International Journal of Advances in Engineering and Management (IJAEM)
Volume 3, Issue 8 Aug 2021, pp: 977-985 www.ijaem.net ISSN: 2395-5252

Static and Dynamic Analysis of Safe Hydraulic Cylinder for Commercial Use

Bhuvan Singh[1], Vivek Gedam[2]
[1]*M.Tech Scholar, "Gyan Ganga Institute of Technology and Sciences, Jabalpur (M.P.)"*
[2]*Assistant Professor, "Gyan Ganga Institute of Technology and Sciences, Jabalpur (M.P.)"*

Submitted: 01-08-2021 Revised: 14-08-2021 Accepted: 17-08-2021

ABSTRACT:
In this paper we are proposing the static and dynamic analysis of safe hydraulic cylinders specifically for commercial use. Hydraulic and pneumatic systems are fluid power systems that are commonly used in the industry nowadays. Although hydraulic cylinders are already in use, hence forth we are trying to improve its working capability. Most failures experienced in hydraulic systems are failures associated with the linear actuator (hydraulic cylinder). Most of these failures are design, materials and structural integrity related one whereby safety standards are not fully satisfied. This paper address the issue of deploying and implementation of acceptable design codes for the design and structural analysis of a double acting double ends hydraulic cylinder basically for industrial automation applications.The combination of Analytical and finite element analysis (FEA) methods was utilized for the development of the cylinder. These are to give credibility to the design for the purpose of future manufacture of the cylinder. The bursting pressure, longitudinal stress piston rod and piston diameter, barbell thickness was determined and analyzed. The methods used for this design work could provide significant knowledge and skill for young design engineers, and this cylinder product may be readily available to industrialist for manufacture.

Keywords: Design, Hydraulics, Cylinder, Industrial, and Automation

I. INTRODUCTION

1.1 HYDRAULIC CYLINDER:

The hydraulic cylinder is the key pressure driven part. It goes comparably a medium and converts the energy of the pressure driven fluid into obliging work. Its information cost is that the pressure driven controlled oil performing outwardly of the chamber of the pressing factor driven chamber. These breezes up in a straight advancement of the chamber, that logically ends up in a partner post related with the pile that progressively winds up in an associating pole associated with the heap.[1] Accordingly, the energy of the pressure driven liquid is brought back to life into manageable force those demonstrations during a line. The water driven medium is now and then oil. In water driven frameworks, produced oils and emulsions, similarly as (water power through pressure) are furthermore used.[2]

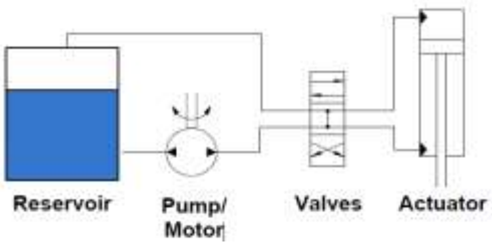


Figure 1: Schematic showing the main components of a hydraulic system [5].

1.2 HYDRAULIC CYLINDER COMPONENTS:

The hydraulic cylinder (pressure driven chamber), includes two fundamental parts, to be unequivocal a chamber and a chamber with a chamber shaft. The chamber base and chamber head autonomously close the different sides of the chamber barrel. [3] The chamber shaft exits through the chamber head. A chamber furnished with a seal and a slip ring portions inside the chamber into two chambers, a lower pressure chamber and an upper chamber bar chamber. The

International Journal of Advances in Engineering and Management (IJAEM)
Volume 3, Issue 8 Aug 2021, pp: 977-985 www.ijaem.net ISSN: 2395-5252

water fuelled crushing variable is made by the chamber, which moves the chamber post in an exact style. This kind of chamber is in addition called a twofold acting water controlled chamber. [5]

II. MATERIALS AND METHODS

The For this research work, the materials adopted include a high-speed computer and a CAD- tool (Solid works) used for the simulation and FEA [8, 9]. The figure below shows the procedure followed in the carrying out of this study.

