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European Journal of Advances in Engineering and Technology, 2019, 6(8):11-16

Research Article ISSN: 2394 - 658X

The Design of a Simple 50 Tons Capacity Three Stage Telescopic Hydraulic Jack for Automobile and Vessel (Ship) Application

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ABSTRACT

This research presents the design of a simple 50tons capacity three stage telescopic hydraulic jack for automobile and vessel (ship) application. Most hydraulic jacks are limited in capacity of load they can carry, in the quest to assist in solving the problem of heavy load lifting within a shortest time and to assist in carrying out maintenance activities onboard a vessel (ship). Lifting of the engine, press fitting of heavy components etc this simple design is considered very useful and safe. The objective of this research is to design a simple 50 tons capacity three stage telescopic hydraulic jack for automobile and vessel application using alloyed steel material, calculating for the minimum thickness that is safe in operation using Birnie's equation of strain energy failure, considering tangential stress acting, and selecting the pump of 2HP for the operation.

Key words: Telescopic, hydraulic, Jack, Load, Pressure

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1. INTRODUCTION

A hydraulic jack is a mechanical device used as a lifting device to lift heavy loads or to apply great forces [1]. A hydraulic jack uses hydraulic power for lifting heavy equipment. Mechanical Jacks are usually rated for maximum lifting capacity from the pneumatic jack [2]. The most common form is a car hydraulic jack, floor jack or garage jack, which lifts vehicles so that maintenance can be performed. Jacks are usually rated for a maximum lifting capacity [1], (for example, 1.5 tons or 3 tons). Industrial jacks can be rated for many tons of loads. Telescopic jack tends to lift heavier loads higher when the mounting space is limited. Telescopic jacks depend on force generated by pressure. Essentially, if two cylinders (a large and a small one) are connected and force is applied to one cylinder, equal pressure is generated in both cylinders. However, because one cylinder has a larger area, the force the larger cylinder produces will be higher, although the pressure in the two cylinders will remain the same. Telescopic jacks depends basically on Pascal's principle to lift loads; they use pump plungers to move oil through two cylinders. The plunger is first drawn back, which opens the suction valve ball within and draws oil into the pump chamber. As the plunger is pushed forward, the oil moves through an external discharge check valve into the cylinder chamber, and the suction valve closes, which results in pressure building within the cylinder. Common Types of Mechanical Jack are: Hydraulic Bottle Type Jacks, Pneumatic Jack, Strand Jack, Long Ram Jacks, Shop Press Jack. Hydraulic cylinders are of the following types: Single-acting cylinders, Double-acting cylinders, Telescopic cylinders, Tandem cylinders and Telescopic Cylinder. Telescopic-is made of sections that can slide into each other to make the object longer or shorter

A telescopic cylinder is used when a long stroke length and a short retracted length are required. The telescopic cylinder extends in stages, each stage consisting of a sleeve that fits inside the previous stage. One application for this type of cylinder is raising a dump truck bed. Telescopic cylinders are available in both single-acting and double-acting models. They are more expensive than standard cylinders due to their more complex construction.

They generally consist of a nest of tubes and operate on the displacement principle. The tubes are supported by bearing rings, the innermost (rear) set of which have grooves or channels to allow fluid flow. The front bearing assembly on each section includes seals and wiper rings. Stop rings limit the movement of each section, thus preventing separation. When the cylinder extends, all the sections move together until the outer section is prevented from further extension by its stop ring. The remaining sections continue out-stroking until the second outermost section reaches the limit of its stroke; this process continues until all sections are extended, the innermost one being the last of all

