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Design and Analysis of a Hydraulic Cylinder for a Soil Cone Penetrometer using Finite Element Analysis

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ABSTRACT: This research paper presents a comprehensive study on the development of a CAD model and the analysis of a hydraulic cylinder for a soil cone penetrometer using Finite Element Analysis (FEA). The primary objective was to design and optimize the different components of the tractor-operated penetrometer to ensure accurate measurement of soil compaction while ensuring the reliability of the components. Selection of different components with strength and reliability is difficult in short time. Cone index measurements were taken at three different locations: Punjab (Ludhiana), Madhya Pradesh (Bhopal), and Maharashtra (Akola), resulting in values of 3793 kPa, 4042 kPa, and 5324 kPa, respectively. Hydraulic flow and design calculations were conducted at a standard insertion speed of 30 mm/s, and the maximum force observed was 3225 N. The cylinder diameter was determined to be 63 mm, with oil flow of 5.61 l/min in the extracting condition and 7.48 l/min in the retracting stroke at the insertion speed. Therefore, structural analysis was done to determine the stress analysis using finite element method. Finite Element Analysis (FEA) was employed to evaluate the structural integrity and performance of the penetrometer prior to fabrication. The FEA analysis was conducted on the cylinder tube at a pressure of 15 MPa, and the results showed total deformation, equivalent von Mises stress, and Factor of Safety to be 0.023 mm, 170.9 MPa, and 1.45, respectively. Overall, the research highlights the successful selection and analysis of the hydraulic cylinder for the soil cone penetrometer, providing valuable insights into its performance and reliability in accurately measuring soil compaction and withstand the double load.

Keywords: Cone Penetrometer, Cone Index, Hydraulic Cylinder, ANSYS, Finite Element Analysis.

INTRODUCTION

In India, the total geographical area is 329 Mha, the gross cropped area is 198.9 Mha with a cropping intensity of 140.5 per cent. Out of which 141.6 Mha is net sown area. The gross cropped area is 7.9 Mha with cropping intensity of 204 per cent. The net irrigated area of Punjab is 4.07 Mha (Anon., 2019). Intensive farming of crops is common all over the world and involves use of heavier machinery and shorter crop rotations that lead to increase in soil compaction (Muckel, 2004). According to Mehta *et al*. (2014) average farm power availability needs to be increased from 1.84 to 2.5 $kW.ha^{-1}$ by 2025 to assure timeliness and quality in field operations which results increase in crop production and cropping intensity. While these advancements have shown promising results in terms of increasing crop yields and farm efficiency, they have also led to the unintended consequence of soil compaction (Pretty, 2018). Heavy machinery, including tractors, can exert considerable pressure on the soil surface, leading to soil particles being compressed and reducing pore space, thus hindering root growth and impacting overall crop performance (Reddy, 2016). Soil compaction is a critical concern in modern agriculture, impacting crop productivity and soil health. As farm mechanization continues to advance in India, the need for precise and efficient tools to assess and address soil compaction becomes increasingly important. Hand operated ring type and micro controller-based penetrometers were available to measure cone index but the problem is to maintain the insertion rate into the soil (Hemmat and Adamchuk 2008). Quantitative methods of detecting compaction include measuring penetration resistance with a commercially available cone penetrometer such as ring type and digital type (Patel *et al*., 2021). One such tool is the tractor-operated soil cone penetrometer, which offers valuable insights into soil strength and compaction levels. To combat the challenges posed by soil compaction, researchers and engineers have focused on developing specialized tools, such as the tractor-operated soil cone penetrometer, to assess soil compaction (Alimardani, 2005). Moreover, as the soil cone penetrometer comprises multiple components, such as the hydraulic cylinder and it is essential to ensure their efficiency and durability. The hydraulic cylinder is responsible for driving the cone into the soil, and its design and material selection are critical to achieving accurate measurements. To determine the reliability with confirming the factor of safety using the stress analysis of the critical component as hydraulic cylinder by the finite element method (Ritchie *et al*., 2014). Finite element analysis (FEA) is a powerful computational tool that enables researchers to simulate and analyze the behavior of various components under different loading conditions (Thakare *et al*., 2015). Finite element analysis (FEA) is the use of calculations, models and simulations to predict and understand how an object might behave under various physical conditions (Saravanan *et al*., 2018). This research paper aims to calculate the design values of cylinder fluid flow, thickness and opening area of hydraulic cylinder for the tractor-operated soil cone penetrometer, along with the implementation of Finite Element Analysis for the critical components' selection. Different materials selection after performing the equivalent von misses stress, total deformation and factor of safety of the cylinder tube.