2.1 Double acting double ends hydraulic cylinders:

Double acting cylinders are normally designed such that pressure can be applied in either inlet or outlet port, providing linear power in both directions [11]. Furthermore, since the exposed areas in the cylinder are unequal during extract and retract operations (forward and return stroke) there is a difference in operation speed and force. The double acting double ends hydraulic cylinder which is the subject of this research is not in any sense different in principle of operation from every normal hydraulic cylinder but it produces both fluid flow and pressure in both directions, and both ends of the piston can be connected to the point of application where work is needed to be done.

2.2 Parts design consideration:

The following assumptions have been taken into the attention of the layout of the cylinder, piston, piston rod and seals with inside the hydraulic cylinder.

1. Working fluid is mineral oil Available pressured =200bar= 200 * 10^5 pa
2. Atmospheric pressure = 1.0135 * 10^5 pa
3. Stroke length= 60mm+80mm =140mm = 0.14m,
4. Cylinder output force =11KN = 11000N,
5. Cutting stroke=1.5m/s,
6. Material for cylinder calculation 1.0552 G260 (plain carbon steel),
7. Tensile stress of material is = 430mPa,
8. Yield stress of material is = 215mPa,
9. Factor of safety = 3
10. Young modulus of the material used is = 210GPa, for 1.0552 G260 (plain carbon steel)
11. End fixing factor = K = 0.7 is chosen because of maintenance purpose, in a case of adjustment i.e. in the case of increasing stroke length. [21-24]

2.3 DESIGN OF PISTON ROD

The piston rod of a hydraulic cylinder is notably stressed, and consequently it ought to be capable ofwithstand the bending, tensile and compressive forces that it is able tocome acrossall through the operation without buckling. In practice, the rod is much more likely to fail with the aid of using buckling below the compressive load than with the aid of using bending. In this case, the rod behaves like a column and is subjected to buckling. The rod diameter may beassociated withvital load. Therefore Euler's systemwith inside the equation beneath for lengthy column may be used to attain the piston rod diameter. [30-33]

---------1

$$P = \frac{\pi^2 . E . I}{L^2 . K^2} \quad (1) \text{ (N)}$$

L = the column length (m)
I = Moment of inertia (m^4)
E = Young's Modulus of Elasticity for the column material (Pa)
K = the end fixing factor
E = Young's modulus of the material used in this design calculation is 210 (Gpa) for 1.0552 G260 (plain carbon steel)
P = cylinder force * factor of safety = 11000 * 3 = 33 * 10^3N L = total stroke length =140mm = 0.14m
K = 0.7, Reason for choosing k = 0.7 is for maintenance purposes in case of adjustment i.e. in case of increase in the stroke length of the rod.
Substitute into the equation 1, we get the value of moment of inertia,
I= 1.6 * 10^{-10} m^4
The moment of inertia and the most permissible strain to keep away from buckling is depending on the sort ofceasesolving of the cylinder. The moment of inertia (I) may beobserved from the method below [12-14]

$$I = \frac{\pi d^4}{64} \quad (2)$$

⇨ $1.6 * 10^{-10} = \frac{\pi d^4}{64}$

⇨ d = 9mm

Hence diameter of the piston rod required, d = 9 mm. Finally, for different calculations and in a case of construction, the diameter of the piston rod used can be 12mm, for protection and due to the fact from Baym Hydraulics Corporation catalogue of metric rod wipers and piston seals the closestpopular rod seal diameter is 12mm.

2.4 DESIGN OF THE PISTON

The hydraulic piston layoutshouldnow no longer be complicated. It should be designed for

International Journal of Advances in Engineering and Management (IJAEM)
Volume 3, Issue 8 Aug 2021, pp: 977-985 www.ijaem.net ISSN: 2395-5252

ease of meeting and disassembly for upkeep purposes. A examinebecomecompleted to discover if a strong piston can resist the compressive pressurethat a piston rod is subjected to. The important failure factorbecomesthe rims of the piston and type of seals used at tolerances among the piston and the cylinder wall. They all have minimalelement of protection of 3. Let A be the wholelocation of the piston and a be the go sectional location of the piston rod. Since the layout is a double appearing double ended hydraulic cylinder, strain is acts on eachfacets of the rod, as a result the location which the strain is appearing on is given by (A-a). The pressure produced is given with inside the equation below. [9-10]

$$F = P(A - a) \qquad \text{------------------- (3)}$$

Since the piston and the piston rod are circular in nature, therefore area of the pressurized part is given by

$$A - a = \frac{\pi D^2}{4} - \frac{\pi d^2}{4} = \frac{\pi (D^2 - d^2)}{4} \qquad \text{----------- (4)}$$

D = diameter of piston
d =diameter of piston rod, 11mm = 0.011m
By substituting the above value into those equations, we have,
D=46MM
Hence diameter of piston required D = 46 mm. Finally, for different calculations and construction, the diameter of the piston is taken to be 47mm. Because from Baym Hydraulics Corporation catalogue of metric rod wipers and piston seals, the closestwidespread rod seal diameter is 47mm.

