Finite Element Analysis and Optimization of Pressure Line Filter of 250bar

Shashank Karne, S. M. Bapat

Abstract- This paper deals with the FEA implementation for analysis and optimization of pressure line filter for 250bar. The main aim is to reduce the cost of the products without compromising on the quality of the output. Using the optimum resources possible in designing the hydraulic products can effect this reduction in the cost of the hydraulic product. One way of doing it will be the optimizing the volume of material utilized for building the structure. An attempt has been made in this direction to reduce the volume of material. So here we consider an industrial application project consisting of mass minimization of a pressure line filter. This filter has to compensate the forces acting on the body and has to fulfill certain critical constraints. ANSYS has been used for this analysis which uses finite element method for solution. The methodology followed in this work is comparison of stresses induced in the filter body used for construction of body of the pressure line filter. These stresses are compared to yield stress and considering minimum factor of safety in range of 2 to 3.

Keywords— ANSYS, FEA, optimization, design, filter

I. INTRODUCTION

The pressure line filters are placed between pumps and the critical components like motors valves, cylinder. They are used to protect the critical component from the large damage. Donaldson pressure line filters are rated up to the working pressure of 450bar. They are many different types and porting sizes, as well as various styles is existing for wide range of application. The pressure line filter is ideal for application in simpler hydraulic system. It provides consistent protection to dirt delicate component. The sintered bronze filter sealed unit is used to provide the complete filtration. The body and cover are made of high power casting with nitrite rubber seal. The porosity of the filtration is available in 10, 20 and 75 micron ratings. To prevent the system from the contamination there are no bypass valves are provided. The maximum working pressure is 140bar and capacity of fluid flow is 20 LPM.

Model code	Filtration capacity (micron)
PLF-03-10	10
PLF-03-25	25
PLF-03-75	75

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II. LITERATURE SURVEY

B. Aruljothi And A. M. Junaid Basha(2014) have examined that the air ship channels must be intended to provide for high reliability and rigorous environmental conditions. The working performance of filter is decided based on the filter media and its evaluation. Filter is evaluated using multi pass test under constant fluid flow conditions. Usually there are two varieties of media which are used in the development of aircraft hydraulic filters first one is glass fibre media and second one is stainless steel mesh media. Glass fibre media is considered as absolute valued and has high filtration efficiency when compared to the stainless steel mesh media. These stainless steel mesh media filters are of non-disposable in environment and have nominal filter grade. This paper defines the absolute study of both filter Medias and valuation of filter rating using multi pass test. To determine the filter performance filter rating is an important parameter. Generally in the aircraft hydraulic system Glass fibre and stainless steel Medias are used. A glass fibre having 10 μ filter multi-pass test is compared with a 12 μ stainless steel media for filter rating performance. Myounggu (2002) has studied the working failure of a hydraulic filter that has been installed on a battle aircraft. Cracking had happened at the filter head and did not find the sign of plastic deformation. After the Chemical inspection and micro-hardness measurement shown that the filter head material was Al 6061-T6 but the material accidentally chosen for filters from the field was Al 2024-T4. So it is confirmed that it is due to the wrong material selection. Metallography has exposed that the micro structural irregularities are the reason to the early fracture of hydraulic filter head. When the surface of the fracture region is examined is revealed that it's due to the series of grooves and so it was confirmed that the fracture type was fatigue. At the beginning position there were corrosion pits given that initiation sites for fatigue cracks. Parker Arlon (2003) has presented different other new system to avoid the breakdown of the hydraulic systems, the MGSB filter. Approximately 80% of hydraulic system will breakdown due to the cause of oil contamination and the cost of maintenance are reduced due to the efficient filtering processes. The MGSB filters which have the higher capacity which can even manage the maximum fluid flow of 250 LPM at 250bar pressure. The head of the filter and the bowl are prepared by using aluminium and steel. The further adaptable MGSB filter can be prepared which are having 3, 6, 10 and 20 micron filter element of glass fibre. In MGSB filter pressure release valve is joined into the head of the filter so called 'third port' concept into its design.

When the valve are opened most of the oil flows which are not filtered through the third port, and then securely goes back into the tank. When the filter desires exchanging or is not working then only pressure relief valves are introduced. It transfers the more traditional by-pass valve. The contamination of the oil in the hydraulic system is protected by the filters and also good performances to avoid unsatisfactory lubrication of system components during cold starts, and holds back a lesser quantity of filtered oil for alternative action, in case if definite components become too hot.