MATERIALS AND METHODS

A. Theoretical design of hydraulic cylinder of tractor operated soil cone penetrometer

Tractor operated soil sensor which measure cone index consist of load cell, ultra-sonic sensor for depth measurement, standard probe with cone tip angle of 30 degree and hydraulic cylinder. Conceptual design of soil sensor to be operated with the help of tractor hydraulic system having compensating valve and pressure control valve was developed (Fig. 1). If the hydraulic fluid pressure was more during the operation so it was managed by the pressure relief valve. During the design calculations the maximum cone index observed by the hand operated penetrometer at three different states of India as Punjab (Ludhiana), Madhya Pradesh (Bhopal) and Maharashtra (Akola). Maximum cone index observed were used for all the standard calculations such as maximum force, pressure on the piston. Before fabrication or the selection of standard component need to check the strength of hydraulic cylinder, tie rod to meet the stress in future field operation. The CAD geometry of the different components were created in CREO 3.0 software and converted in STEP format to import in ANSYS 17.0 software for finite element method. This process is completed in three steps such as a) Pre-processing: CAD design, meshing and boundary condition, b) Solution: computing process and c) Post processing: viewing result, verification and conclusion (Patel *et al*., 2020).

The hydraulic pressure needed to operate the cylinder and the strength of the cylinder material are assessed to withstand the maximum pressure experienced during field operations, considering a safety factor of two. Hydraulic cylinder consists of piston rod, tie rod and cylinder housing were tested by the finite element method. A conceptual flow diagram of tractor operated soil sensor for measuring cone index. Finite element analysis was done by two types of material such as low carbon steel (BS 970 070M20) EN 3A.

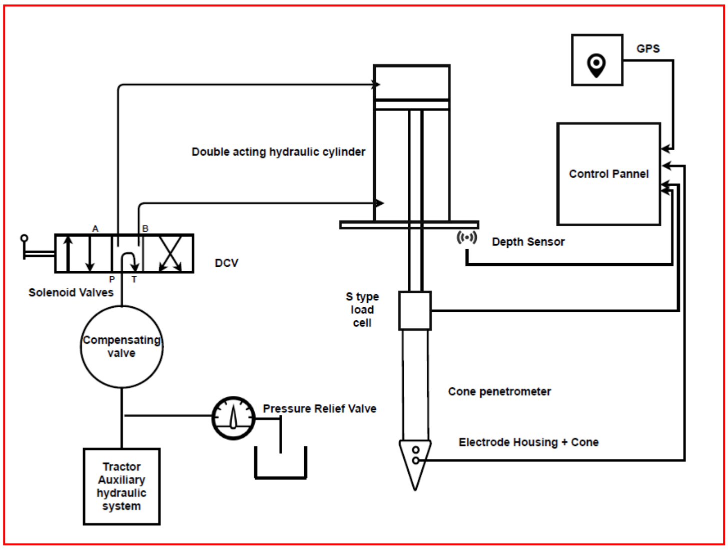

Fig. 1. Conceptual design of tractor operated soil sensor.

(i) Design of hydraulic system

Hydraulic Cylinder. Hydraulic cylinder was the key component of the soil sensor. It serves as a hydraulic consumer that converts the energy of the hydraulic fluid into useful work. Its input value is the hydraulic fluid under pressure acting on the surface of the hydraulic cylinder piston. This causes a linear movement of the piston and thus the piston rod, which is connected to the load (Engrraihan, 2015). A hydraulic cylinder consists of a cylinder barrel, piston, and piston rod. The piston contains sliding rings and seals and is closed on the top by a cylinder head or gland. The cylinder is closed on the bottom by a cylinder bottom or cap (Jackob *et al*., 2013)

Double acting tie rod cylinder. Tie-rod cylinders have square or rectangular end caps secured to each end of the barrel by rods that pass-through holes in the corners of the end caps. Nuts threaded onto the end of each tie rod secure the end caps to the barrel. Static seals in the barrel/end-cap interface prevent leakage.

