New York Institute of Technology
MENG 486 - Design Project 3

Optimizing the Hydraulic Press Foot of a Compressed Earth Brick Press

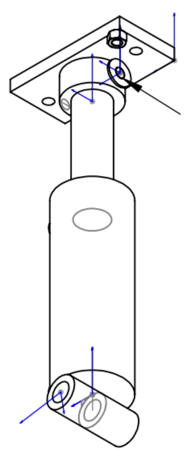

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Table of Contents

Introduction & Design Criteria	3
Research	4
Materials	4
Fabrication	5
Method of Analysis	6-7
Design FEM Analysis	8-9
References	11
Appendix	12-13

Introduction:

The Press Foot of the OSE Compressed Earth Brick Press uses 78,540 lbs of force to compress soil into a 6x12x5 cubic inch brick. The overall effectiveness of the brick press is highly dependent on the integrity of the press foot which must resist deformation and distribute extreme loads efficiently. In this report the original design is compared to an alternative design. Both designs are modeled and analysed in Hypermesh to better understand and improve the OSE CEB Press.

Design Criteria:

The major design considerations for the alternative design were cost, ease of fabrication, and maintaining a safety factor of at least 1.2, meaning that the Press Foot should be able to withstand a force 20% greater than the maximum anticipated force before plastic deformation (irreversible stretching), or fracture/cracking.

In order for the alternate design to be feasible the materials cost should be less than or equal to the materials cost of the original press foot. The materials cost of the original press foot is estimated to be $150, most of this cost coming from the two 1 inch thick steel plates fastened back to back.

Ease of fabrication is the third major design consideration in the Alternate Press Foot Design. Parts must be made of homogeneous materials, and uniform thickness. Also, the steel used should either be the standard cold drawn steel used for the majority of the machine, or readily available from steel distributors in and around major cities.

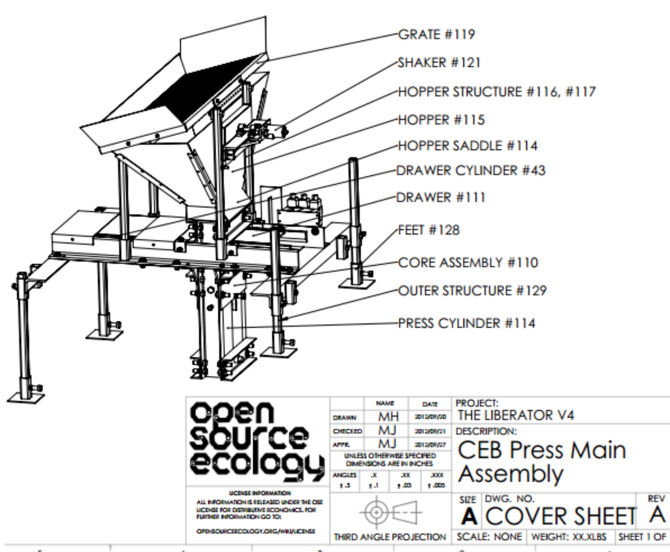

Figure 1: A diagram of the OSE brick press

Research Notes:

Area of plate: 6” x 12” = 72 in^2
Hydraulic Force: 78,540 lbs.
Pressure on plate: (78,540 lbs / 72 in^2) = 1090.83 psi
Brick size: 6” x 12” x 4” to 6”

Materials Research:

	C1018 Cold Drawn	A36	A572 Gr 50
Ultimate Strength	440 MPa	400 MPa	450 MPa
Yield Strength	370 MPa	250 MPa	345 MPa
Poisson's Ratio	0.29	0.26	0.27
Maximum Von Mises	296 MPa	240 MPa	240 MPa
Safety Factor	1.25	1.04	1.473
Unit Cost (Per CC)	$0.56	$0.46	$2.1
Total Cost	$44.66	$36.68	$167.50

The table above compares the cost and performance of 3 different specifications of material for fabrication of component. The main criteria for comparison of these metal specs are availability and affordability.

C1018 is AISI specification for cold drawn steel. It is very economical and widely available in different sections and sizes. An added advantage is that it is available as 1” x 6” flat stock. This reduces the amount of fabrication work required to make the base of dimension 6” x 1” x 12”. As the table shows it is the best fit for our component as the safety factor is large enough with acceptable increase in cost compared to A36.

