

# At-Home Motorcycle Tire Changer

A Baccalaureate thesis submitted to the  
Department of Mechanical and Materials Engineering  
College of Engineering and Applied Science  
University of Cincinnati

in partial fulfillment of the  
requirements for the degree of

Bachelor of Science

in Mechanical Engineering Technology

by

Eric Wellman

April 2017

Thesis Advisor:  
Professor Ahmed Elgafy, Ph.D.

**Contents**

LIST OF FIGURES ..... 3

INTRODUCTION: ..... 4

OBJECTIVE: ..... 5

RESEARCH:..... 5

CONCEPTUAL DESIGN: ..... 8

ALTERNATE DESIGNS: ..... 11

BUDGET: ..... 11

MANUFACTURING PROCESS: ..... 11

MATERIAL SELECTION: ..... 12

DESIGN FACTORS:..... 12

DATA COLLECTION: ..... 13

PRODUCT TESTING: ..... 14

RESULTS: ..... 16

CONCLUSION:..... 17

WORKS CITED ..... 20

APPENDIX A: ENGINEERING DRAWINGS ..... 21

APPENDIX B: CALCULATIONS ..... 29

    TORQUE NEEDED TO MOUNT TIRE .....29

    FORCE APPLIED AT TIRE.....29

    INTERNAL FORCES OF TOOL .....30

    BENDING FORCES IN HANDLE .....31

**LIST OF FIGURES**

Figure 1 Visual representation of a pinch flat. Note that this example is exaggerated for clarity ..... 4

Figure 2 Tire Machine at Beechmont Motorsports..... 6

Figure 3 Profile of Tire Spoon. The hooked end is used to grab the aluminum rim ..... 7

Figure 4 Installing a Tire Using Spoons ..... 8

Figure 5 Early conceptual CAD model..... 9

Figure 6 CAD model displaying the tool/wheel interface ..... 10

Figure 7 A tire being mounted with a duck head..... 11

Figure 8 Apparatus for testing loads during a tire change ..... 13

Figure 9 FBD of forces during a tire change ..... 14

Figure 10 Final product..... 15

Figure 11 Device in use ..... 17

Figure 12 Triangle to be used in FBD ..... 30

Figure 13 FBD of forces on tool ..... 31

### INTRODUCTION:

I have work as a motorsports technician for several years now. Changing tires is the bane of routine service, both for professional technicians and those who perform their own maintenance at home. A common occurrence at work is customers dropping off dirt bike tires that are flat due to pinched inner tubes. Dirt bike tires are installed using tire spoons to pry the bead over the rim. A pinch flat is caused when an operator accidentally grabs the inner tube with the tire spoon, pinching the tube against the rim and ruining the tube. Why are these pinch flats such a headache? If you're lucky, you realize your mistake as soon as it is made, remove the tire, install a new tube, and start over. If you're not lucky, you finish mounting the tire without catching your mistake. The mistake is caught when attempting to inflate the tire. It is necessary to remove the tire and start from the very beginning. There is also no guarantee that the user will not make the same mistake again with the new tube. Many customers have fought to install the tire only to find that the tube was damaged in the process. Discouraged, they then bring the wheel and tire to the shop to be done professionally. However, it proves that customers do have the ambition to perform their own work.



Figure 1 Visual representation of a pinch flat. Note that this example is exaggerated for clarity

My idea involves engineering a fulcrum that mounts to the hub of the wheel. The operator will manipulate a lever, which will in turn move an arm that “pushes” the bead of the tire over the rim. This eliminates the need to pry against the trim with a spoon, and therefore reduces the chances of a pinch flat. In addition, this system will:

- Reduce the likelihood of cosmetically damaging the rim (which is common when spooning a tire)
- Be a safer alternative to prying the tire on. It is easy for a spoon to slip and send a technician’s hand into the sprocket or machined edge of the brake rotor
- Reduce the amount of time needed to change a tire
- Reduce the amount of physical exertion needed.

Serious riders can go through a set of tires in a week. With a shop charging around \$30 per tire, the savings would quickly add up. Shops utilize tire machines that cost thousands of dollars. The goal here is create a tool that is practical for novices.

### **OBJECTIVE:**

Create a simple, inexpensive device to aid dirt bike enthusiasts in changing tires

### **RESEARCH:**

There are currently no products quite like this on the market. Two methods currently exist to change a motorcycle tire. The first of which involves a pneumatic, electric, or hydraulic machine. A professional-grade tire machine can easily exceed \$10,000. In addition, they are large, heavy, and require frequent maintenance. The rim is held using a clamping pressure on the outside diameter. The technician then moves an arm into place on the rim, and pries the bead over the rim lip. A foot pedal is then depressed, and the rim is rotated by the camps while the arm is held stationary. An inclined plane on the end of the arm

encourages the bead to slip over the rim as the rim is rotated 360 degrees. The chances of pinching a tube are low, but spoon must still be utilized at the beginning of the process, which is an opportunity to damage the rim or tube. In addition, modern tires are made with high-strength sidewalls that can include materials such as Kevlar. If a tire is too stiff, the rim will simply slip in the clamps as it rotates since frictional forces are all that is holding it.