Design of tie rod Hydraulic cylinder. The most critical aspect of the study was designing of the hydraulic cylinder. Its main purpose was to apply pressure with the help of tractor hydraulic to insert the probe. The stroke length of hydraulic cylinder was selected on the basis of insertion depth. Hydraulic cylinder was designed such that it can apply maximum pressure to complete insertion of probe to 60 cm depth. All the components of hydraulic cylinder were designed to sustain maximum pressure on piston, piston rod, cylindrical tube and good quality material was selected with factor of safety.

CAD model of hydraulic cylinder. Boolean view of hydraulic cylinder and its components is presented in Table 1, CAD model of different components were used for static structural analysis. Cylinder tube and tie rod were used for finite element analysis.

(ii) Determination of force required for pressure calculations. Maximum force requirement for cylinder was selected on the basis of force needed for insertion of probe. It depends on the cone index and base area of the cone. Probe was attached to the hydraulic cylinder to ensure insertion into the soil and the force was also calculated (Eq. no. 1). Cone index was measured in three city of India as Ludhiana, Bhopal and Akola (Fig. 2).

Table 1: Parts of hydraulic cylinder.

Sr. No.	Part name
1.	Upper cap end
2.	Cylinder tube
3.	Rectangular plate
4.	Flange nut
5.	Lower cap end
6.	Seal ring
7.	Tie rod and nut
8.	Piston Rod
9.	Piston
10.	Guide nut
11.	Hose pipe

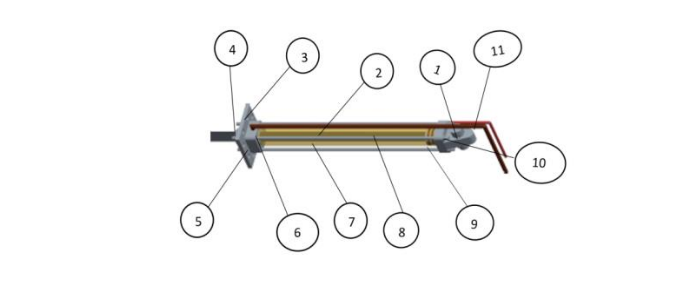

Fig. 2. Measurement of cone index at different locations of India by hand operated penetrometer.

Maximum force (N) = cone index (N.mm^{-2})× base area of cone (mm^2) (1)

(iii) Design of piston

a. Piston rod. The piston rod of hydraulic cylinder was present in the form of strut, when it was subjected to a compressive load, it exerts a thrust. Piston rods were typically made from high–tolerancesteel. Piston rod was mounted onto the piston on one side and enter from the cylinder through the cylinder head on the other (Engrraihan, 2015).

The piston rod diameter was checked for buckling by Euler's formula mentioned in Eq. 2. Whether strut can withstand buckling was determined by using Euler's strut theory. Parameters were given below for the calculation of buckling of rod when the material was 15 CDV 6 Steel (Kumar, 2012). Two commercially available materials of rod for designing and comparison of its properties were considered and studied in (Table 2)

Table 2: Material specification piston of rod.

Sr. No.	Mechanical property	Content	
		EN 8 or 080M40	AISI 4140 Chrome-Molybdenum
1.	Composition (%)	C=0.4, Mn=0.8, P≤0.05, Fe≥97.91, S≤0.05, Si=0.4	C=0.38, Mn=0.80, P≤0.035, Fe=97.77 S≤0.04, Mo=0025
2.	Condition	Normalized	Normalized
3.	Yield Stress (MPa)	280	415
4.	Tensile stress (MPa)	550	655
5.	Elongation (%)	16	25
6.	Modulus of elasticity (MPa)	219000	205000
7.	Bulk modulus (MPa)	140000	140000
8.	Density (g/cm^3)	7.48	8.03
9.	Cost, Rs/kg	55	90

(2)

Buckling eq. of column given by Euler's,

$$d_{min} = \sqrt[4]{\frac{F \times K^2 \times L^2 \times 64}{\pi^3 \times E}}$$

Where,
F= buckling load on cylinder rod (maximum force applied on cylinder×2)
E= Young's modulus of elasticity
I= moment of inertia ($A = \pi \frac{d}{64}^4$)
D_{min}= minimum diameter of cylinder rod
L=length of cylinder rod, m
K= 2 (one end fixed and other end free)

The minimum diameter required to sustain pressure of insertion was calculated. The rod diameter was selected greater than the minimum value according to Indian Standard (IS 4218-1976).