ASTM Specification A36 steel is a material very commonly used in metal fabrication. Produced as hot rolled coils it is available everywhere as 6’ or 12’ X 4’ sheets. Although A36 is the most affordable material of the 3 metals, due to the low factor of safety it cannot be chosen for use in the component.

We also considered a higher yield strength mild steel - A572 Grade 50. Although this offers the highest factor of safety amongst the 3, the increase in cost of the component is not justifiable.

Methods of fabrication

The selected material AISI C1018 is widely used for material fabrication due to its ease of workability. As explained earlier the fastest way to fabricate our component would be to cut foot long pieces of 6'X1' straight bars. However, prefabricated metal shapes from the mill often contain unacceptable imperfections in shape and sizes. It is easier and more economical to fabricate the parts of the component from large sheet metal using plasma cutting or shearing.

Plasma Cutting

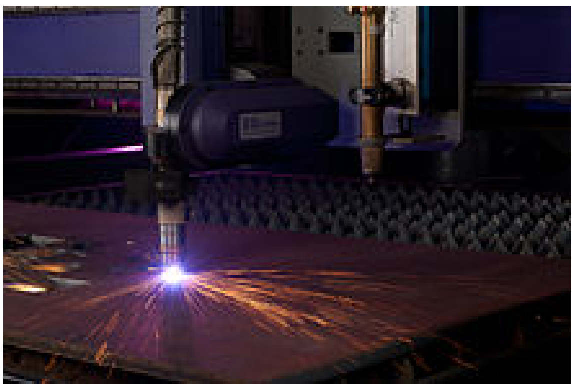

Figure 2: CNC Plasma Cutter

Plasma cutting is a process that is used to cut steel and other metals of different thicknesses (or sometimes other materials) using a plasma torch. In this process, an inert gas (in some units, compressed air) is blown at high speed out of a nozzle; at the same time an electrical arc is formed through that gas from the nozzle to the surface being cut, turning some of that gas to plasma. The plasma is sufficiently hot to melt the metal being cut and moves sufficiently fast to blow molten metal away from the cut.

Shearing

Shearing, also known as die cutting is a process which cuts stock without the formation of chips or the use of burning or melting. This is usually done using a hydraulic guillotine shearing machine or an iron workhorse.

Figure 3: Iron Workhorse used for shearing and punching.

Method of Analysis:

1. Create 2D profile in Freecad. (Figure 5)
2. Export as STEP file (Figure 6)
3. Import 2 times in Hypermesh, on separate components
4. Translate 1 copy 1 inch in negative Z direction (Figure 7)
5. Create 2D mesh, using Plane
6. Drag collar mesh 2 inches in positive Z direction, new component
7. Drag small plate mesh 2 inches in negative Z direction, new component
8. Drag large plate 1 inch in negative Z direction, starting from translated plane (step 4)
9. delete temp nodes, delete 2d elements, equivalence (0.1mm).
10. constrain inner circle face dof3=0.
11. external force, +Z direction on lgPlate surface. 66.48N per node (5255 nodes on face)
12. Finally, LinearStatic loadsteps were created, and Optistruct was run.

$$1\ \mathrm{lbf} = 4.4482\ \mathrm{N}$$

$$\frac{78540\ \mathrm{lbf}}{5255\ \mathrm{node}} = 66.4821\ \frac{\mathrm{N}}{\mathrm{node}}$$

Figure 4: Example Force Calculation, 78,540 lbs is the maximum force of the hydraulic cylinder.