Figure 2 Tire Machine at Beechmont Motorsports

Tire spoons are inexpensive, but are difficult to use and present a high chance of tube or rim damage. Essentially, spoons are glorified pry bars.



Figure 3 Profile of Tire Spoon. The hooked end is used to grab the aluminum rim

Generally, two to four spoons are used as pry bars to pull the bead over the rim. The operator begins by using one spoon to get started. That spoon is left in place while another is used several inches away to continue the prying process. Once all the spoons have been used, the first is removed and used to continue the pattern. Every time a spoon is inserted, there is a chance of pinching the inner tube, resulting in a flat. Also, large amounts of physical exertion are required to manipulate the stiff bead. Often times, spoons will slip and cause damage to the rim, or worse, the technician. The brake rotor and sprocket on the rim are frequently the cause of injury as a technician's hand slips and makes hard contact. However, spoons are easily stored and very portable. They can be used to effectively mount a tire, but it takes much practice.



Figure 4 Installing a Tire Using Spoons

### CONCEPTUAL DESIGN:

The tire changer takes place of the axle as the wheel is off the bike. A shaft slightly smaller in diameter than the axle is inserted into the hub, securing the tool. Rims vary in diameter from 18" to 21", so the tool must be adjustable. The slider block is a slip-fit over the lever arm. A relief cut is placed in the rear of the slider. Perpendicular to the relief is a through-hole which a cam lock is inserted. When the cam lock is engaged, a clamping force is applied, locking the slider in place through friction force. Setting the required throw for the rim size is as simple as opening the cam lever and moving the slider up or down the fulcrum arm. The user will then work incrementally to get the tire over the rim, rotating the tool as they go.