EN 8 or 080M40 medium carbon steel (EN-emergency number)

EN8 is a very popular grade of unalloyed medium carbon steel, which was readily available in the market for different operating condition. It is a medium strength steel and has good tensile strength, wear resistance and is suitable for general-purpose axles and shafts, gears, bolts and studs, stressed pins, keys etc. Maximum diameter of cylinder rod was calculated from the eq. 3, which can resist the load (Kumar, 2012). Whereas, Yield stress σ=415 MPa and Factor of safety=2

$$d = \sqrt{\frac{4F}{\pi\sigma}} \quad (3)$$

AISI 4140 Chrome-Molybdenum high tensile. Chromium-molybdenum alloy steel was an alloy suitable under high working condition pressure and temperature. It is commonly in oil and gas, energy, construction and automotive industries because of its corrosion resistance, high-temperature sustainability and tensile strength.

b. Piston Diameter (D)

Cylinder bore diameter (D_1) was selected as per mentioned in BIS standard (IS 11146:1999). Based on the cylinder bore diameter D_1, piston dimension was calculated as mentioned below

Determination of piston dimensions

The main function of the piston was to separate the pressure zones inside the cylinder. The piston was provided with grooves to fit single acting or double acting metal seals and bearing elements. According to BIS (IS 11146:1999) the piston diameter D should be less than the bore of cylinder so it can easily move inside the cylinder tube. The forces acting on face of piston and was used for calculation of piston dimensions using following formula (Fig. 3 and eq. 4). Thickness of piston cylinder was calculated in the same way as calculated by (Khan, 2016).

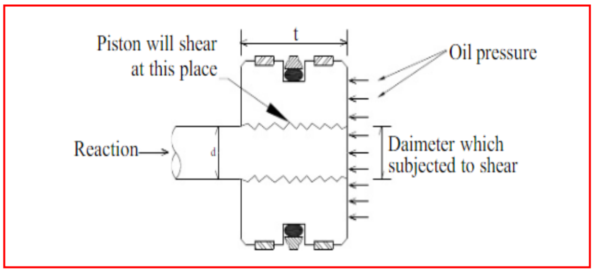

Fig. 3. Forces acting upon face of piston.

$$t = \frac{D_1^2 \times p}{4 \times d \times f_s} \quad (4)$$

Where,
P=Working pressure (MPa)
d=Ram diameter (mm)
f_s=shear stress (MPa)
t=thickness of the piston (mm)

Determination of piston dynamics

Velocity of piston. According to American standard (ASAE S313.3) penetration velocity of cone penetrometer should be 30 mm.s^{-1} into the ground. The probe was operated through the movement of piston, at a velocity of 30 mm.s^{-1}.

Required amount of oil flow. The speed of the piston depends on the volumetric flow and the effective piston area. The speed of hydraulic cylinder was calculated by eq. no.5. The volumetric efficiency of the cylinder has effect on the speed, but generally the leaks were so small, calculations were done with η_{vol} = 0.95 (Mikkola, 2014).

$$V = \frac{Q \times \eta_{vol}}{A} \quad (5)$$

Where,
V=movement speed (m.s^{-1})
Q=Volumetric flow (m^3.s^{-1})
η_{vol}=Volumetric efficiency, 0.95
A=Effective piston area (m^2)

Amount of oil flowing from tractor hydraulic system to designed hydraulic cylinder for extending the position of piston from full bore end (eq. 6) was calculated in eq. 9 based on full bore area and velocity of piston during extending condition (eq. 8). Amount of oil flowing from tractor hydraulic system to designed hydraulic cylinder for extending the position of piston from annulus end was calculated in eq. no. 10 based on annulus area (eq. 7) and velocity of piston during extending condition (Fig. 4 and eq. 8).