III. PROJECT DETAILS

The following objectives are proposed in the present analysis work for pressure line filter.

- To analyse the stress induced in the filters due to the pressure of 250bar.
- To identify the flaws in the design.
- To build a prototype using CATIA and analyze the same using ANSYS.
- To estimate the maximum and minimum stress acting on the material.
- To validate the results with manual results.
- To optimize the material cost of the product.

1st stage: - The dimension of the filter is finalized by the sponsors.

2nd stage: - Taking the dimensions from the AutoCAD model the filter parts are modeled in ANSYS.

8-node solid 45 is used for three dimensional modeling of solid structures. 8-node solid 45 has been selected for the analysis of the body. It provides more accurate results for fusions automatic meshes and can tolerate unpredictable shapes without as much loss of precision. The 8-node elements have good displacement shapes and are appropriate to model boundaries. These 8-node elements have defined by 8-nodes having three degree of freedom at every node; changes in the nodal x, y and z directions. The element have plasticity, creep, and swelling: stress stiffening, great deflection, and huge strain abilities. Element loads are described in node and element loads. Pressure may be the involvement as surface loads on the element. Positive pressures act into the element on a full 360º.One can include the effect of pressure load stiffness in a geometric nonlinear analysis. Temperature maybe input of element body loads at the nodes. The solution input associated is in two forms one is the nodal displacement of the element and other is the nodal stress of the element. The element stress direction is parallel to the element coordinate system. Zero volume components are not permitted additionally the component might or not be turned such that the component has the different volumes. This happens frequently when elements are not numbered properly. Material properties are constitutive properties of material such as modulus of elasticity, density independent of geometry. These material properties are obtained from experimental testing. Depending upon application, property may be lined, nonlinear, isotropic, anisotropic, etc. For this analysis the material properties are isotropic. Details are given underneath.

3rd stage: - Application boundary conditions and loads are the most important part of the ansys for the designer. For this through understanding of the problem is necessary. The boundary conditions are applied for the housing or body of the filter. The maximum pressure applied inside the body of the filter is 250bar and after that Structural analysis is carried out to identify stress and deflection.

4th stage: - The results obtained from the analysis are taken and checked for their validity and Material optimization is carried out.

5th stage: - Interpretation, Suggestion & Optimization Stress and Deflection obtained from the analysis are compared with the optimum values taking into consideration of minimum of factor of safety of 2.0. The thickness of body of the filter is reduced to next standard size of thickness available in the company if the factor of safety comes to know from the analysis is above 2.0

IV. ANALYSIS

Modeling: Building a finite element model helps additional time than whatever other parts of the examination. First and foremost, we indicate a job name and examination heading. At that point, you can utilize the PREP7 preprocessor to characterize the component sorts, component real constants, material properties, and the model geometry. The model made is the housing or the collection of the pressure line filter having the length 71mm. The entire assembly is comprised of mild steel.

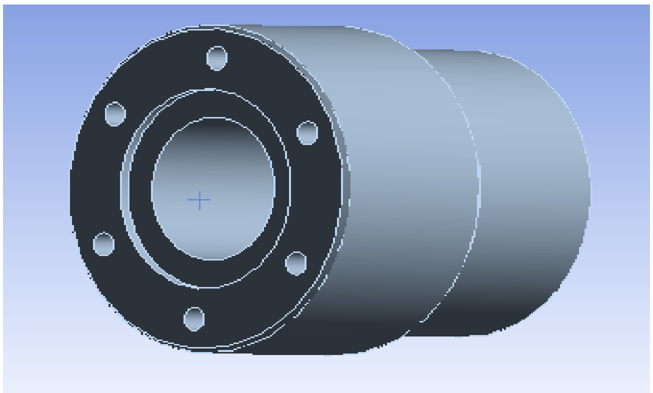

Fig. 1. Modeling of the body

Meshing: When we have constructed strong model of the housing, built up component characteristics, and settled meshing controls, we are arranged to create the limited element mesh. Mesh controls permit building up such elements as the component shape, moderate size node arrangement, and component size to be utilized as a part of meshing the solid model.