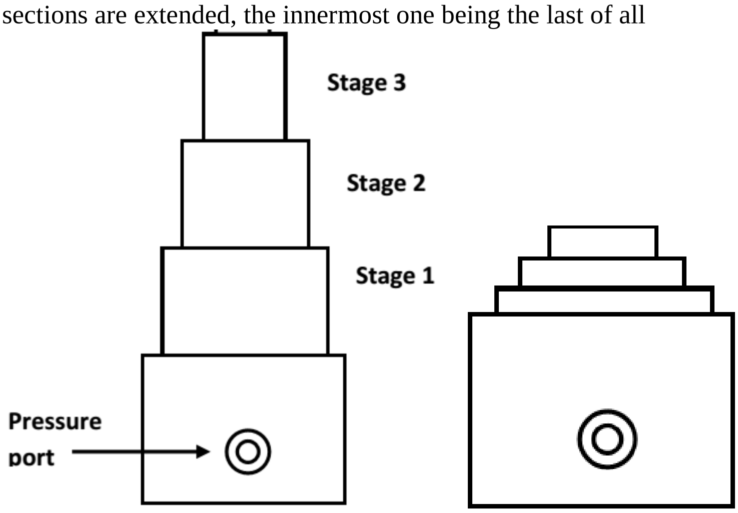


Fig. 1 Telescopic cylinders

For a given input flow rate, the speed of operation increases in steps as each successive section reaches the end of its stroke. Similarly, for a specific pressure, the load-lifting capacity decreases for each successive section. The two basic types of telescopic hydraulic jack are: Single acting and Double acting [3-18].

2. MATERIALS AND METHODS

2.1. Materials

The materials that were used in the design process are:

a) Alloy steel,
b) Bronze sleeves as bearings,
c) wiper seals, hydraulic seals,
d) hydraulic quick coupler,
e) hydraulic hoses,
f) hydraulic valves
g) hydraulic pump

2.2. Method

The procedure for the design of the telescopic jack is as follows:

1. The ideal design of the double acting telescopic jack was conceived and its functional requirements of the product were established
2. Making a design sketch.
3. Selection of appropriate materials: these materials were selected based on the design requirement after relevant calculations have been made.
4. Determination of the size of different parts of the double acting telescopic jack
5. Manufacturing of the individual parts will be carried out using the available process of manufacturing after which assembly of parts is done using detailed engineering drawings as guide
6. Testing and documentation: the double acting telescopic jack would be tested to see that it meets design specifications

Design Analysis, Calculations and Equations

For the 50tons three stage telescopic Hydraulic jack calculations

Using Birnie's Equation

Suitable for the design of open-end cylinders, rams etc made of ductile materials.

It is derived base on the maximum-strain energy theory of failure.

Given as: $t = ri[\sqrt{(\frac{\sigma t+(1-\mu)p}{\sigma t-(1+\mu)p})}-1]$ (1)

r_i= Internal radius of cylinder

σ_t= Tensile stress

μ= Poisson ratio= for steel is between 0.25-0.33 (extracted from textbook of machine design, J.K Gupta, pg111 Tale 5.5 Values of poisson's ratio for commonly used materials.

P= Pressure (Internal Pressure of the fluid).

Maximum Load Capacity =m =50tons= 50,000kg

F=mg=50000 x 9.81 =490,500N
Force F = Pressure P x Area A
490,500 = π x (200^2/4) x P
$P=\frac{4\times490{,}500}{\pi\times40000}$
P = 15.61N/mm^2
Internal radius =d/2=200/2= 100mm
Take allowable tensile stress (σ_t=140MPa or N/mm^2 (From Table 8.1 Values of allowable tensile stress for pipes of different materials (Solid drawn steel tube), Adopted from Textbook of Machine design by R.S Khurmi.)
Applying Birnie's equation to obtain thickness

$$t = ri[\sqrt{(\frac{\sigma t+(1-\mu)p}{\sigma t-(1+\mu)p})}-1]$$

$$t = 100[\sqrt{(\frac{140+(1-0.33)15.61}{140-(1+0.33)15.61})}-1]$$

t=13 mm
t=15mm is adopted
t=20mm for target thickness for a better safety selection to confirm with solid works software report.