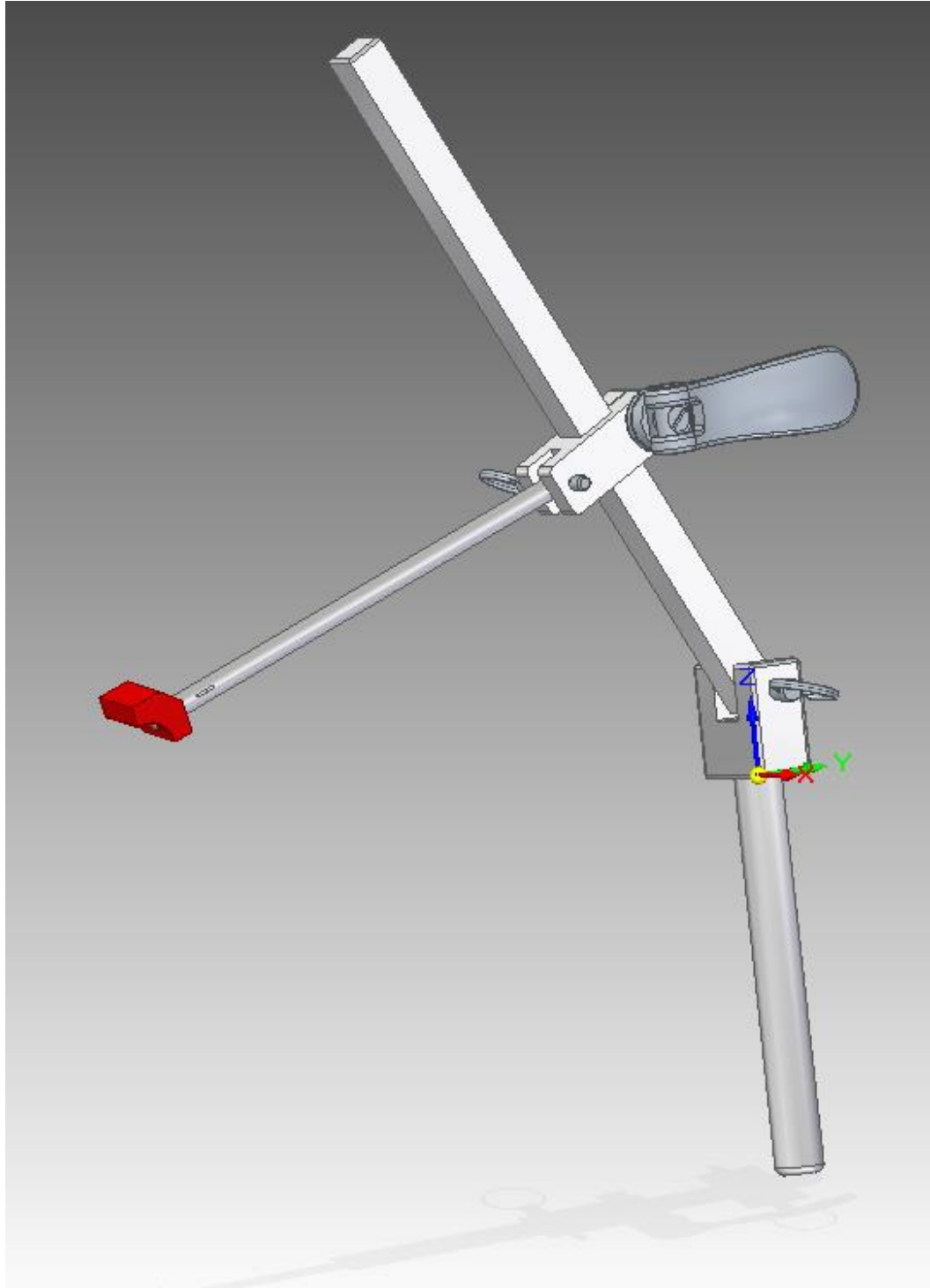


Figure 5 Early conceptual CAD model

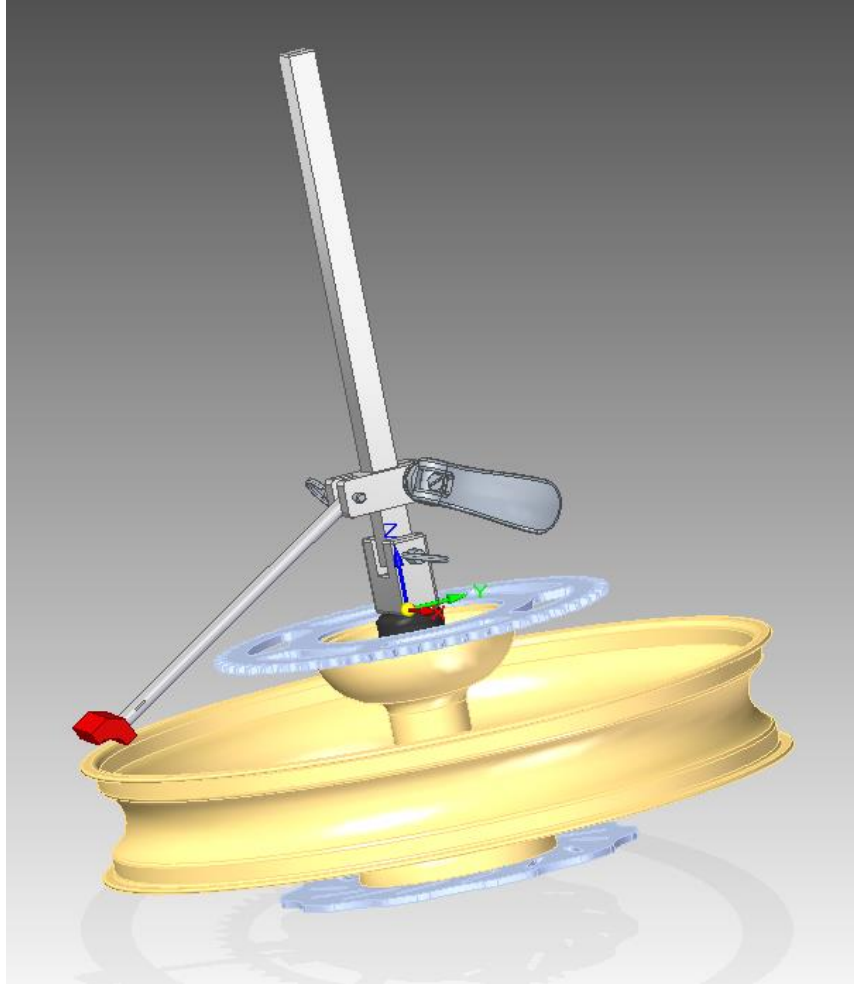


Figure 6 CAD model displaying the tool/wheel interface

**ALTERNATE DESIGNS:**

One alternative considered consisted of a hub-mounted conventional “duck head” design. This is the preferred device when using profession-grade tire changers.



Figure 7 A tire being mounted with a duck head

The head would be mounted to the hub in a similar fashion to the chosen design. The user would then manually rotate the duck head around the tire, and the inclined plane would slip the bead over the wheel. However, machines that utilize a duck head also use high-power clamps to secure the wheel. It would take too much effort for a single person to hold the wheel and seat the bead simultaneously.

**BUDGET:**

Having access to the equipment for manufacturing, materials are the only expenditure. Anticipated cost is approximately \$100

**MANUFACTURING PROCESS:**

All components have been designed to be machined on manual knee mills and lathes. The geometries of the components are such that CNC is not required. The materials selected meet the physical requirements of the design, but are also easily machined. Standard-size

High-speed-steel cutters will be adequate. Two-flute end mills will be used for chip clearance in the aluminum. Speed and Feed rates will be determined using the Machinery's Handbook.

**MATERIAL SELECTION:**

With the exception of the end effector, all machined components are made of 6061-T6 aluminum. This material was selected due to its strength, corrosion resistance, light weight, machinability, and low cost.

The end effector is made of Nylon 6/6. The mechanical properties of this material make it a good choice to withstand the loads applied. It is also wear-resistant. Finally, Nylon will not mar or scratch aluminum wheels

The pivot pins are commercially available, and have a shear strength of 9600 lbs.

**DESIGN FACTORS:**

The tool will be subjected to repeated loads. This dictates a design factor of 8. The yield strength of aluminum 6061-T6 is 40,000PSI, and the ultimate strength is 45,000PSI. The dimensions of the piece parts were engineered to ensure that they were loaded to a value no greater than 5,000PSI.