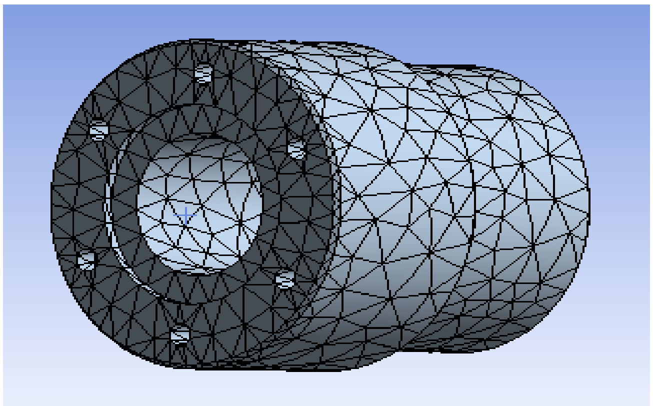

Fig. 2. Meshing of the body

Boundary Conditions: We can apply most limit conditions and excitations to a harmonic high-recurrence investigation either on the solid model elements or on the limited element model substances. Put on limit conditions to the solid model is helpful in that they are independent of the principal limited element meshing. Ensuing meshing refinement does not need reapplying the boundary conditions and excitation if adaptive meshing is utilized.

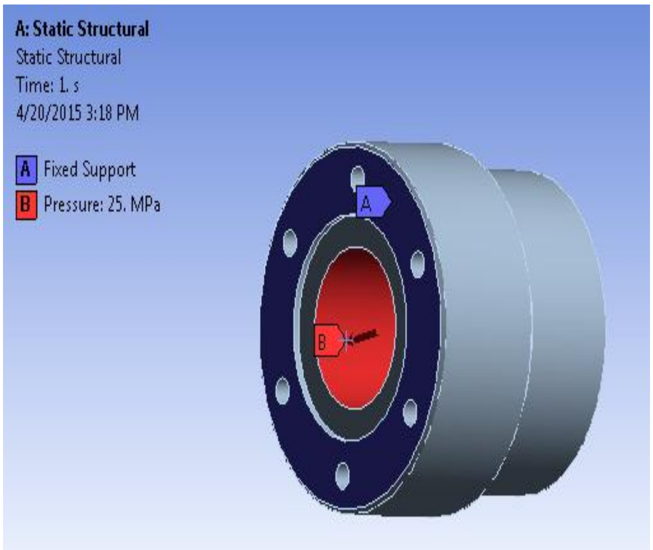

Fig. 3. Pressure applied on the body

The essential objective of this analysis is to take a look at how a structure responds to loading conditions. Distinguishing the suitable loading conditions is, along these lines, a key in the analysis. We can apply the loads on the model in an alternate ways in the ANSYS programs. With the assistance of load step alternatives, while doing the arrangement we can have the control over the loads. The body is constrained in all DOF. Loads Applied: We can apply the majority of the loads either on the solid model or on key, point, lines, and regions and even we can apply on the FEM on nodes. Case in point, we can distinguish forces at a key point or a node. Likewise, we can indicate convections and further surface loads on lines and area or on nodes and elements. The particular of the load does not make a difference; the solver accepts all loads should be regarding the finite element model. Consequently, when the particular of the loads on the model is done, the project regularly transfers them to the nodes and element toward the start of result. A pressure of 250bar is applied at the inward side of the body.

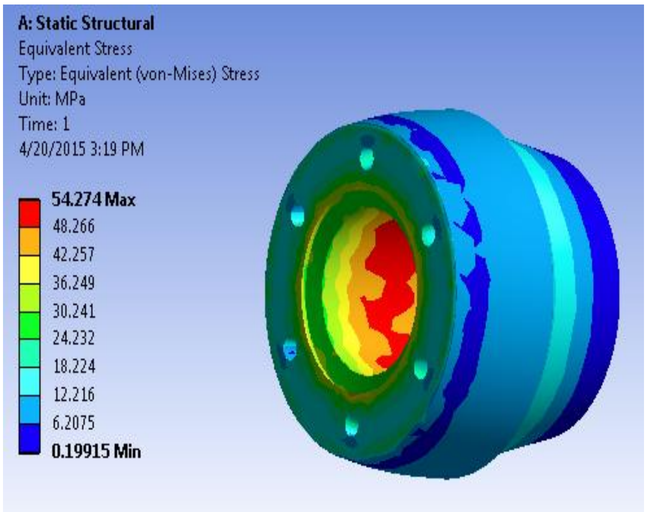

Fig. 4(a)