2.5 DESIGN OF THE CYLINDER

Let OD = outside diameter of the cylinder.
Tensile stress of G260 (plain carbon steel) = 50 * 10^7 N/M^2
Factor of safety (N) = 3
Determine the maximum working stress (σm) is given as

$$\sigma_m = \frac{\text{Tensile stress of material}}{FOS} = \frac{\sigma_t}{N} \qquad \text{------------------- (5)}$$

σ_m = 163.3 *10^6 Pa

Applying the lame's equation to determine OD
------------------- (6)

$$\Rightarrow \; OD^2 - \frac{D^2(\sigma + P)}{(\sigma - P)} \; 52m = 52 \text{ mm}$$

2.6 CYLINDER TUBE THICKNESS

The tube thickness of a cylinder barrel is a completelyessentialthingwithin side thelayout of a hydraulic cylinder. The energy of the cylinder tube is proportional to its wall. If a cylinder is just too thick or too skinnycan also additionally pose extremeprotection and operational issues and subsequently the tube thickness of the cylinder needs to becautiously chosen. The wall thickness required for the cylinder may be calculated from the components in equation (3.9).

$$\text{Thickness (t)} = \frac{OD - d}{2}$$

external diameter, 52mm and small "d" is the piston seal diameter (cylinder internal diameter), 47mm
⇨ Thickness (t) = 9 mm

2.7 Cylinder Wall Thickness Design:

Based on the theory, it's far believed that the tensile straindue to hydraulic strain of the cylinder with inside the circumferential route is identical. Its powercircumstance is the principlestrain, the loop tensile strain is much less than or identical to the allowable strain.

$$\sigma = {PD'}/{2l} \leq [\sigma] \qquad \text{-- (8)}$$

Therefore, the Wall thickness is

$$l = {PD'}/{2[\sigma]} \qquad \text{--- (9)}$$

Where P is the runningstrain of hydraulic cylinder, D' is the internal diameter of the cylinder. Materials of the important thingcomponents of hydraulic cylinder is 1.0552 G260 (simple carbon steel). Allowable strain of the 1.0552 G260 (simple carbon steel) is 785Mpa. It need to be noted, the strain P of the componentsisn't always the rated runningstrain, however thetake a look atstrain of the hydraulic cylinder. In order to evaluate the energy of the hydraulic cylinder, take a look atstrain of the hydraulic cylinder with inside the factorial take a look at is frequentlybetter than the rated strain. When the rated strain is much less than or same to 15.69Mpa, the take a look atstrain is 1.fiveinstances the rated strain. When the rated strain is extra than 15.96Mpa, the take a look atstrain is 1.25 instances the rated strain. But in real calculation, we frequently use the paintingsstrain.[8-10]

2.8 The Design of End Cover:

Assuming the liquid pressure is fully covered by the end cover.

$$h=\sqrt{\frac{\pi D^2}{4}p\frac{4}{\pi\,[\sigma]}\frac{d_H-d_m}{(D_e-d-2d_H)}} \qquad \text{———————————(10)}$$

$$h=AD\sqrt{\frac{d_H-d_m}{D_e-d-2d_H}} \qquad \text{———————————(11)}$$

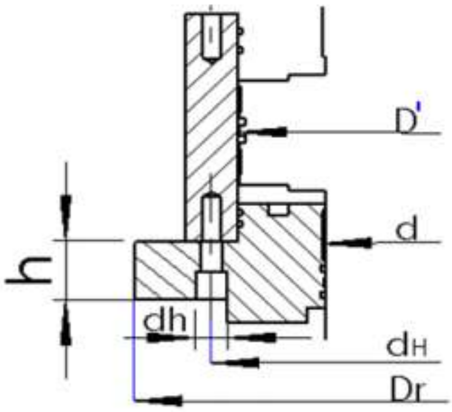


Figure 2: Hydraulic cylinder size (8)