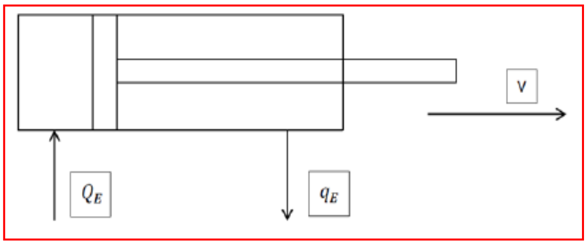

Fig. 4. Systematic view of hydraulic cylinder during extending condition.

Full bore area, $A = \frac{\pi}{4}(D^2)$ (6)

Annulus area, $(A - a) = \frac{\pi}{4}(D^2 - d^2)$ (7)

Velocity of piston during extending condition, $V = \frac{Q_E}{A} = \frac{q_E}{A-a}$ (8)

Where,

Q_E = Flow of liquid into full bore end of cylinder during extending condition $= A \times V$ (9)

q_E = Flow of liquid from annulus end of cylinder during extending condition = $(A - a) \times V$ (10)

Amount of oil flowing from tractor hydraulic system to designed hydraulic cylinder for retracting the position of piston from full bore end was calculated in eq. no. (12 a) based on full bore area and velocity of piston during extending condition (eq. 12 b)

Velocity of piston during retracting condition, $V = \frac{Q_R}{A} = \frac{q_R}{A-a}$ (11)

Flow of liquid into full bore end of cylinder during retracting condition, $Q_R = A \times V$ (12a)

Flow of liquid from annulus end of cylinder during retracting condition, $q_R = (A - a) \times V$ (12b)

$$Q_E = Q_R \quad (13)$$

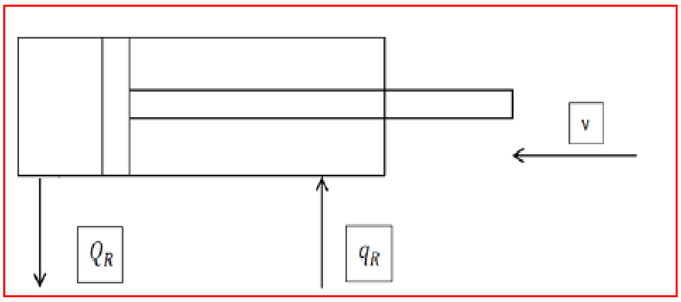

Fig. 5. Systematic view of hydraulic cylinder during retracting condition.

(

d) Design of cylinder outer diameter. The cylinder outer diameter was designed on the basis of calculation given in eq. 15 (Boye *et al.*, 2017). EN 3A material was applied for determine the cylinder thickness.

Tensile stress of **BS 970 070M20** = 430MPa (EN 3A), Factor of safety (F) = 2

Determine maximum working stress

$$\sigma_m = \frac{\text{Tensile stress of material}}{\text{F}} = \frac{430}{2} \quad (14)$$

$$= 215 \times 10^6 \, Pa$$

Applying lame's eq. to determine outer diameter OD

$$\text{OD}^2 = \frac{D_1{}^2(\sigma + \text{P})}{(\sigma - \text{P})} \quad (15)$$

Where,

σ_m= tensile stress of material

OD = cylinder external diameter (mm)

D_1= cylinder internal diameter (mm)

(v)Design of cylinder wall. The main function of the cylinder was to sustain hydraulic pressure. The strength of the cylinder was proportional to its wall thickness. If a cylinder was too thick or too thin it may pose serious safety issues, and operational problems. Hence, the tube thickness of the cylinder wall was precisely calculated from the formula given in eq. 16

$$\text{Cylinder Wall Thickness (t)} = \frac{\text{OD-D}_1}{2} \quad (16)$$

Stress estimation

Bursting stress

The tensile strength of the material of the cylinder BS 970 070M20 (low carbon steel) was 430*10^6 pa. The hoop stress; (σ_H) of a cylinder was determined from the Barlow formula as follows:

$$\sigma_H = p \times \frac{(d_o^2 + d_i^2)}{(d_o^2 - d_i^2)} \quad (17)$$

Where,

p =oil pressure; 250 bar=250×10^5 Pa

d_o=outer diameter of cylinder,

d_i=inner diameter of cylinder

Longitudinal Stress. Following forces acting on the body of cylinder tube and helpful for calculating of piston dimensions by using following formula (eq. 18)

$$\sigma_l = \frac{P_1R_1^2 - P_2R_2^2}{R_2^2 - R_1^2} = 63.4 \times 106 \, Pa \quad (18)$$

$$= 63.4 \, MPa$$

Where,

P_1=internal pressure (250×10^5 Pa)