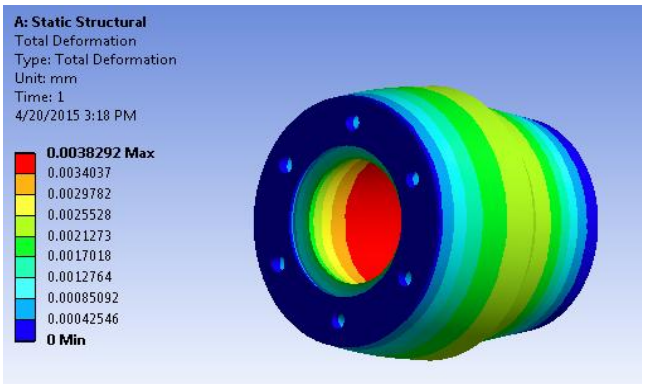

Fig. 4(b)

Fig. 4(a), (b) shows maximum stress and deformation of the body

Results Obtained: - The Result obtained from the analysis.

- The Maximum stress induced in the housing or body = 54.274MPa
- The Maximum Displacement for this pressure = 0.003829 mm
- The Maximum stress induced in the body (54.274 MPa) is far below the yield stress of Mild steel is i e 250MPa.
- Therefore now we can reduce the body weight.

V. OPTIMIZATION

In this period of hard competition, every industry cracks to have an advantage over their complements by,

- Introducing the new products to certain range.
- Modifying the previous products.
- To reducing the cost of the material without ant loss in performance level.

Components created in CATIA, are as follows;

- Cover plate:-

Figure shows the circular end plate or cover plate which is made up of mild steel material which is having the thickness 12mm and diameter 78mm, also it consist of six holes of diameter 5.5mm to fasten it with the body or housing. At the center it consists of 14.5mm diameter hole for the outlet of the fluid.

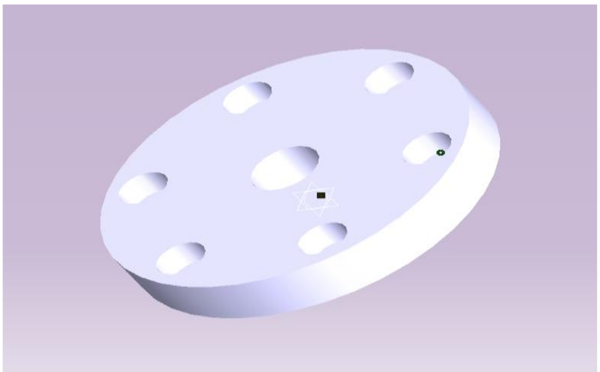

Fig. 5. Cover plate

- Housing:-

The figure shows the external cover of the filter made up of mild steel material. The filter is placed at the center of the body. It also consists of six holes of diameter 5.5mm for fastening of the cover plate. The inlet hole is having the diameter 14.5mm.

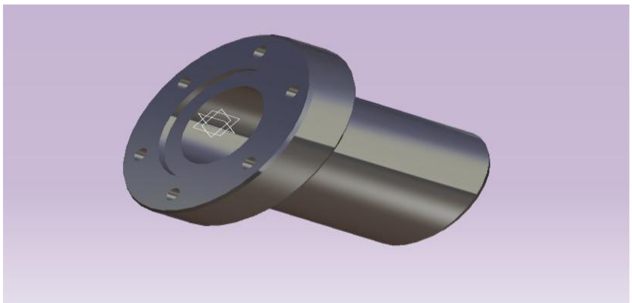

Fig. 6. Housing

- 'O'-Ring:-

The O-ring is made up of polyurethane and it is having the diameter of 47.5mm. It is located in-between the cover plate and the housing. Its main role is to avoid the leakage of fluids from the filter. Some of the features of the product are it has better strength and wear resistance extends seal life, extended temperature range, make simpler installation, decrease damage due to spiral failure, water resistance and extrusion resistant.