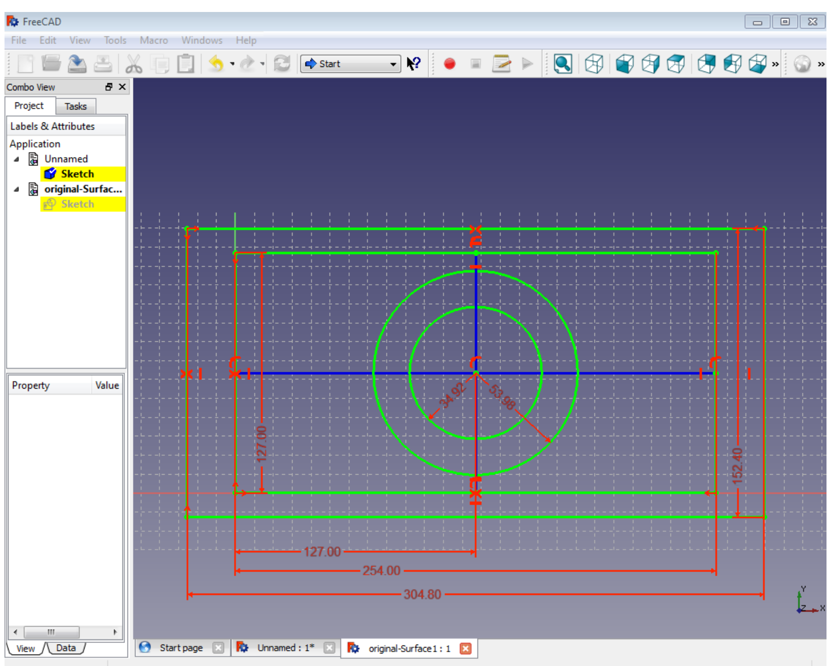

Figure 5: Step 1, Creating the 2D profile in FreeCAD.

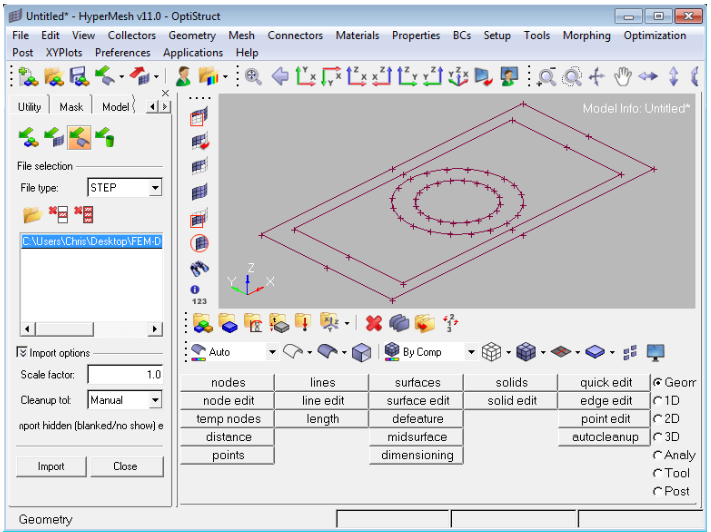

Figure 6:
Step 2, Importing the 2D STEP file into Hypermesh.

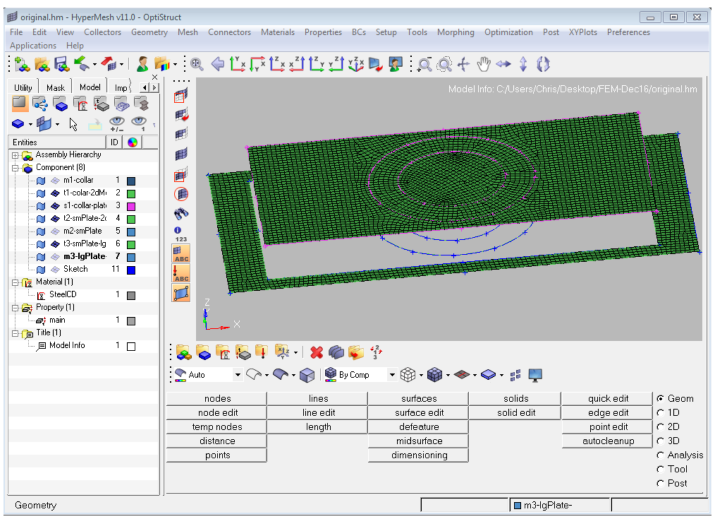

Figure 7:
Organization of lines, surfaces 2D elements, and 3D elements.

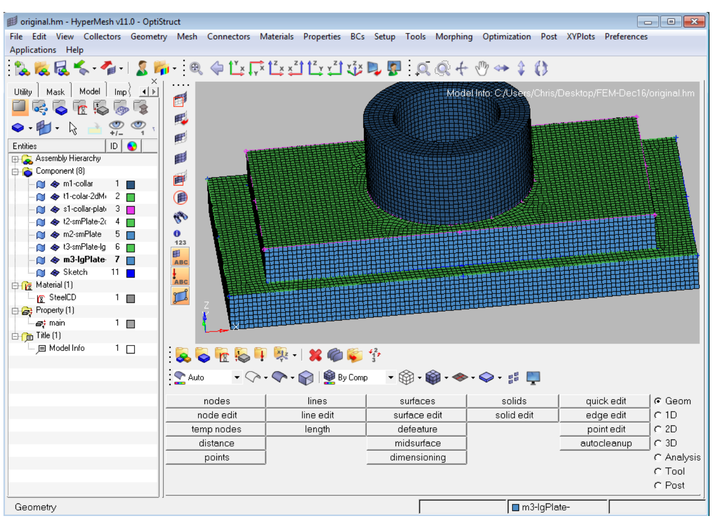

Figure 8:
Use of Drag function to create 3D elements.