P_2=external pressure

(atmospheric pressure=1.0135×10^5 Pa)

R_1=internal radius, R_2=external radius

Finite element analysis of hydraulic cylinder (Boye, 2017). The choice of material plays a huge role in the functionality of a mechanical system. In the study, for the design of hydraulic cylinder low carbon steel (BS 970 070M20) EN 3A was selected because of its light weight, optimum yield strength, tensile strength, corrosion resistance and good surface hardness for wear resistance (Table 3). CAD geometry was imported in ANSYS software and assign the engineering properties of the said material given below. Tetrahedron meshing is created over the cylinder tube with the boundary conditions is given under the setup selection. In solution section equivalent von misses stress, total deformation and factor of safety were selected and at last the results are generated.

Table 3: Material specification of low carbon steel for cylinder.

Sr. No.	Mechanical property	Content
1.	Composition (%)	C=0.2, Mn=0.7, P= 0.05 S= 0.05, Ni, Cr, Mo=0 (Nil)
2.	Condition	Normalized
3.	Yield Stress (MPa)	215
4.	Tensile stress(MPa)	430
6.	Elongation (%)	21
7.	Modulus of elasticity (MPa)	210000
8.	Bulk modulus (MPa)	160000
9.	Density (g/cm^3)	7.85

The material selected was used for the construction of the hydraulic cylinder components such as the cylinder, piston rod, piston, the end caps and tie rods. Firstly, the basic parameters of mechanical design were taken in to account which are strength, toughness, and weight. The system (double acting double ends hydraulic cylinder) was designed to perform the basic function of producing a shearing force from 3200 N to 3500 kN, such that velocity of cutting stroke should not exceed 300 mm.s^{-1}. The limiting factor of the design is the strength of the material and its capacity to withstand the high pressures built-up inside the cylinder.

RESULT AND DISCUSSIONS

Cone Index from different location such as Ludhiana (3793 kPa), Bhopal (4283 kPa) and Akola (5324 kPa) has the maximum value which was used for all the design calculations of soil cone penetrometer (Fig. 6). For considering the factor of safety, soil cone penetrometer was designed at 10000 kPa. Maximum force was calculated as 3225 N. For 3225 N or 329 Kg, S type load cell was selected of 500 Kg capacity available in the market.

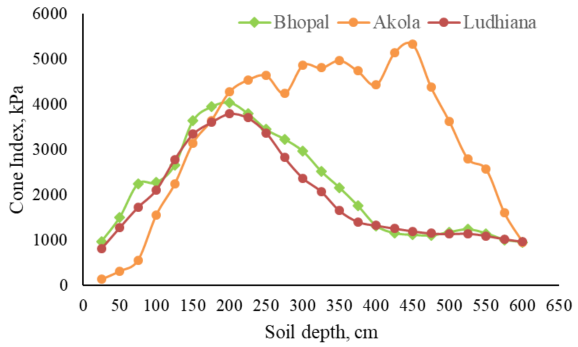

Fig. 6. Conde index measurement at three different cities of India.

A. Hydraulic cylinder

(i) Piston rod diameter. As per the discussed in the previous chapter, the design of hydraulic cylinder was done based on the maximum thrust required to insert the probe of soil sensor into the soil. Maximum force came out 3225 N. The minimum diameter of rod which could be not buckle was calculated by Euler's strut theory and came out 19 mm. Minimum diameter of cylinder rod which can resist the load was calculated as 4.65 mm. Select the standard rod diameter according to IS (11446:1999) i.e d= 36 mm and hence, the cylinder rod is safe for buckling and can also resist the load. Different parameters used to find at the minimum diameter of rod.F = 3225 N, K = 2, L = 650 mm, E = 206000 MPa, FOS = 2

Cylinder bore was 63 mm as per the Indian standard which had the capability to produce 10 MPa pressure from the previous section in the eq.1, pressure required to develop 3225 N thrust on the annular side of the cylinder was 15.36 bar.

