Graduation Thesis

of

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DESIGN
FOR A
HYDRAULIC ARBOR
PRESS
7 TONS PRESSURE
UNIFORM STRENGTH
Outline

Object

Computations for

1. Outer cylinder.
2. Inner cylinder.
3. Supporting rods.
5. Base.
6. Pump lever.
7. Pump attachment.

Specifications for

1. Outer cylinder.
2. Inner cylinder.
3. Supporting rods.
5. Base.
6. Pump attachment.
7. Pump.
8. Minor details.
The following is a design for a tool to be of convenience for general machine shop use, such as pressing in bushings, shafts, mandrels, or tight fitting pairs of any kind. It has a maximum power of seventeen tons and a sixteen inch throw. The cylinders are strong enough for pumping up to one thousand pounds pressure per square inch. It is to be operated by the hand, the effort being exerted through a medium of oil instead of water.

Computations

If 7 tons is the desired working pressure, then $7 \times 2000 = 14000$# the desired maximum pressure in pounds in the cylinder.

The desired effort ($45^\circ$) is to be exerted on a plunger through a lever, in which the resistance bears a ratio to the effort of 1:3. If $45^\circ$ is the maximum effort to be exerted on the lever, then $3 \times 45^\circ = 135^\circ$, the resulting force exerted on the pump plunger.

The desired area of pump plunger is $\frac{1}{3}$ square inch. Hence, a force of 135 pounds acting on plunger $\frac{1}{3}$
Square inch in area, will give a maximum working pressure of 540 pounds per square inch in the cylinder.

Since the maximum pressure to be exerted is 14000 pounds, then \( \frac{14000}{24.9} \) square inches, the sectional area of a cylinder necessary to give the desired result.

The area of a piston with a diameter of 6 inches is 28.2743 sq. inches. Therefore, a cylinder with a 6 inch bore will be used.

From H. S. Armstrong's table for cast-iron cylinders, for an interior pressure of 1000 pounds per square inch, a cylinder with a diameter of 6 inches must be 1.552 inches thick. This corresponds to the formula

\[ t = 1.75 d + 0.48 \]

**Cylinder volume necessary for a 16 inch stroke**

Area of a piston with a diameter of 6 inches is 28.2743 square inches. Length of stroke 16 inches; therefore, 16 x 28.2 square inches = 452.32 cubic inches, volume of the outside cylinder at the end of a 16 inch stroke. Also the volume of oil to be contained in the inner cylinder, necessary to produce the maximum stroke.

Taking a 16 inch stroke and allowing 12 inches for lap and 4½ inches for the bottom of the cylinder, the following result is obtained: 16 + 12 + 4½ = 32½ inches the stroke length of the outer cylinder.
Inner cylinder.

The ultimate compressive strength of cast iron is 9,000 pounds per square inch. For varying stresses a factor of safety 15 should be used. Therefore, \( \frac{9000}{15} = 600 \) pounds per square inch, allowable unit working stress.

Area of piston 6 inches in diameter, 28.2743 square inches.

Area of piston 5 inches in diameter, 19.635 square inches. Therefore, \( 27.27 - 19.635 = 7.642 \) of cast iron in a cylinder with an assumed thickness of \( \frac{1}{2} \) inch.

Now 8.647 of cast iron is to sustain a maximum pressure of 14,000 pounds, from this it follows that \( \frac{14000}{8.647} = 1614 \) pounds will be the unit working stress per square inch. The inner cylinder will be made \( \frac{1}{2} \) inch thick allowing for attachment and a larger factor of safety.

Since 452.32 cubic inches is the volume of the outer cylinder at the end of a sixteen inch stroke, \( \frac{452.32}{19.68} = 23 \) inches, length of a cylinder of a 6 inch bore necessary to contain 452.32 cubic inches of oil, the amount required to give the outer cylinder a 16 inch stroke.

Supporting rods.

To be made of wrought iron.
Ultimate tensile strength of wrought iron 55,000 pounds per square inch. For varying stresses, a factor of safety of 10 should be used. \( \frac{55,000}{10} = 5,500 \) pounds is the unit working stress of wrought iron.