Fig. 7. O-ring

- Filter:-

In the hydraulic systems filters are used to avoid the unwanted material passing along with the fluid which may cause damage to the system. Here the material used is bronze and it is manufactured by powder metallurgy process. The powder is packed into the mould, the most important factors that can affect the high porosity of the sintered bronze are size, shape and the spreading of the powder particles now it has to be sintered. Sintering is the process where the bonding between the powder particles through fusion at temperature below melting point.The pores are mechanically fixed regarding size and position after sintering. The length of the filter is 49.5mm.

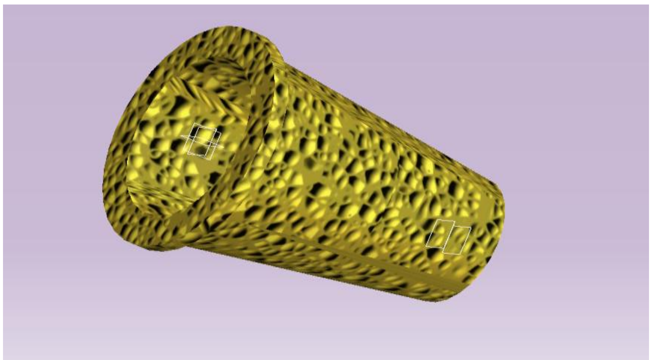

Fig. 8. Filter element

The material used to manufacture the filter is bronze (89%Cu,10%Sn, 1%phosphorous). It will be manufactured by powder metallurgy process. The main advantage of using porous powder metallurgy bronze is the low cost.

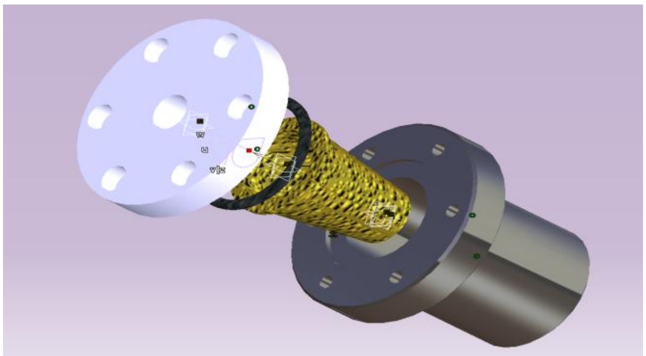

Fig. 9. Assembly

Modeling:-

The body is reconstructed by decreasing the diameter and also removing some of the material. The views are shown below.

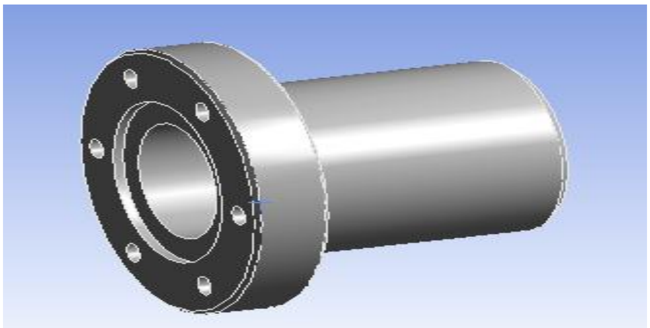

Fig. 10. Modeling view of the body

Meshing:-

Mesh controls permit building up such elements as the component shape, moderate size node arrangement, and component size to be utilized as a part of meshing the solid model.

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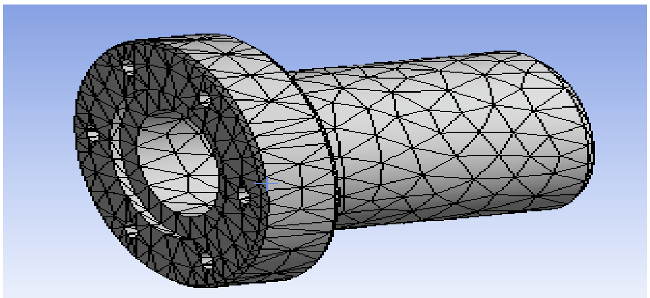