(ii) Piston Area. Diameter of the cylinder bore was 63 mm and the effective piston diameter was 62 mm having 1 mm as piston seal (Boye, 2017). Selection of Piston diameter (Fig. 7) was made according to Indian Standard (IS 11146: 1999)

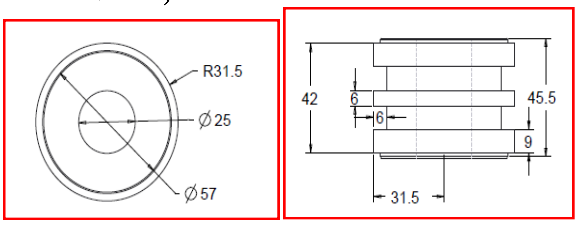

Fig. 7. A 2D view of piston.

Followings were determined from the materials and methods (eq. 6 and 7)

Full bore area = 31.17 cm^2, effective dia. of the piston = 62 mm and annulus area = 20.98 cm^2. Actual diameter of the piston was 63 mm

(iii) Velocity of piston during extending and retracting. Extending velocity or insertion velocity is 30 mm.s^{-1} according to (ASABE, 2006 a)

Retracting velocity, v = 4.46 cm.s^{-1}

(iv) Required amount of flow during the operation. Following parameters for required amount of oil flow during the usage were selected for designing the required soil sensor. Oil flow during the extending of the piston were given below. Height of the piston was selected 40 % of the cylinder diameter (Khan, 2016)

Oil flow at the full bore area, Q_E = 5.61 lpm

Oil flow at the Annulus area, q_E= 3.77 lpm

Oil flow during the retracting of the piston

Oil flow at the full bore area, Q_R =7.48 lpm

(v) Design of cylinder tube. Outer diameter of the cylinder was calculated (eq. no. 15) and found 70 mm, length of 700 mm and the internal diameter of 63 mm.

(vi) Cylinder tube thickness. The tube thickness of a cylinder barrel was a very important factor in the design of a hydraulic cylinder. The strength of the cylinder tube is proportional to its wall. If a cylinder is too thick or too thin may pose serious safety. Thickness t = 3.5 mm

Bursting stress and longitudinal stress of cylinder tube. This bursting stress (σ_H) and longitudinal stress

(σ_l) was calculated (eq. 17 and 18) and it also helpful for the analysis of cylinder in ANSYS. σ_H = 238 MPa, σ_l = 106 MPa

B. Analysis of Hydraulic cylinder tube

Hydraulic cylinder tube was analyzed in ANSYS 16.0 (Static Structural) software for checking its strength, directional deformation, displacement and factor of safety of the cylinder tube against the oil pressure transmitted from tractor hydraulic to push the piston assembly. For the cylinder body BS 970 070M20 steel was selected and Finite Element Analysis (FEA) was performed was done using the ANSYS 16.0 software. Pressure was applied at the inner surface of the cylinder and the total deformation of 0.023 to 0.024 mm (Fig. 8a and 8b). Maximum stress was found at the both end of cylinder. Cylinder was fixed at the both ends and the stress value of 171 MPa (Fig. 9a). However, the yield stress of the steel was 250 MPa. As it was more than 150 percent of the stress on the part, so the cylinder tube was safe. The minimum FOS was 1.46 (Fig. 9b) and the result analysis (Table 4).