2.9 Bursting stress

- To determine the bursting stress of the cylinder we need to apply lame's equation for thick cylinder because the ratio of inside diameter t/d is > 1/20.
- When a thick-walled tube or cylinder is subjected to internal and external pressures, hoop and longitudinal stresses act on the wall.
- The bursting stress can be referred to as the amounts of hoop stress and longitudinal (axial) stress that are produced in the wall of the cylinder when subjected to internal and external pressures that may cause the material which the cylinder is made from to fail. This happens if the hoops stress exceeds the tensile strength of the material.

In this design calculation, the hoop stress must be lower than a tensile strength of the material which the cylinder is made from to ensure the safety of the cylinder and personnel during actual operation.[34-36]

Material of the cylinder 1.0552 G260 (plain carbon steel) Tensile stress = 520 * 10^6pa. The hoop stress of a cylinder can be determined from the Barlow formula as shown in the equation below.

$$\sigma_H = p.\frac{d_o^2 + d_i^2}{d_o^2 - d_i^2} \qquad \text{--------------------------------- (12)}$$

p= oil pressure, 200bar = 200 * 105Pa
do= outer diameter of cylinder, 52mm
di = inner diameter of cylinder, 47mm
Substituting into equation 10
= 149.6 mPa
Also the longitudinal stress is given by:
$\sigma_L = P_1R_1^2 – P_2R_2^2 / R_2^2 - R_1^2$
Where
P1 = Internal pressure (200 * 105pa)
P2 = External pressure (atmospheric pressure = 1.0135 * 105pa)
R1 = Internal radius
R2 = External radius

herefore;
σ_L = 65.4 * 10^6Pa
= 65.4 Mpa

2.10 MATERIAL FOR THE HYDRAULIC CYLINDER

In the design of mechanical frameworks, the choice of texture plays out an enormous capacity with inside the ability of the framework. There are various sorts of substances utilized for building pressure driven chamber, and the decision in huge part depends upon at the prerequisite of the water powered chamber. However, with inside the instance of this examination, 1.0552 G260 (basic carbon metallic)as demonstrated in become chosen on the grounds that the texture for the water driven chamber as it joins the ideal gentle load with sublime yield power, elastic force, erosion opposition and genuine floor hardness for put on obstruction. [23-25] It has insignificant yield force of 215 Mpa, negligible elastic force 430 Mpa, 21% lengthening, with a creation of 0.2% of carbon(c) and 0.7% of manganese (Mn) and standardized condition. 1.0552 G260 is a totally not uncommon spot state of metallic because of its low rate and its fit texture houses in any case. It is neither weak nor bendable and espresso carbon metallic has a colossally low tractable force, anyway it's far sensibly evaluated and pliant. Its floor hardness might be progressed through method of method for carburizing. It is by and large utilized for monstrous sum needs, for instance, underlying metallic. The thickness of low carbon metallic has been found to be about 7.85g/cm3, and Young's modulus is 210,00Mpa. The texture chose might be utilized for the improvement of the water driven chamber added substances along with the chamber, cylinder pole, cylinder, the stop covers and tie poles. The methodology followed for the decision of the texture become from (Materials decision in mechanical design, Prof. M F Ashby.) First and preeminent, it thought about the central boundaries of Materials decision in mechanical design which are, force, durability, and weight. The principal highlight for planning the framework (twofold performing twofold finishes water powered chamber) is for it so as to create a shearing pressure from 10KN to 11KN and that speed of decreasing stroke should now presently don't surpass 1.5m/s. The Constraint of the chamber is the general presentation and limiting viewpoint for example force of the texture 1.0552 G260 (basic carbon metallic) - on the off chance that it very well might be equipped for face up to the unnecessary pressing factors built up in the chamber. [12-13]