There are two exceptions to this rule. The lever arm itself undergoes a maximum bending moment that results in a design factor of approximately three. The tire arm experiences a load of approximately 6280Psi. These were deemed acceptable for two reasons. The first of which is the manner in which the load is applied. The force applied is very gradual, resulting in low acceleration. This low acceleration mimics a static loading, which requires a design factor of only 2. The second reason an acceptance to the design factor convention is that the calculations have been based on a worst-case-scenario. Realistically, most tires will not provide that level of resistance. In addition, when working even the hardest tires, the high loads are only applied during the last "push" with the tool.

**DATA COLLECTION:**

In order to better understand the forces required to change a tire, a spring scale was attached to a tire iron at a known length. The apparatus is displayed in Figure 8.



Figure 8 Apparatus for testing loads during a tire change

Four brands of tire were testing, including a Dunlop Geomax, which is known to be one of the hardest tires to mount as a “worst case scenario”. In addition, the tires had been sitting in a 58-degree Fahrenheit shop for several days. At this cooler temperature, the tire is difficult to manipulate. The tires were then spooned on to the wheel using the scale to record peak linear force. The known moment arm length and linear force allowed for calculating the torque, which came to be 79.5 ft\*lbs. Also, the tires’ distance from the point of rotation was measured. Figure 9 represents the calculations required. When the sum of the forces is equal

to zero, the force required at X is the force at the tire itself. The calculations can be found in the Appendices.

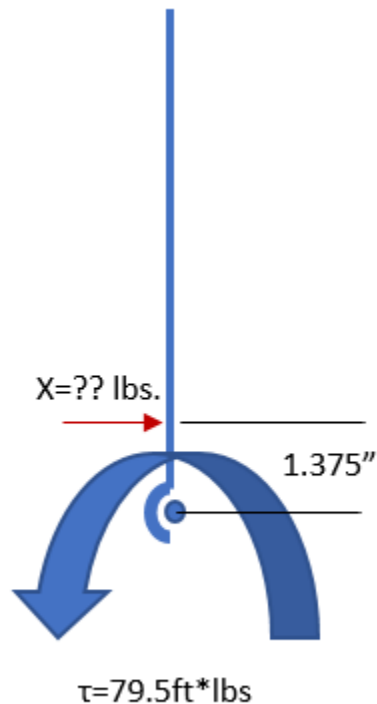


Figure 9 FBD of forces during a tire change

### PRODUCT TESTING:

For initial testing, I chose to leave the lever arm at 24" rather than cutting it to a shorter length. After usage, it was deemed appropriate to leave the arm at this length. The longer arm gives the user more mechanical advantage. The longer length has minimal effect on storage and transport aspects. In addition, a dirt bike grip was added to the end of the lever for added comfort.

The end effector was an unknown in the design phase. Originally, the plan was to create a profile that mimicked the geometry of the tire bead. However, it was found that this shape

did not effectively engage the tire. The next design was a 1"x1"x1" cube with a varying angle of engagement. As the angle of the face of the end effector became more parallel to the tire bead, the tool more effectively engaged the tire with reduced slipping. However, once the bead cleared the rim, this angle did not encourage the bead to slip into the valley of the rim. It was found that leaving the block as a cube was the best balance between a secure engagement and ensuring the tire is inclined to slide downward over the rim. This is also convenient for manufacturing, being that a cube is the simplest of the geometries to machine.

The final change made during testing involved threading the axle support on the opposite side of the slider block. It was noticed that occasionally, the tool would rise up and out of the wheel hub rather than push the tire. By threading the axle support, a bolt and fender washer can be inserted once the tool is in the wheel. This prevents any rising.



Figure 10 Final product

After making these changes, I was able to quickly and effectively change tires. However, being that I am more experienced in this type of work than most, I chose to enlist a fellow enthusiast for testing. He has minimal tire changing experience, and has pinched tubes trying to change his own tires in the past. With a brief explanation of how the tool worked and my coaching through the experience, he was able to get a tire mounted. I then removed the tire from the rim and had him install it again. This time, he was much more proficient and quickly picked up the technique.

**RESULTS:**

The tool essentially eliminates the risk of pinching an inner tube. The device has been tested on over 15 tires, and there is yet to be a single damaged tube. In addition, the physical exertion needed to mount a tire has been reduced. Typical tire spoons are 12” long. The lever arm on this tool is nearly double that, reducing the amount of force needed to achieve the same torque. The time it takes to mount a tire has also been reduced. After a bit of practice, I can have both beads over the rim in under four minutes. Using spoons, it typically takes me approximately 10 minutes. I have witnessed those who are less experienced with spoons take upwards of 30 minutes to get a tire mounted. As mentioned in the Product Testing segment of this report, a novice can learn to be proficient with this tool quickly with little guidance.