Finite Element Analysis, Original vs. Alternate:

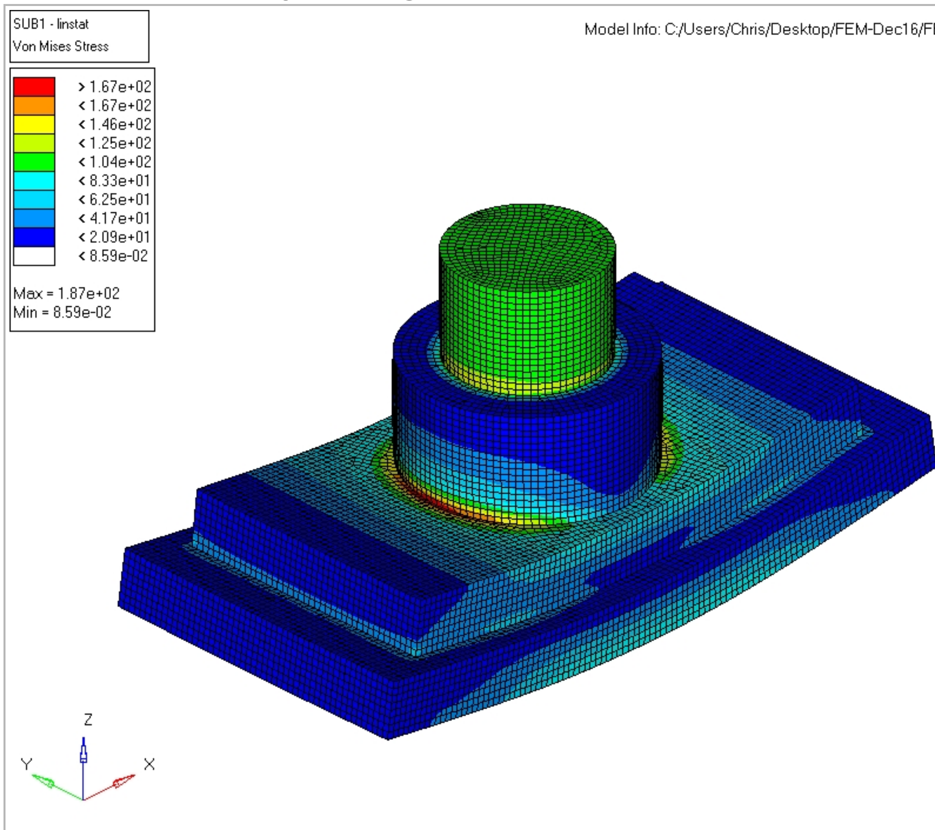

Figure 9:

Linear static analysis of ***original*** *design.*

Max VM: 187 MPa.
Mass: 21.00 Kg
Max Deform: 0.195mm
Saftey Factor: 1.98

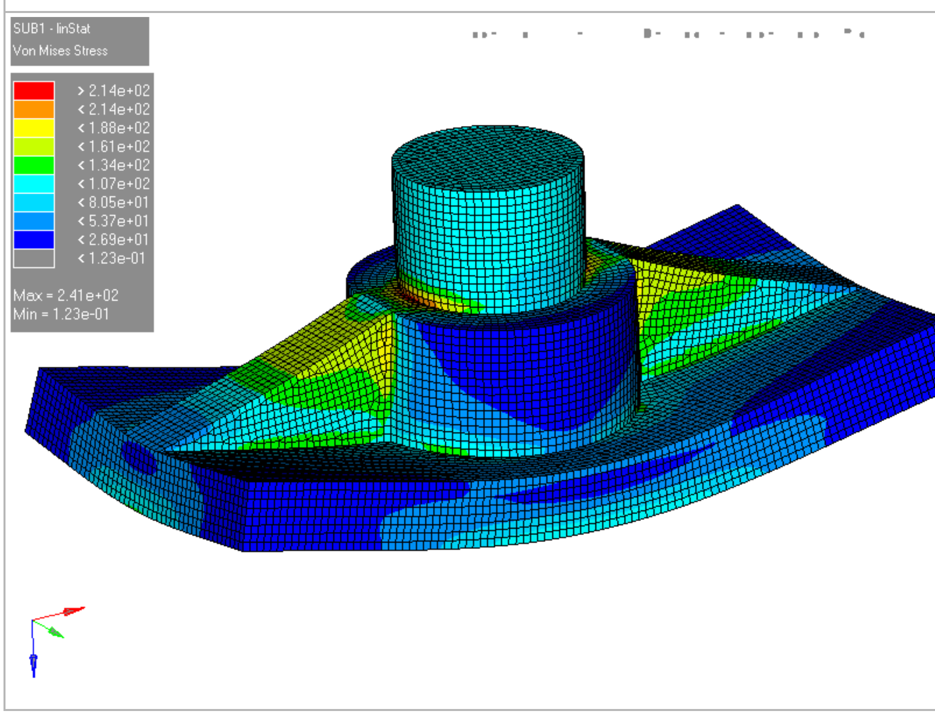

Figure 10:

Linear Static analysis of ***alternate*** *design.*

Max VM: 241 MPa.
Mass: 15.04 Kg
Max Deform: 0.362mm
Saftey Factor: 1.54

(Deformation exaggerated x100 in both images)

Frontal View comparison between original and alternate designs:

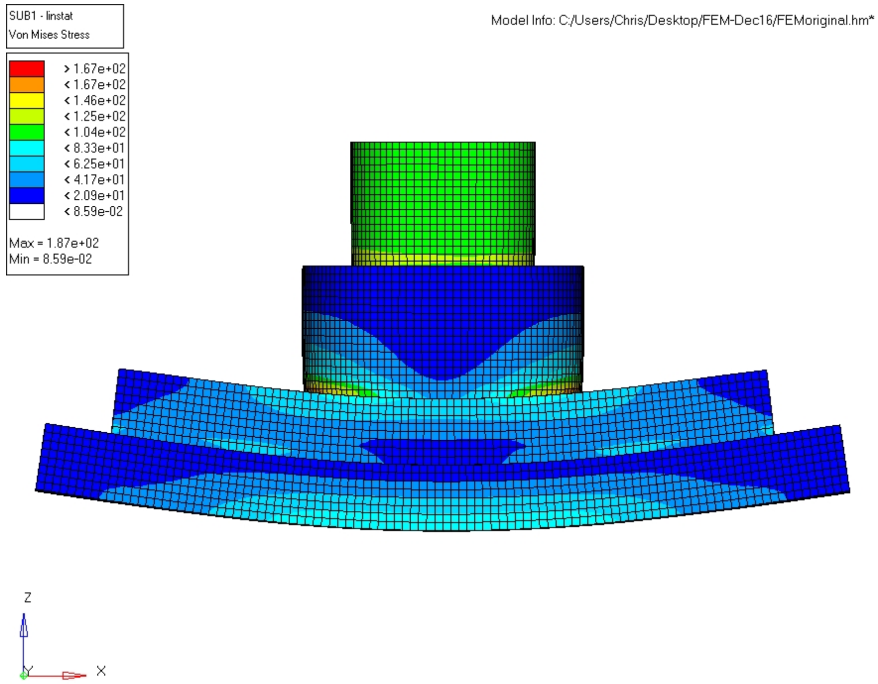

Figure 11: Original design

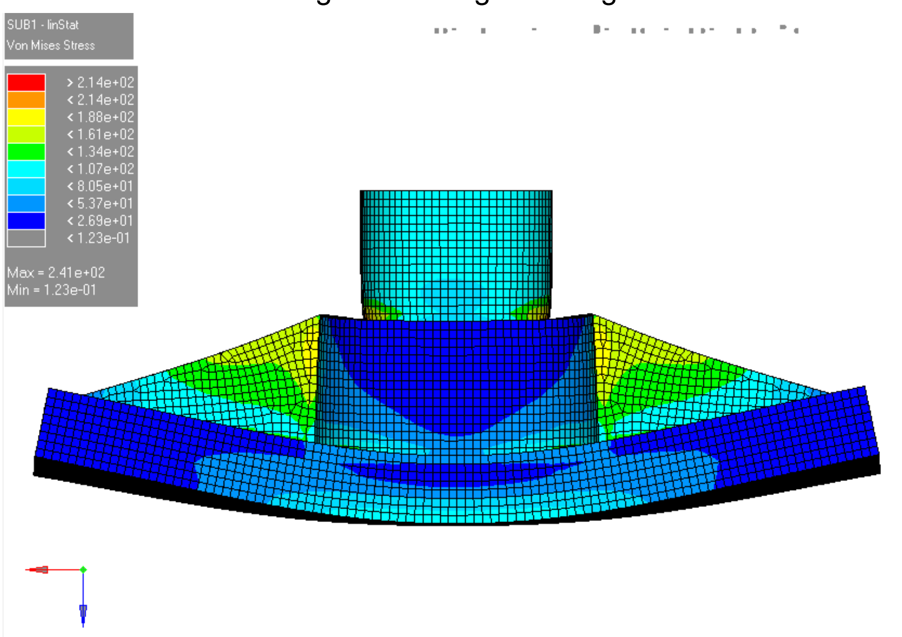

Figure 12: Alternate design

In the frontal view comparison it is clear that the resistance to deformation is comparable, even though the mass of the alternate design has been reduced 28.6%, from 21 kg to 15 kg. This indicates a more efficient distribution of stress throughout the body.

Conclusion:

The goal of this study was to make cost effective modifications using basic fabrication processes and readily available parts. The alternate press foot is simpler to fabricate because the original design required machining of 2 threaded holes for attaching the second plate, whereas the alternate design requires 8 small welds. The modifications can be done in any fabrication shop with easily accessible tools and materials which adheres to the principles of Open Source Ecology.

By eliminating the need for a second plate the material cost savings would be significant, almost 50%. The alternate design uses less material and maintains a satisfactory maximum deformation of 0.362 mm. Also, the alternate design's safety factor of 1.54 is still within the design criteria.

The entire design process shed light on the importance and challenge of designing within the constraints of economics and steel fabrication.

Figure 13: Prototype 4 of the OSE Brick Press, aka “The Liberator”

References:

- CEB Press
    - http://opensourceecology.org/wiki/CEB_Design#Specifications
    - https://archive.org/details/CebPressSensorConstructionInstructional
    - http://opensourceecology.org/w/images/e/ef/CEBIVFab.pdf (schematics)

- Soil:
    - http://www.oneplan.org/Images/soilMst/SoilTriangle.gif

- Hydraulic Cylinders:
    - http://baileynet.com/index.php?page=Search&id=14&srchsrc=SearchBox&sbmfrmas=Submit&baileynum=216-380
    - https://www.surpluscenter.com/Hydraulics/Hydraulic-Cylinders/Double-Acting-Hydraulic-Cylinders/2-5x14x1-125-DA-HYD-CYL-LION-25LH14-112-3000-PSI-9-8261-14.axd
    - http://baileynet.com/hydraulics/chief_whp_welded_hydraulic_cylinders

- Material Properties:
    - http://matweb.com/search/DataSheet.aspx?MatGUID=9ced5dc901c54bd1aef19403d0385d7f
    - http://www.matweb.com/search/DataSheet.aspx?MatGUID=3a9cc570fbb24d119f08db22a53e2421&ckck=1
    - http://www.matweb.com/search/DataSheet.aspx?MatGUID=9ced5dc901c54bd1aef19403d0385d7f
- Fabrication Methods
    - http://en.wikipedia.org/wiki/Plasma_cutting
    - http://en.wikipedia.org/wiki/Shearing_(manufacturing)

Appendix:

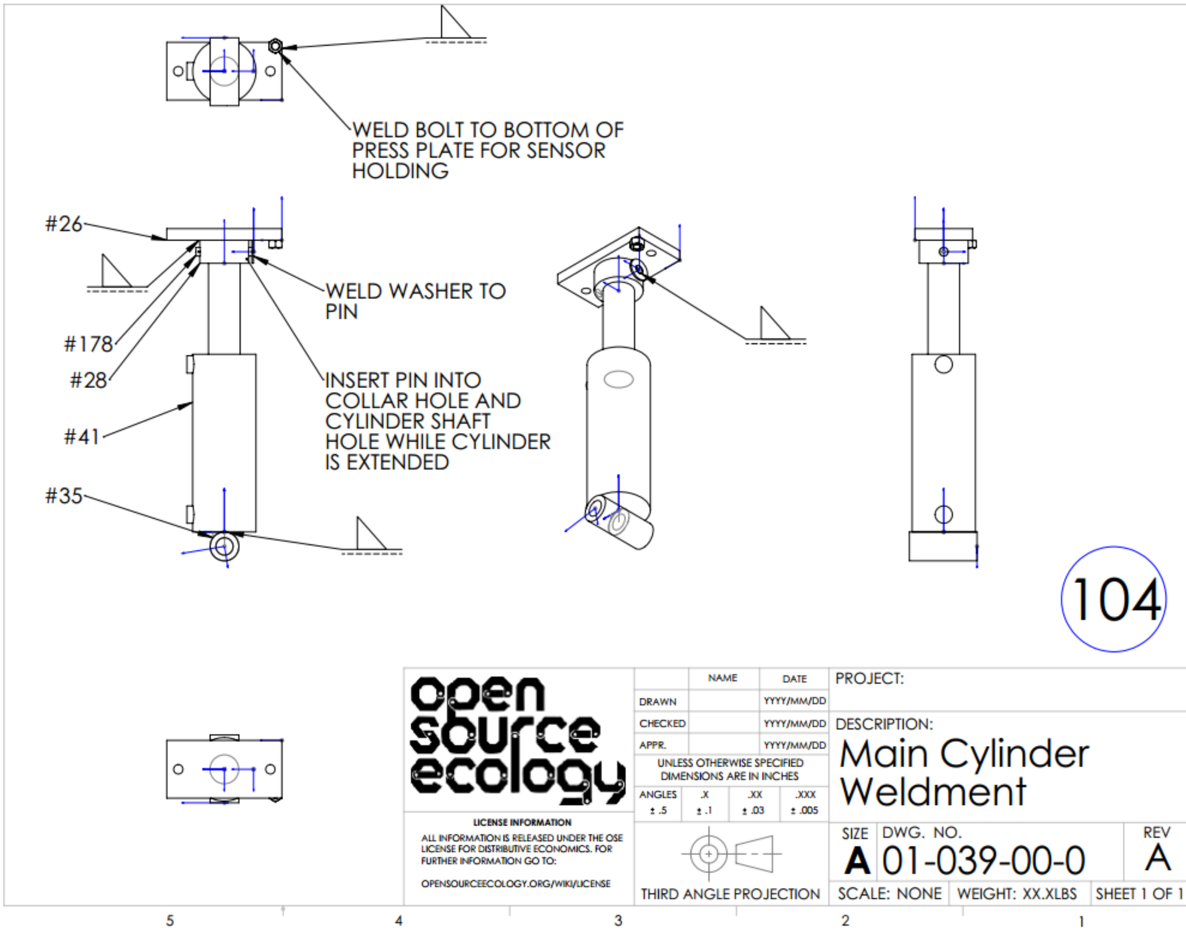

Figure 14: 2D Fabrication Drawing

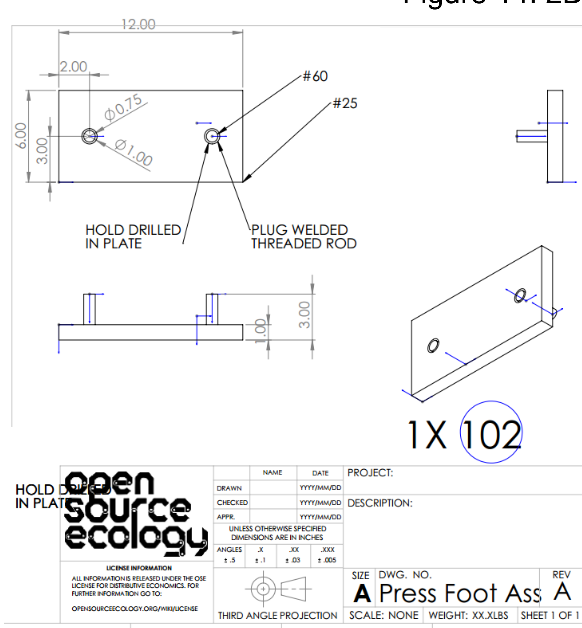

Figure 15: 2D Fabrication Drawing

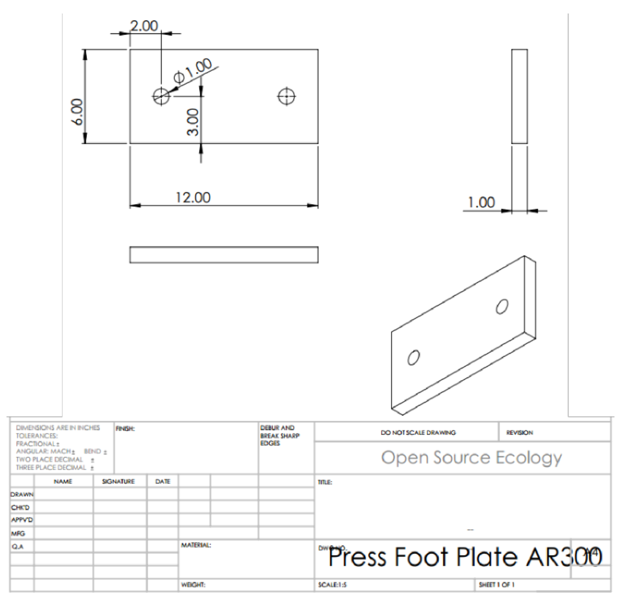

