer.
- The Test and trial indicates that a maximum of 22% reduction in noise over conventional method is possible by us of modified diverter chamber noise reducer.

## 9. FUTURE SCOPE

The Test and trial on the device can be done by controlling the output valve opening to study the drop in pressure across the noise suppressor indicating system noise as a function of pressure drop, this will be done using pressure gage 1& 2 in circuit.

Analysis of other components of system will be done.

Recommendations will be made on basis of testing data as to application and usage of the noise suppressor.

An comparative analysis of the diverter noise reducer to the conventional method will be done to show effect on the accuracy of the MQL system after use of the diverter chamber noise reducer

## ACKNOWLEDGEMENT

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