Fig. 11. Meshing of the body

Boundry conditions:-

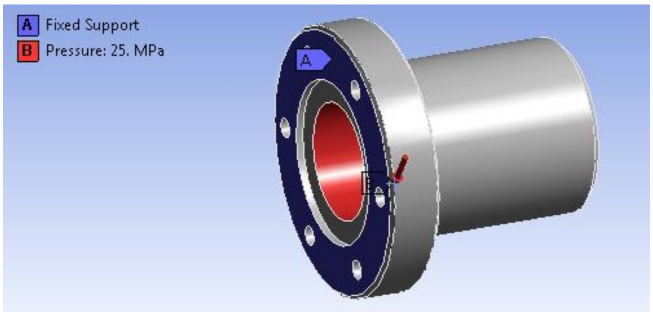
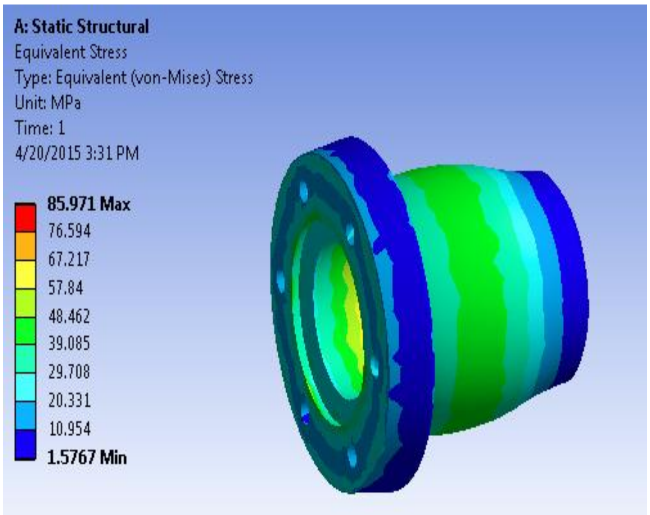
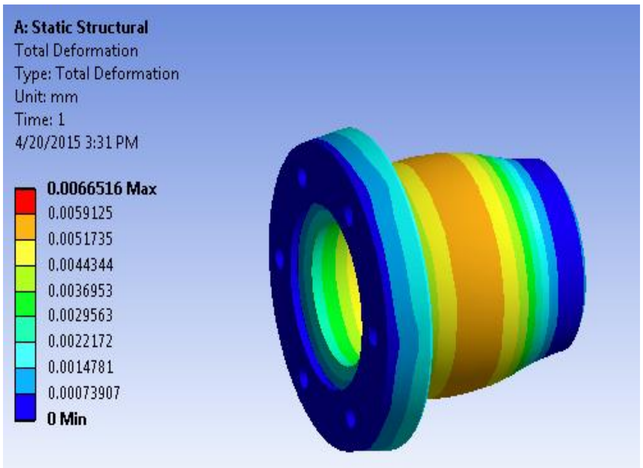


Fig. 12. Boundary condition applied

Results:-



13 (a)



13 (b)

Fig. 13(a), (b) shows maximum stress and deformation of the optimized body

Results obtained after optimization; After optimizing the pressure line filter body, analysis is carried out and results obtained are as follows; After applying 250bar pressure to the filter body internally, The obtained maximum stress in the filter body = 85.9MPa. After applying 250bar pressure to the filter body internally, the obtained maximum deflection in the filter body pressure = 0.00667 mm. The stress obtained now is now slightly below the half of yield stress. Here we are considering factor of safety minimum 2.0.

- The yield stress of Mild steel = 250MPa.
- Maximum stress induced in the body = 85.97MPa.
- The factor of safety = Yield stress / Maximum stress induced in the machine.
- The factor of safety = 250 / 85.97 = 2.9

COMPARISON OF THE RESULTS

Sl. no.	Parameters	Before optimization	After optimization
1	Maximum stress in the body.	54.27Mpa	85.97Mpa
2	Maximum deformation of the body	0.003829mm	0.00667mm
3	Weight of the body	1.935kg	0.982kg
4	Yield strength	250Mpa	250Mpa
5	Factor of safety	4.6	2.9

VI. CALCULATION

The pressure vessels can be classified into thin and thick shell. If the ratio of diameter (d) to thickness (t) ‘d/t’ is more than 10 then it is said to be thin shell and if it is less than 10 then it is said to be thick shell. In the case of the thick cylinder, the stresses are not assumed to be uniformly distributed on the surface. When the cylinder is under the internal pressure only, then there will be two stresses acting on it (i) Tangential stress (ii) Radial stress.