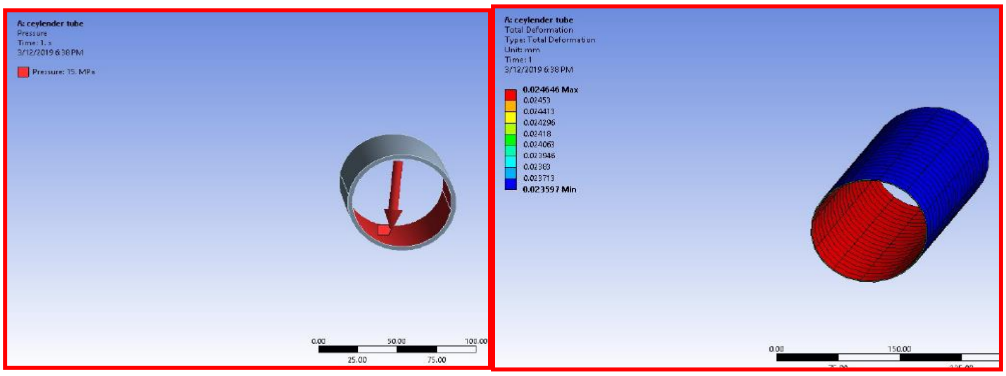

Fig. 8 (a) A view of pressure applied inside the cylinder tube (b) Analysis of total deformation in static structural

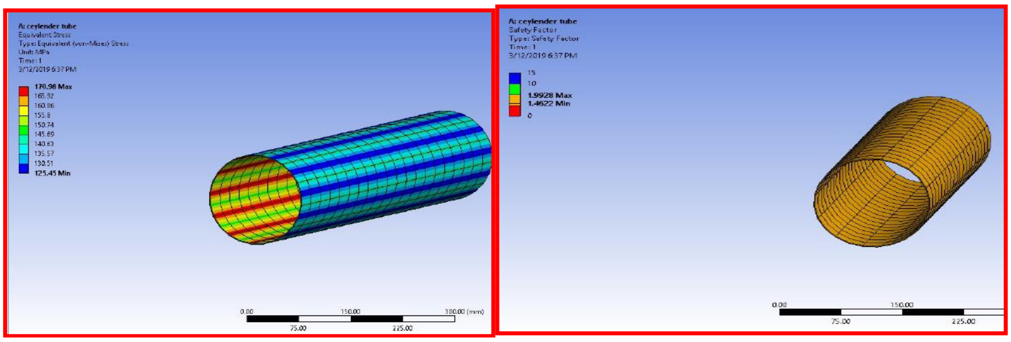

Fig. 9 (a) Analysis of equivalent stress in static structural; (b) Analysis of Factor of safety in static structural.

Table 4: Analysis result of cylinder tube in ANSYS 16.0.

Name	Value	
Material	BS 970 070M20 Steel	
Density (Kg/m^3)	7850	
Young's modulus (N/m^2)	2×10^{11}	
Poisson's ratio	0.3	
Yield strength (Mpa)	250	
Results	**Minimum Value**	**Maximum Value**
Total deformation (mm)	0.023	0.024
Equivalent von misses stress (MPa)	125.4	170.98
Estimated local error (%)	0.108	0.108
Factor of Safety	1.46	15

Table 5: Calculated design values of double acting hydraulic cylinder.

Sr. No.	Type	Double acting
1.	Cylinder diameter	63 mm
2.	Rod diameter	36 mm
3.	Stroke length	600 mm
4.	Volumetric efficiency	95 percent
5.	Stroke speed	30 mm.s^{-1}
6.	Return stroke speed	44.6 mm.s^{-1}
7.	Oil flow required in forward speed	5.61 l.min^{-1}
8.	Oil flow required in return stroke	7.48 l.min^{-1}

CONCLUSIONS

Soil cone index measurement was done at three different locations of India by the digital cone penetrometer and found the 5324 kPa and 3225 N force and considered for the design calculation of different components. Theoretical and CAD model of soil cone penetrometer was done with the finite element approach for the selection of material, thickness and mitigate with the standard components as per considering the factor of safety. Forward speed or insertion speed of hydraulic cylinder was 30 mm.s^{-1} with the cylinder diameter of 63 mm, oil flow in forward speed was 5.61 l.min^{-1} and in return stroke was 7.48 l.min^{-1}. For the analysis of cylinder tube with steel material, the maximum and minimum total deformation was (0.023 & 0.0246 mm), equivalent stress was (125.45 & 170.9 MPa) and FOS was (1.45 & 15). All the critical components were designed and selected after the finite element analysis and will work with the reliability. After getting the result the components can be fabricated and for the actual development of tractor operated soil cone penetrometer.

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