3. RESULTS AND DISCUSSION

Below is a detail analysis of the result of the selected thickness.

Table -1 Thickness Analysis Report obtained from software

Report Name	Analysis of first stage
Model Name	C:\Users\Mojeric\Documents\Hydraulic Press\Hydraulic Cylinder.SLDPRT
Configuration Name	Default
Created On	03/19/2017 17:57:54
Created By	Peter Anaidhuno

Options Used

Parameter	Value
Analysis type	Thin analysis
Target thickness	20mm
Target thickness color	
Full color range	On
Faces for local analysis	Full model
Resolution	Low

Summary

Total surface area analyzed	292143.54mm^2
Critical surface area(% of analyzed area)	109593.91mm^2 (37.51%)
Maximum deviation from target thickness	19.99mm
Average weighted thickness on critical area	18.64mm
Average weighted thickness on analyzed area	38.08mm
Number of critical faces	16 Face(s)
Number of critical features	8
Minimum thickness on analyzed area	13mm
Maximum thickness on analyzed area	20mm

Table -2 Analysis Details

Thickness range	Number of faces	Surface area	% of analyzed area
20mm to 15mm	3	100177.55mm^2	34.29%
15mm to 10.01mm	0	693.71mm^2	0.24%
10.01mm to 5.01mm	7	4656.56mm^2	1.59%
5.01mm to 0.01mm	6	4066.09mm^2	1.39%

Critical features
Boss-Extrude1
Cut-Extrude5
Cut-Extrude4
Combine1
Cut-Extrude2
Boss-Extrude2
Cut-Extrude7
Cut-Extrude8

Model View(s)