Since the maximum tensile force to be exerted is 14,000 pounds, then \( \frac{14,000}{5,500} = 2.54 \) square inches necessary to sustain the given tensile force. Since there is to be two supports, \( 2 	imes 2.54 = 5.08 \) square inches required area of the cross section of each support. This gives a rod 1\% inches in diameter. However, the supports will be made 1\% inches in diameter to give rigidity to the tool, and will also make allowance for the cutting of a shoulder for the joint and to not warp at the same time doing away with the upsetting of such a large bar. An eight of an inch shoulder will be allowed.

Heads.

From Love and Bevis, the short diameter = \( 1\frac{1}{2} \) in + \( \frac{1}{8} \) when \( \frac{1}{8} \) is the diameter of the bolt. This makes the short diameter of a hexagon nut 2\% inches. Thickness of nut = \( \frac{1}{8} \) or 1\% inches. Long diameter = 3\% inches.

Cap.

To be made of cast iron, and formed like an I beam.
Spacing 2 feet.
Load 14,000 pounds. Formulas for a simple beam with concentrated load \( M = \frac{wL^2}{8} \).

\[
M = \frac{wL^2}{8} = \frac{14 \times 10^3 \times 4 \times \frac{6}{12}}{8} = 84,100 \text{ pound inches.}
\]

Ultimate tensile strength of cast-iron 20,000 pounds per square inch. For shocks, a factor of safety 20 will be used.

Hence \( \frac{20}{20} = 1000 \) pounds per square inch, unit working strength for cast-iron. Since \( M = \frac{S I}{C} \) in which \( M \) is the bending moment and \( \frac{S I}{C} \) is the resisting moment. From \( M = \frac{S I}{C} \) the formula \( \frac{I}{C} = \frac{M}{S} \) is obtained. Since \( M = 84,100 \) pound inches and \( S = 1000 \) pounds, then \( \frac{I}{C} = \frac{84,100}{1000} = 84 \).

From Merzianu, according to Hodgkinson's investigations, the following are dimensions for cast-iron beams of equal ultimate strength:

<table>
<thead>
<tr>
<th>Thickness of web</th>
<th>( t )</th>
</tr>
</thead>
<tbody>
<tr>
<td>Depth of beam</td>
<td>( 13.5t )</td>
</tr>
<tr>
<td>Width of tensile flange</td>
<td>( 12t )</td>
</tr>
<tr>
<td>Thickness of tensile flange</td>
<td>( 2t )</td>
</tr>
<tr>
<td>Width of compressive flange</td>
<td>( 5t )</td>
</tr>
<tr>
<td>Thickness of compressive flange</td>
<td>( 1\frac{1}{3}t )</td>
</tr>
<tr>
<td>Value of ( c )</td>
<td>( 9t )</td>
</tr>
<tr>
<td>Value of ( I )</td>
<td>( 923t^4 )</td>
</tr>
</tbody>
</table>

From this, \( \frac{I}{C} = \frac{923t^4}{9t} = 102.5t^3 \) and \( 102.5t^3 = 84 \).

\[ t^3 = \frac{84}{102.5} = 0.82. \]
\[ t = \frac{3}{1.82} \]
\[ t = 1.66 \]

For convenience, taking the value of \( t \) as one inch the following results are obtained:

- Thickness of web: 1"
- Depth of beam: 13.5"
- Width of tension flange: 12"
- Thickness of tension flange: 2"
- Width of compressive flange: 6"
- Thickness of compressive flange: 1/4"

The beam is to be 3 feet between supports, and as there is 3 1/2 inches for support holes and it is to project 5 inches beyond the supports on either side it will have a total length of 31 1/2 inches.

**Base.**

The base will be made 21 1/2, 18 inches wide, and 5 3/4 inches high. This is extra heavy.

**Pump Lessor.**

To be made of steel.

The ultimate tensile strength of steel is 10,000 pounds per square inch. For shores a factor of safety 15 should be used. Hence, \( \frac{10,000}{15} = 666 \frac{2}{3} \) pounds per square inch, unit working strength for steel.
For a cantilever beam, loaded at the end, \( M = Wl \), in which \( M \) = bending moment, \( W \) = weight, and \( l \) = length. In this case \( W = 45 \) pounds, and \( l = 18 \) inches. Hence, \( M = 45 \times 18 = 810 \) inch pounds.

From the above, \( \frac{810}{\pi} = 13 \) square inches, area of cross-section of lever necessary to sustain the effort of 45 pounds. However, the lever will be made with the area of its cross-section equal to \( \frac{1}{2} \) a square inch, so it will be \( 1 \times \frac{1}{2} \) inch.

For pump attachments see drawings.