2.11 FINITE ELEMENT ANALYSIS (FEA) OF THE HYDRAULIC CYLINDER

The fundamental format of the chamber changed into result of paper with portrays and with design computations gave. The various components/added substances had been replicated the utilization of Solid works. These added substances had been then furnished all things considered in a gathering to verify they fit as a fiddle all in all and that the ideal development directions had been practical without issues. Static reproductions had been done on the significant thing components to verify they could be equipped for adapt to the most burdens throughout activity and to help with upgrading weight. The assessment changed into broadly used to affirm the cost of deformity and first burdens showing up on each segment. A security issue of three changed into utilized for the design. This changed into completed because of the reality the burdens are appropriately characterized, and weight of the gathering changed into vital. The prerequisite for low weight changed into the main source until further notice as of now not the utilization of a greater insurance issue.[12-13]

2.12 STEPS INVOLVED IN DESIGN OF HYDRAUIC CYLINDER ON SOLIDWORKS 2013

Step 1 –setting the mates between the axis of the Piston Rod Kit and of the cylinder. Thus, the relative degrees of freedom of the PRK to cylinder body are set to 2: longitudinal translation and rotation around its axis.
Step 2 – setting mates between the axis of the cylinder front head and the axis of the cylinder. The axis of the cylinder front head is automatically aligned towards the cylinder axis.
Step 3 – setting „Face to Face “the front surface of the cylinder front head and the front surface of the cylinder. The cylinder front head automatically touches the front of the cylinder.
Step 4 – orientating the cylinder front head towards the nut port opening and establishing the final PTHC appearance.

2.13 Finite Element Analysis of End Cover:

Below Figure offers the nephogram of overall deformation, pressure deformation, the middle-segmentpressure deformation and the protectionissue of the cylinder's give upcowl. Material of subjacent give upcowl is 1.0552 G260 (undeniable carbon steel), tensile electricity (σb/MPa):≥980, yield point (σb/MPa): ≥785. Seeing from the parent that the awarenessregion of essentialpressureplacedwithin side the port and the most deformation is 0.014mm. The mostpressureawareness can't be better than 24Mpa and the protectionissueneed to be approximately 15. Fortunately, this shape meets the requirement of electricity completely.

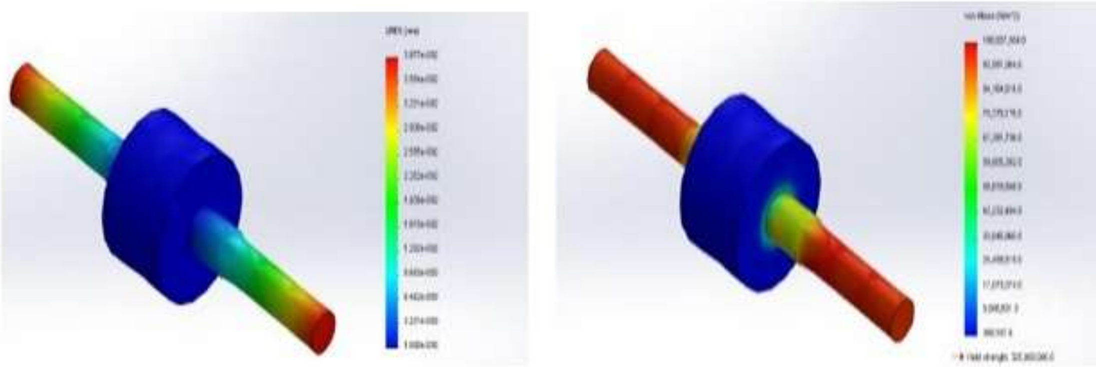
2.14 Finite Element Analysis of Cylinder Barrel

The material of the Cylinder barrel is 1.0552 G260 (simple carbon steel). It may bevisible from the discern that the most deformation takes placeon thestress part. The deformation can't exceed 0.01mm. Due to the most clearance of the rotary stress seal, F=0.05, it

International Journal of Advances in Engineering and Management (IJAEM)
Volume 3, Issue 8 Aug 2021, pp: 977-985 www.ijaem.net ISSN: 2395-5252

maymake sure the sealing overall performance of the sealing ring. Maximum pressure does now no longer exceed 40Mpa. Thus it may meet the realmanufacturing demand.