According to Lames Equation;

To design the thick cylinder under pressure Lames equation is used.

Tangential stress;

$$\sigma_t = \{(p_i r_i^2 - p_o r_o^2) / (r_o^2 - r_i^2)\} + \{r_i^2 r_o^2 (p_o - p_i / x^2 (r_o^2 - r_i^2)\}$$

Radial stress;

$$\sigma_r = \{(p_i r_i^2 - p_o r_o^2) / (r_o^2 - r_i^2)\} + \{r_i^2 r_o^2 (p_o - p_i / x^2 (r_o^2 - r_i^2)\}$$

r_o – Outer radius of the cylinder
r_i – Inner radius of the cylinder
p – Internal pressure
t – Thickness of the cylinder
μ – Poisson’s ratio
σ_t - Tangential stress
σ_r - Radial stress
E – Young’s modulus

Here we are dealing with the internal pressure only;

Maximum tangential stress (Tensile)

$$\sigma_{t(max)} = p r_i^2 / r_o^2 - r_i^2 \ (1 + r_o^2/x^2) \quad (x = r_i = 17)$$
$$= (25*17^2 / 25^2 - 17$$
$$= 68 N/mm^2$$

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The internal pressure is always lesser than the maximum tangential stress and also we know that the tangential stress is maximum at the inner surface and minimum at the outer surface.

Maximum radial stress (compression)

$\sigma_{r(max)} = pr_i^2 / r_o^2 - r_i^2 \; (1 - r_o^2/x^2)$

$= (25*17^2 / 25^2 - 17^2) \; (1 - 25^2/17^2)$

$= -25N/mm^2$

Therefore;

Maximum shear stress,

$\tau = p(r_i+t)^2 / (r_i+t)^2 - r_i^2$

$= 25(17^2 + 8^2) / (17+8)^2 - 17^2$

$= 46.5N/mm^2$

The radial stress is maximum at the inner surface and zero at the outer surface.

Deflection;

$\delta d = pd^2/2*t*E \; (1 - \mu/2)$

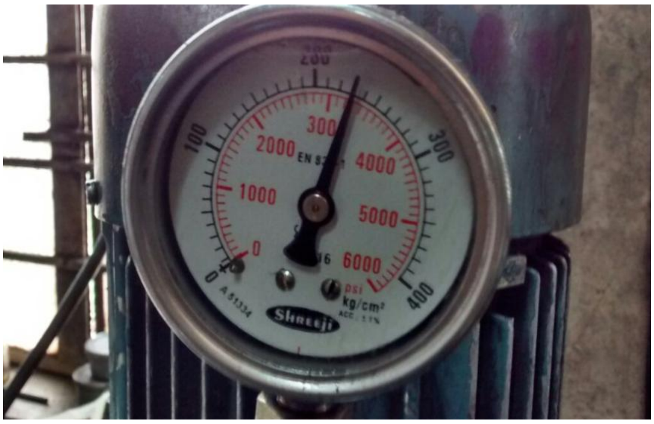
$= (25*34^2 / 2*8*2.1*10^5) \; (1 - 0.3/2)$

$= 0.0073mm$

VII. TESTING

The test is carried out to check any leakages and also to know that the filter can withstand the pressure of 250bar. The figure below shows that, the pressure of 250bar is applied to the filter. It can withstand the pressure without any leakage.

14 (a)



14 (b)

Fig 14(a), (b) Show the pressure of 250bar applied to the filter

VIII. CONCLUSION

An effort is made to analyse the pressure line filter by using the ANSYS software and also optimization is carried out successfully to minimize the cost of the product. The project work carried out is successfully designed to meet the requirement of the company. The pressure line filter is carefully designed and cross checked with the manual calculation. The models of the filter parts are created in the ANSYS software, finished the analysis and also got the maximum stress acting inside the filter and maximum deflection, when 250bar is applied. The maximum stress induced in the filter body is 85.97Mpa that is far a lesser amount than the yield stress of the material having the factor of safety 2.90. And also the maximum deflection found is 0.00667. The weight of the filter body is reduced. The total weight reduced per filter is 0.953kg.And validated the analytical results with the manual results. The filter is working satisfactorily at 250bar pressure without any leakage.

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