The total cost of materials was under \$70. With tire changes typically costing \$30, the tool would pay for itself by the third tire change. The small size, ability to be broken down, and light weight mean the tool can be easily stored. In addition to taking up a small amount of room during storage, it can also be easily transported in a gear bag. Since users can bring the tool with them to riding events, an accidental flat during a ride will not constitute ending the ride early. The tire can be removed from the bike, repaired, and reinstalled in under 30 minutes.

The individual components of the tool are easily removed and replaced if damage were to occur. This is unlikely, but accidents do happen and it would be unprofessional to assume the tool is indestructible. Finally, the Nylon end effector eliminates the risk of scratching or marring the aluminum rim. While this damage is typically cosmetic, it is still upsetting to bike owners. This has become increasingly prevalent as black anodized rims have gained traction in the market.



Figure 11 Device in use

### **CONCLUSION:**

The tool changes tires more quickly and easily than conventional manual tools. It is almost impossible to damage the tube while using this method. In addition, its small size and light weight means it can be transported. This means that if a rider requires a tire change during a riding trip, this tool can be at the ready. Overall, the device simplifies and increases the efficiency of tire changes.

Many people have asked if the device will work on tires intended for street use. The simple answer is yes, the tool can mount street tires assuming the axle support will fit through the wheel hub. However, street tires require balancing, whereas off-road tires do not. Therefore, the end user will ultimately need to take the wheel to a professional for balancing, as this cannot be done at home. The time and cost involved in taking a tire to a professional shop negates the original objective of the tool.

**WORKS CITED**

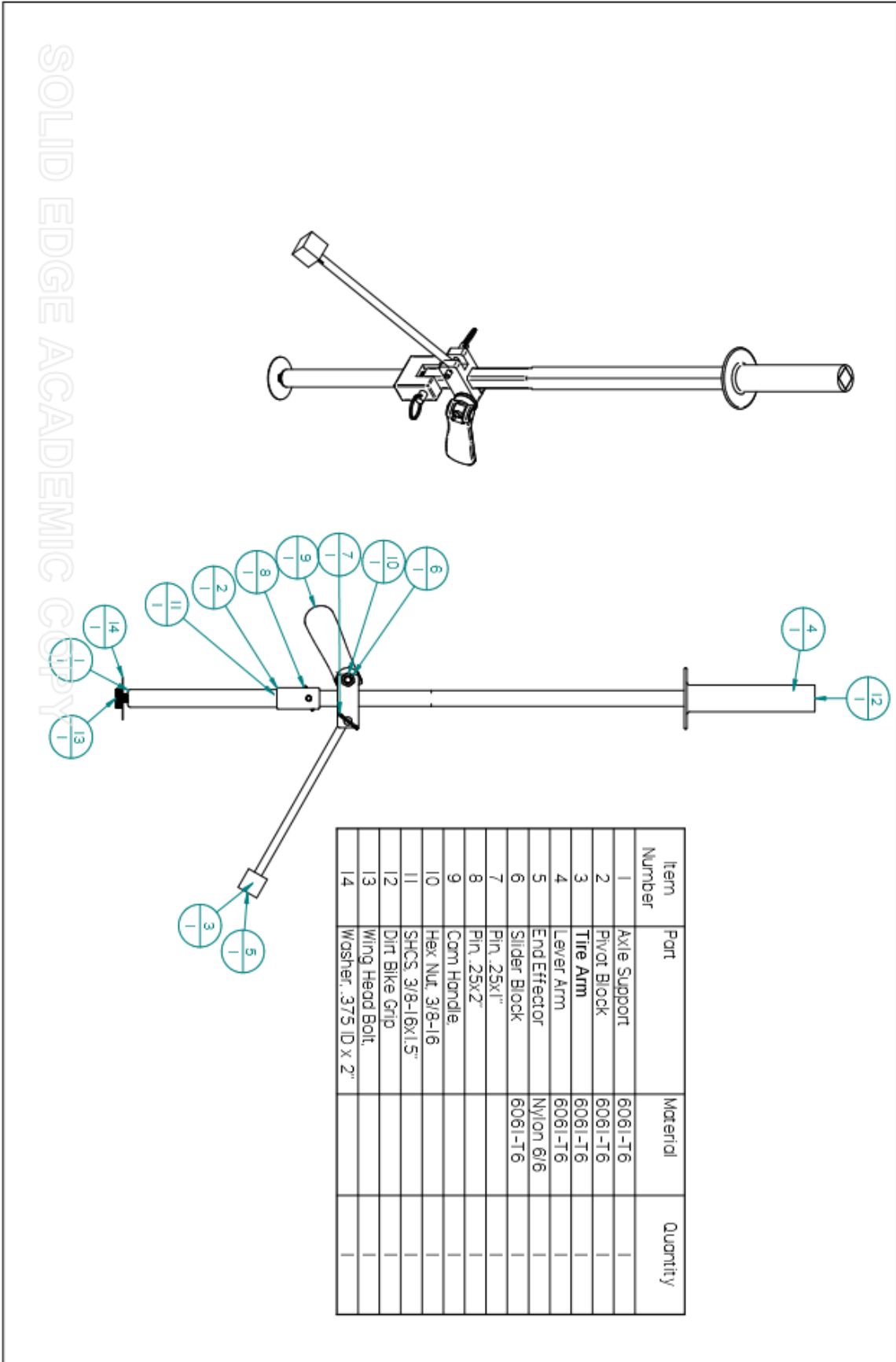
BikeBandit, 2011, *Dirt Bike Rear Tire and Tube Changing* [online]. [video]. 2011.  
[Accessed 1 October 2016]. Available from:  
<https://www.youtube.com/watch?v=DqiSV4WZb-c>