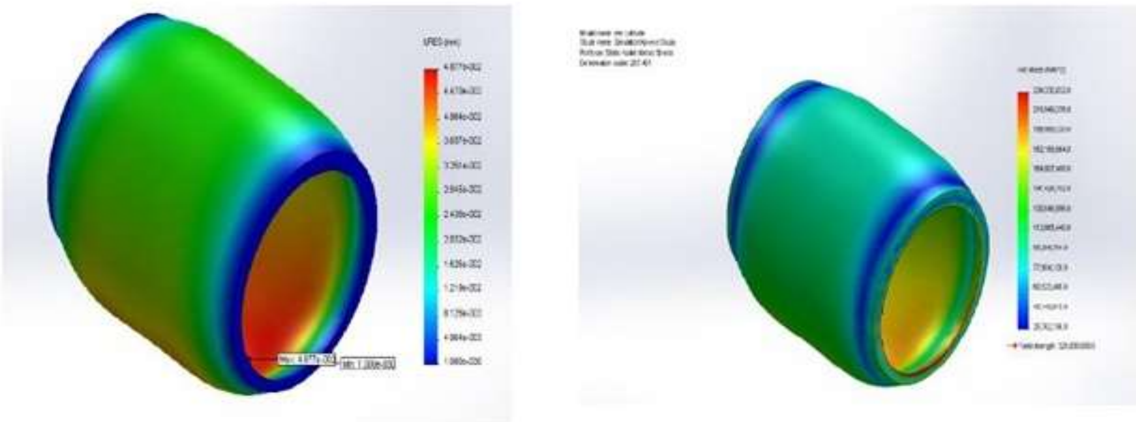
III. RESULTS AND DISCUSSION



Deformation of piston and piston rod under maximum load of 14KN

Stress analysis of piston and piston rod under maximum load of 14KN

Figure 3: **Stress Analysis of Piston Rod**



Deformation analysis of cylinder With 200bar internal pressure

Stress analysis of cylinder under 200bar internal pressure

Figure 4:Stress Analysis Cylinder Configuration

International Journal of Advances in Engineering and Management (IJAEM)
Volume 3, Issue 8 Aug 2021, pp: 977-985 www.ijaem.net ISSN: 2395-5252