Figure 16: 2D Fabrication Drawing

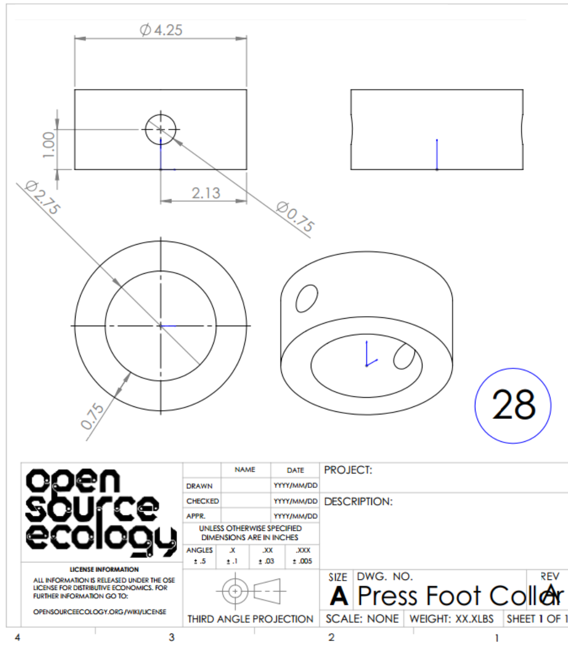

Figure 17: 2D Fabrication Drawing

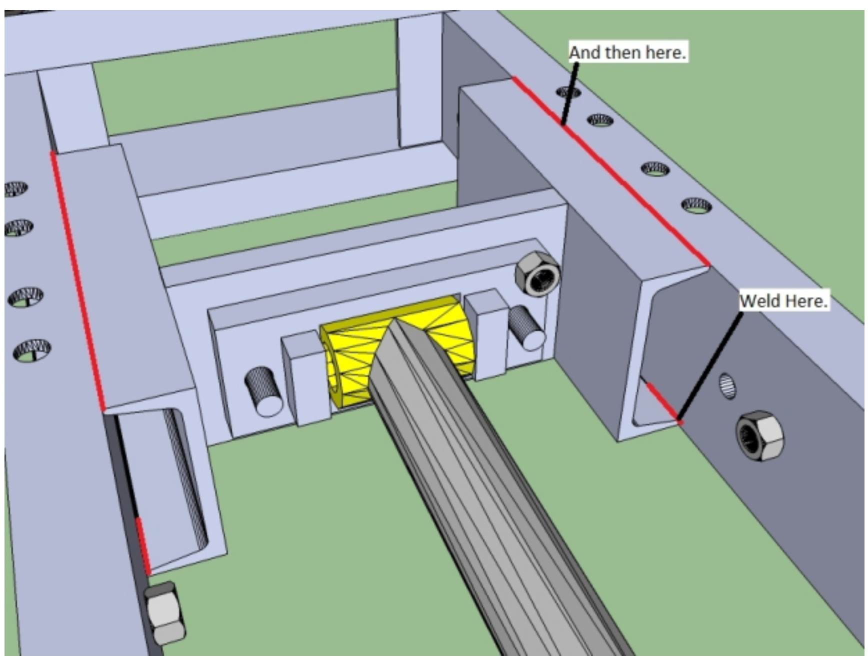

Figure 18: Early concept of the press foot. (opensourceecology.org)