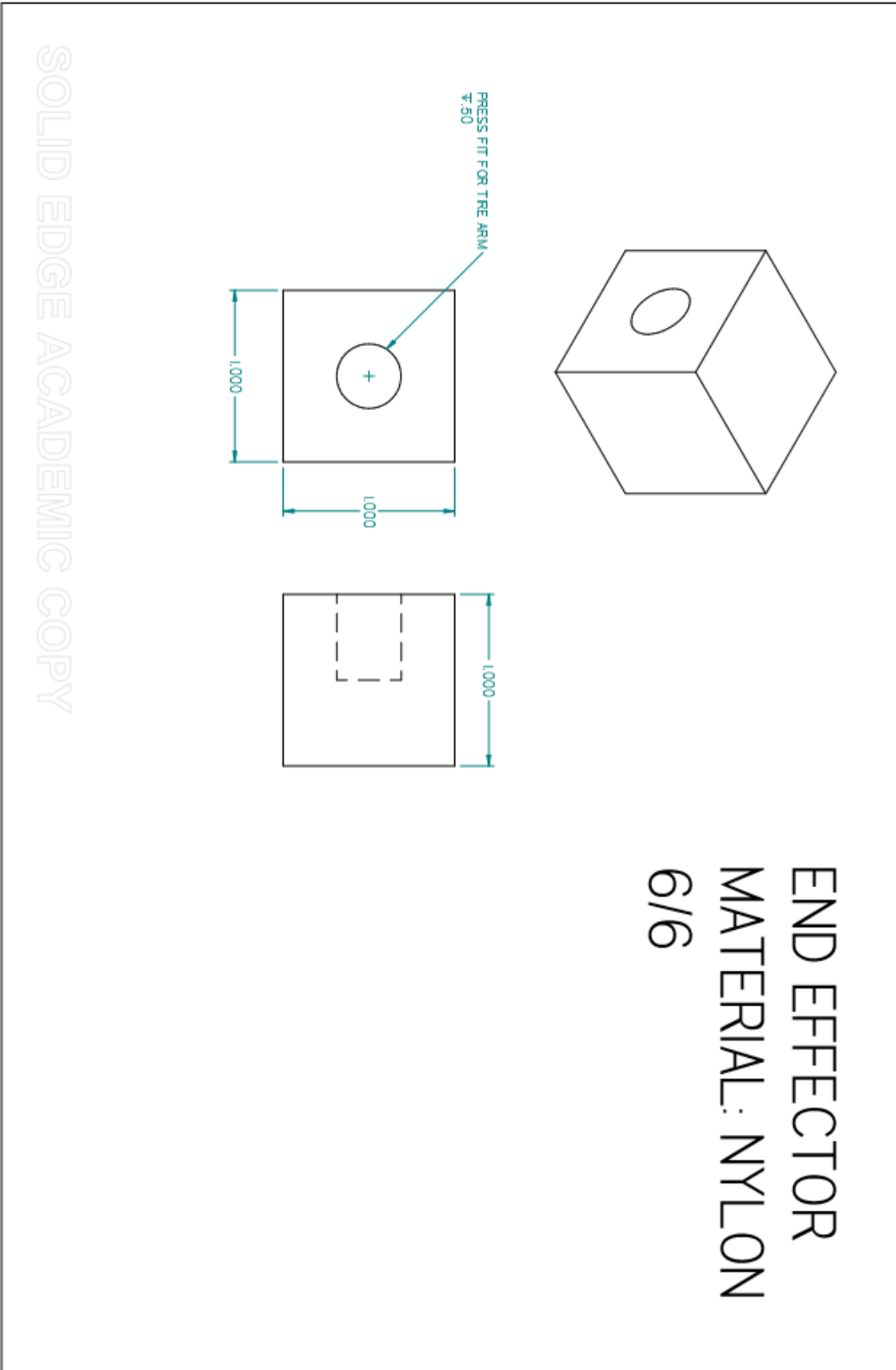
"Garage Equipment, Automotive Repair and Maintenance." *Garage Equipment Automotive Repair and Maintenance*. SUTO Automotive, n.d. Web. 04 Dec. 2016.