The rod will be made \( \frac{3}{16} \) inch in diameter at the plunger end, and to give rigidity \( \frac{3}{4} \) of an inch in diameter alone that.
Specifications

Outer cylinder, 40 cm.

The outer cylinder is to be made of cast iron, 1 1/2 inches thick. The bore is to be 6 inches in diameter, and 28 inches long. The bottom will be 4 1/2 inches thick, below 1 1/2 inches it will be turned down to a 5 inch diameter. On the part with a 5 inch diameter, 2 1/2 inches of threads will be turned, but at the bottom 1/2 of an inch of the threads will be removed. This will allow for the attachment of a clamp for holding various tools, and it may still be used without the attachment for press work. At the upper end of the cylinder there will be a collar left, 1/2 of an inch wide and 1 1/2 inches deep. This will allow the attachments of weights, to be used in raising the cylinder back to its initial position after the clothe has been completed.

At the bottom of the bore, a hole will be drilled, thus a water connection may be made with a pressure gauge on the outside.

Inner cylinder.

The inner cylinder will be made of cast iron. It is to be 1/2 of an inch thick. The outside diameter is 6 inches and the inside diameter is 5 inches. The length of the bore is 38 1/2 inches. Thickness of bottom 1 1/2 inches, making a length overall of 80 inches.
In the bottom, two ½ inch bolt holes for counter sunk heads will be bored, 3 inches apart from centre to centre. There will also be a ½ inch hole, for the attachment of a release cock, and a ¾ inch hole for communication between the inner and outer cylinders. On the outside of the bottom of the cylinder, a shoulder will be turned off, for a ring of ½ inch V packing. The packing will be held in place by a ½ inch plate fastened at the middle by a screw.

At the upper end of the of the cylinder, a flange will be left, ½ inches wide, and ½ of an inch deep. There will be two ¾ inch holes drilled to provide for attaching the cylinder to the cap.

The Supporting Rods.

The supporting rods will be made of wrought iron, 2 inches in diameter and 64 inches long. A shoulder of ½ of an inch will be left at the ends for the jam nut to rest upon, this leaves a diameter of the threaded part of the support of 1½ inches. For the length of threaded part, see drawings.

The Cap.

The cap is to be made of cast iron, and will take the form of an I beam, for dimensions, see computations and drawings. A hole 3½ of an inch in diameter will be cast in the exact center. The holes for the supporting rods will also
be cast six as shown by the drawings. Allowance must also be made for the attachment of relief valve and pump mechanism as shown.

The Base.

The base is to have the dimensions shown by the drawings. The bottom will be cast corrugated, and a hole 4 inches in diameter will be cast in the center.

Pump Attachments.

The liner will be made so that the plunger rod is attached 18 inches from the effort end of the lever arm and 6 inches from the fulcrum end; it must be made to given dimensions. The shroud is to be made of wrought iron to fulfill the graphical dimensions. The plunger rod is to be 41 1/2 inches long, for 37 inches of its length it will be 3/4 of an inch in diameter, but 4 1/2 inches from the end it will be turned to a diameter of 3/8 of an inch. The end will be covered by a piece of cupped leather packing fastened down by a plate and screw. The plunger rod guide will consist of a brass stuffing box, to be made according to the given dimensions.

The Pump.
The frame is to be made of cast iron and is to be fastened to the bottom of the inner cylinder by two 1/2 inch bolts with countersunk heads. The dimensions given on the drawings must be followed. The hole is to be 3/8 inch in diameter and 4 1/2 inches long, at the bottom, it is to be intersected by the valve hole. The valves to be used are as follows: For admission, a Lucaskeimer horizontal drop valve, and for the connecting valve, a Lucaskeimer angle check valve will be used. The connection with the cylinders will be made by joints of go-pipe.

A high pressure gage will be attached to the outer cylinder, so the working pressure can be noted while the tool is in action.

The release valve will be of the plug form, and will be operated by a lever attached to the compression flange of the cap.

The weights to be used in raising the ram after its stroke and as soon as the release valve is turned, may be suspended by wires passing over pulleys fastened to the shute in the roof house, and done; and to be fastened in the other lift on the upper end of the outer cylinder.

In building the tool all work must be done from the drawings, which if well and properly, it is to be trusted will make a successful machine for the use of mechanics in ordinary shops, or more especially in the shop of the Kansas State Agricultural and Mechanical College.