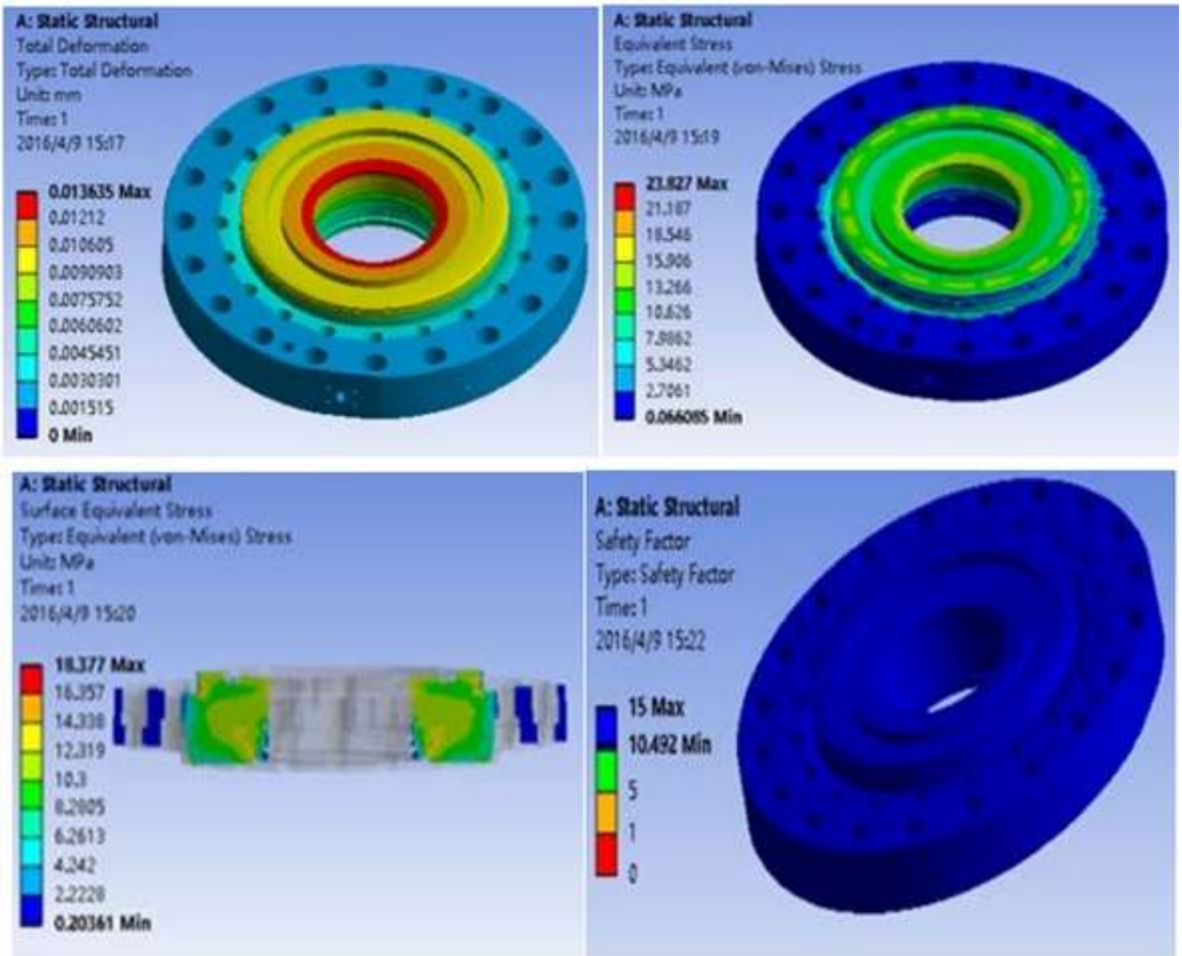


Figure5: Finite Element Analysis of End Cover

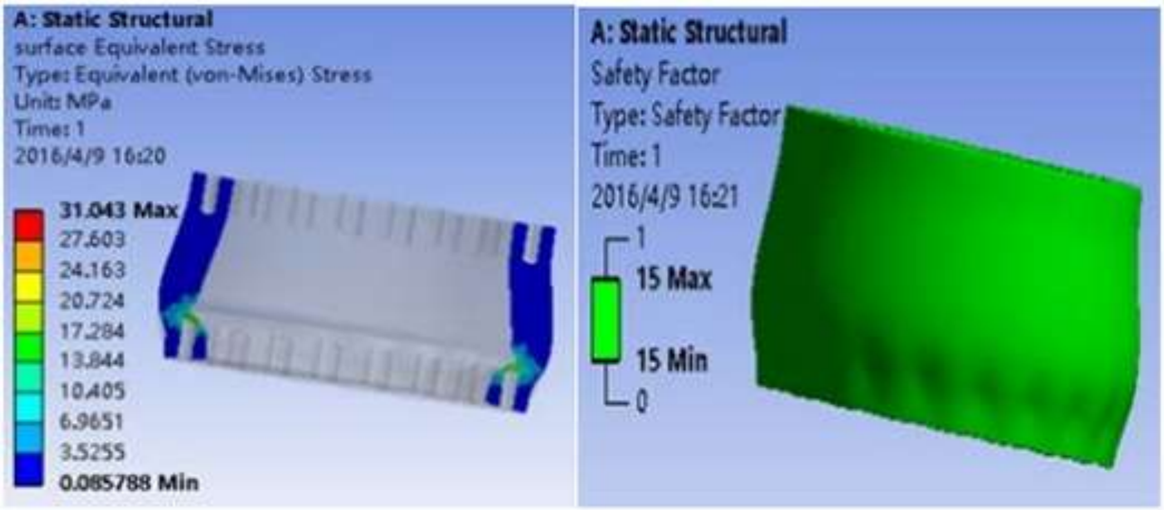


Figure6: Finite Element Analysis Cylinder Wall

IV. RESULT &CONCLUSION

RESULTS OBTAINED

A 3-d form of a double acting hydraulic cylinder, execution and terminations stress pushed chamber with the going ends, changed into masterminded the utilization of 1.0552 G260 (basic carbon metallic) and from the satisfaction results as can be found in above figures in any case, while offered to an inside crushing component of 200bar, the greatest ludicrous squeezing factor experienced at the fulfilments will be way by and by not genuinely the yield force of the material.