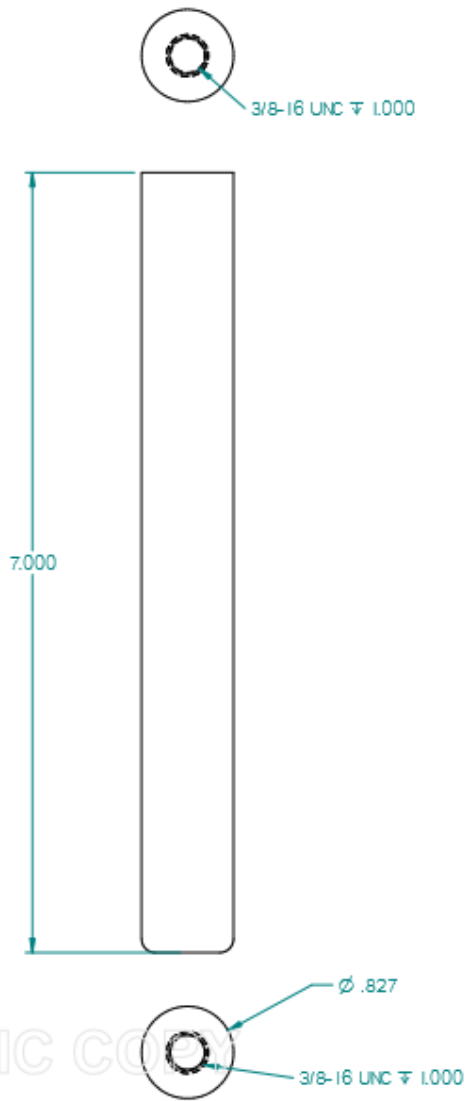
Mott, Robert L. *Applied Strength of Materials*. 5th ed. Upper Saddle River: Peason, 2008.  
Print.

Snap-On Inc., 2016, Operation Instrucions. *Snap-On Equipment* [online]. 2016.  
[Accessed 2 October 2016]. Available from: <http://www.snaponequipment.com>