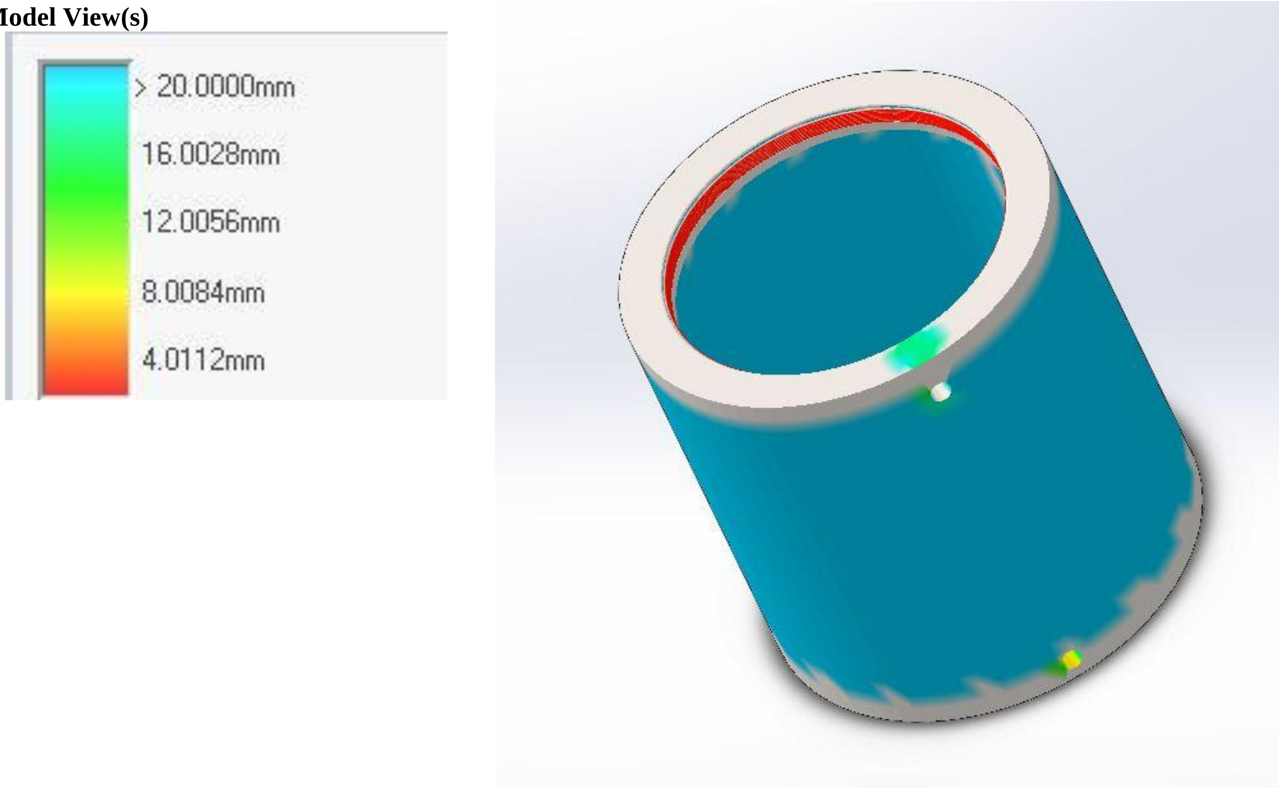
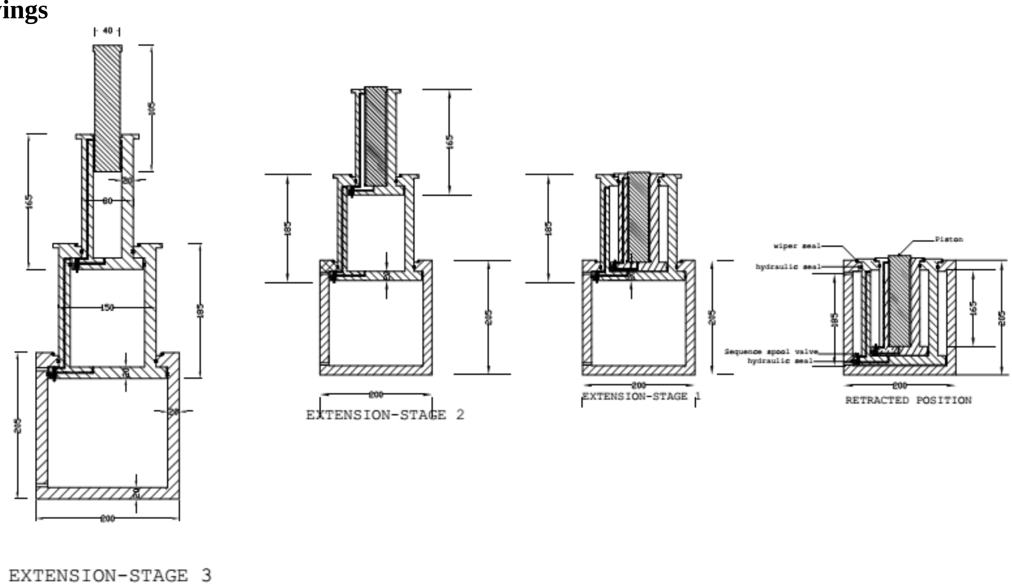


Fig. 2 Modeled view

4. DISCUSSION

Following the confirmed result of the 20mm thickness obtained which would be very safe for construction of the Telescopic Jack to withstand a maximum load of 50 tons, the Telescopic Jack can now be constructed. It shall be operated with the control valve in the chamber on the bottom of the piston for it to be pressurized, the volume under the piston is released upon producing enough force to move the piston, the piston of stage 1 begins to move towards the end of the stroke of stage 1, a spool valve on the piston of stage 1 is actuated and allows hydraulic to flow for stage 2 to begin. Also, towards the end of stage 2 a spool valve on the piston of stage 2 is actuated, thus opens the hydraulic oil for stage 3 to begin. This will continue until the end of stroke for stage 3. When the retraction of the jack is needed, the control valve is operated to the second position, thus, the hydraulic oil flows to the upper part of the jack housing, in the process forcing the jack to retract while the pressure on the lower side of the housing is relieved.