It can as well be seen from the stress analysis results that the von Mises stress on both the flange and piston and piston rod assembly do not exceed the yield strength of 1.0552 G260 (plain carbon steel). This implies that using this material with the following specifications will yield optimum results without failure. The results can as well be extrapolated. Also deformation between end cover and cylinder barrel did not exceed 0.01mm. Thus, the rotary sealing could prevent oil leak effectively when the hydraulic cylinder rotating.

CONCLUSION

A double acting double ends hydraulic cylinder was successfully designed and analyzed. Relevant standards and codes were used in the material selection process, and choosing of seals also follows. Therefore the design of double acting double end hydraulic cylinder was achieved and is ready for manufacturing. The cylinder external and internal diameters were determined to be 57mm, and 48mm, piston diameter with a seal is 48mm, piston rod diameter is 12mm and the stroke length is 140mm. The FEA analysis carried out on the hydraulic cylinder provided credible validation for the reliability, functionality, and safety of the hydraulic cylinder designed. This designed double acting double end hydraulic cylinder can be effective employed when manufactured for industrial automation such as hydraulics system for cutting and crimping of hydraulics pipe hoses, power steering for earth moving vehicles among others industrial applications.

REFERENCES

[1]. V.N. Ashikhmin, M.B. Gitman, P.V. Trusov, Optimal design of hydraulic cylinders subjected to autofrettage, J. Strength of Materials,1999,306.

[2]. K.W. Liao,C. Ha, Application of reliability-based optimization to earth-moving machine: hydraulic cylinder components design process, J.Structural and Multidisciplinary Optimization,2008,365.

[3]. Berglund L,Samson M,An K N, Four axial structural and material test machine, J. Biomedical sciences instrumentation,1994,30.

[4]. F. Rummel, C. Fairhurst, Determination of the post-failure behavior of brittle rock using a servo-controlled testing machine, J. Rock Mechanics Felsmechanik Mécanique des Roches, 1970,24.

[5]. V.Ya. Martenson, I.Kh. Kaplan, V.D. Ser'ga, A.A. Kholodov, Ways to create and improve high-parameter hydraulic drives for hydraulic structures, J. Hydrotechnical Construction,1988,2112.

[6]. Willian E. Hurst, Piezo-Hydraulic actuator Design, and Modeling Using Lumped Parameter Approach. M.S Thesis Virginia Polytechnic Institute and State University, 2002.

[7]. Izzettin Osman Egüz,Hydraulic Press Construction for Fitting the Bearing to a Housing,Vaxjo University School of Technology and Design SE- 351 95 Växjö Sweden, 2008.

[8]. Ashby F.M and Jones, R.B.H., Engineering Material: An introduction to their properties and application (2nd Edition), Oxford Butter Worth Heinmann, 2002..

[9]. Parker, Series of MH Hydraulic Heavy Duty Mill Cylinder. Parker Hannifin Corporation, motion and Control Division 160 Chishom Drive Milton, 2008.

[10]. William Durfee, Zongxuan Sun and James Van de Ven, Fluid Power System Dynamics,Center for Compact and Efficient Fluid Power University of Minnesota Minneapolis, USA 2015.

[11]. CHEN, Luo, and Ji-zhao LIANG. "Application of complex method in optimal design of hydraulic cylinder supported with flange [J]."Machinery Design & Manufacture 3, 2010): 038.

[12]. Tenalli V. S. Simulation of Electro Hydraulic Servo Actuator.M S. thesis Department of mechanical engineering national institute of Technology, rourkela. Rourkela 2012.

[13]. RavishankarN., Finite Element Analysis of Hydraulic Cylinders.Journal Mech. Des 103(1), 239-243, 1981

[14]. Ţălu D.L.Mihai1, Ţălu D.L. Ştefan, A Finite Element Analysis Of Hydraulic Cylinder Of Linear Hydraulic Motor From Horizontal

Hydraulic Press – 2 Mn, Journal of Engineering Studies and Research – Volume 16 (2010) No. 4 pp.59-62

[15]. JayantSirohi, Inderjit Chopra, Design and Development of a High Pumping Frequency PiezoelectricHydraulic Hybrid ActuatorJournal of Intelligent Material Systems and StructuresVol. 14, Issue 3, 2003.