Detailed Drawings



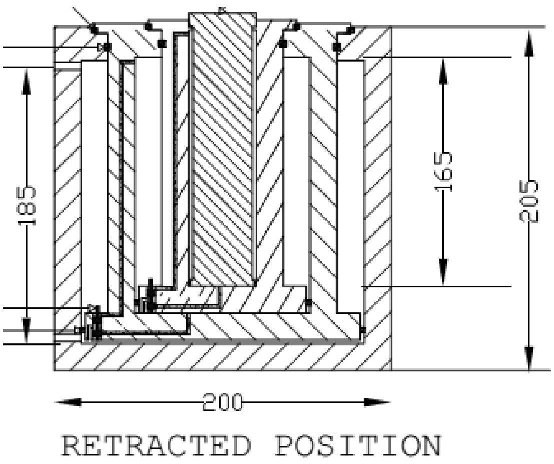


Fig. 3 Detailed dimension drawing of the Telescopic Hydraulic Jack

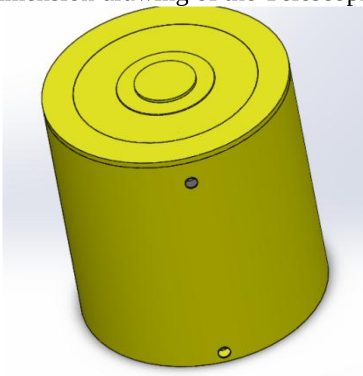


Fig. 4 Retracted full drawings of the 50tons, 3-stage Telescopic Hydraulic Jack

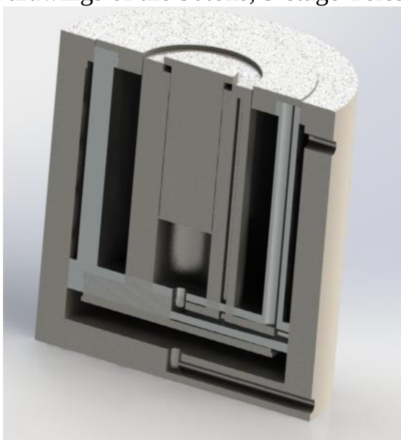


Fig. 5 Section A-A of the 50 tons, three stages Telescopic Hydraulic Jack

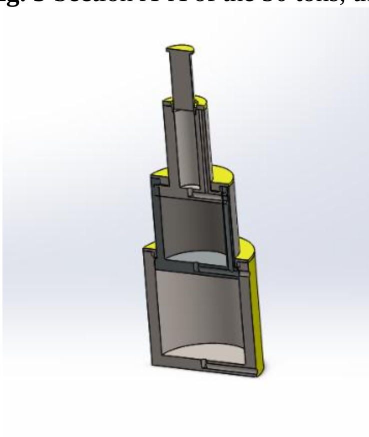


Fig. 6 Section A-A of Full view

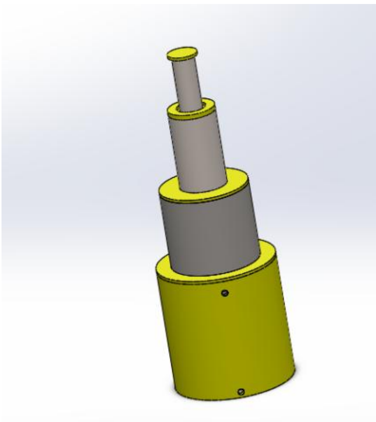


Fig. 7 Full view

Fig. 8 Component part of the first stage base cylinder.

5. CONCLUSION

The design and construction of the 50tons three stage Telescopic hydraulic jack would be very useful in automobile maintenance, marine vessels diesel engines maintenance because of its ease of operation and speed in lifting load. This could be further constructed using steel and other materials with the aim of adding value and maximizing local content.

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