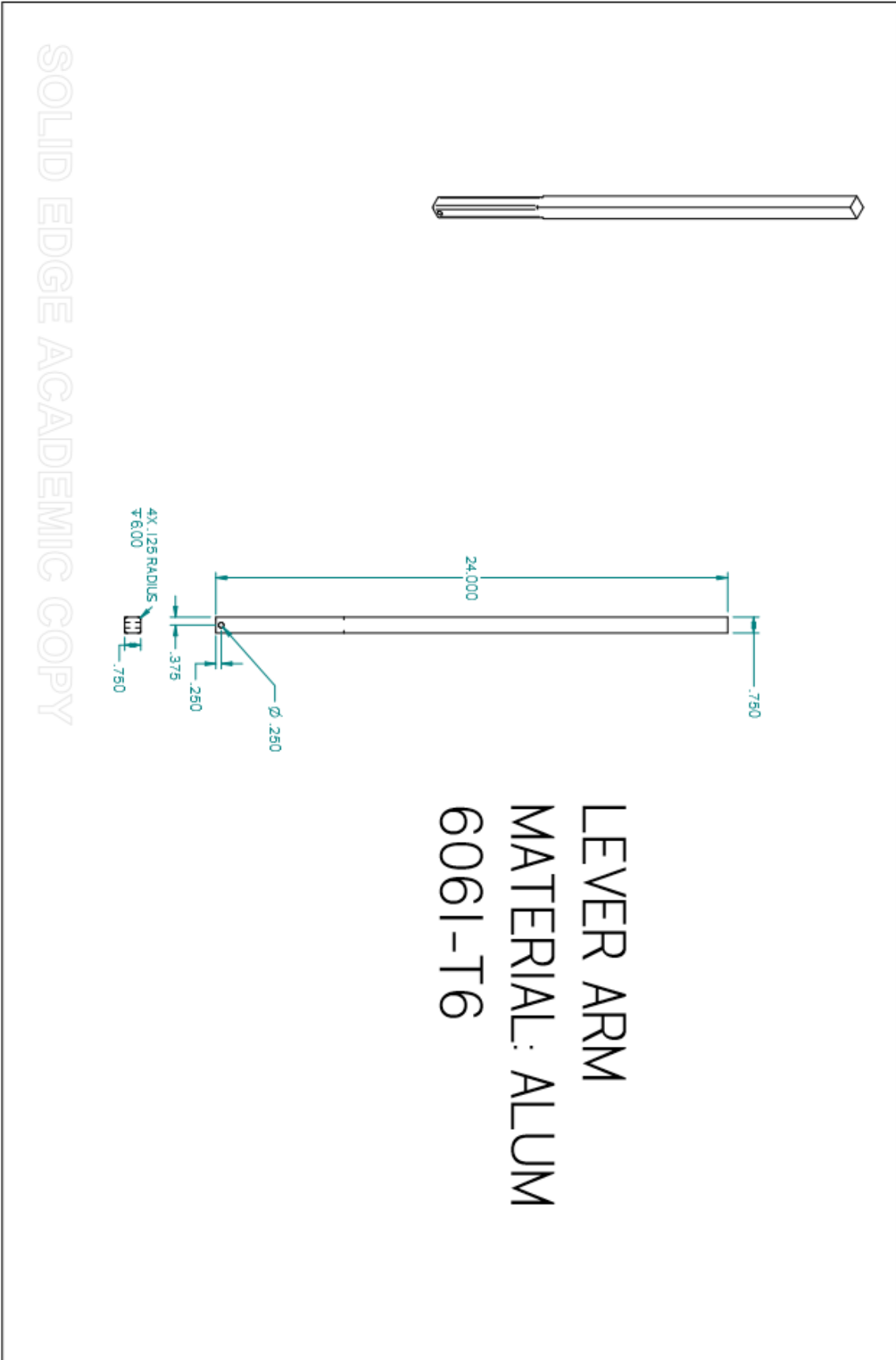
**APPENDIX A: ENGINEERING DRAWINGS**



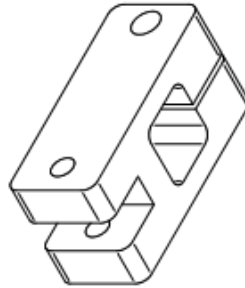




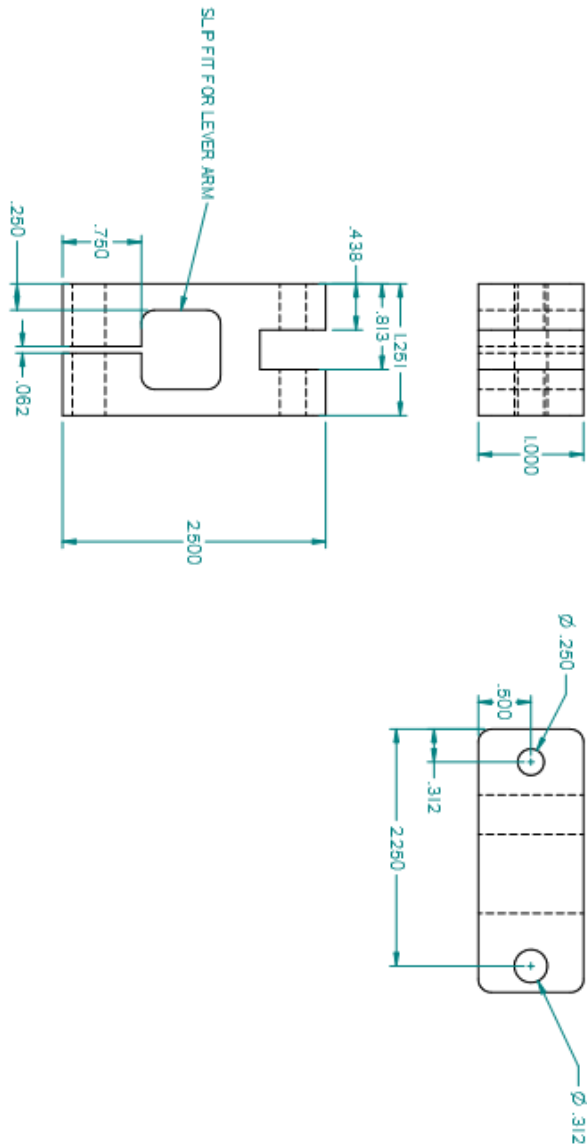
AXLE SUPPORT  
MATERIAL: ALUM  
6061-T6





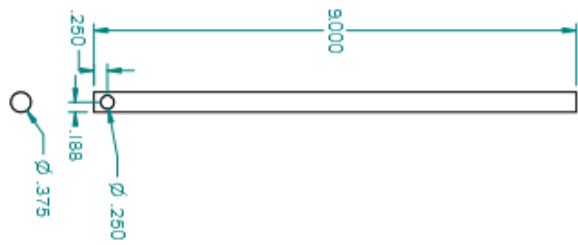


SLIDER BLOCK  
MATERIAL: ALUM  
6061-T6



SOLID EDGE ACADEMIC COPY

SOLID EDGE ACADEMIC COPY



TIRE ARM  
MATERIAL: ALUM  
6061-T6

## APPENDIX B: CALCULATIONS

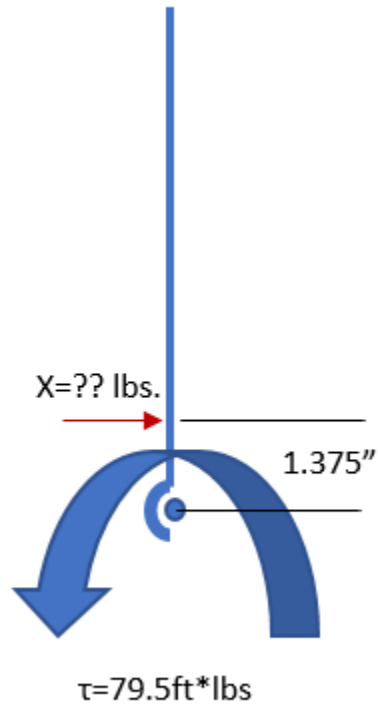
### *TORQUE NEEDED TO MOUNT TIRE*

Force measured with scale in test apparatus: 53 lbs.

Length of moment arm: 18"

$$\text{Torque} = \text{Force} * \text{Distance} = 53\text{lbs} * 1.5\text{ft} = 79.5\text{ft} * \text{lbs}$$

### *FORCE APPLIED AT TIRE*



$$\begin{aligned} \Sigma \text{forces} = 0 &= 79.5\text{ft} * \text{lbs} - \left( x * \frac{1.375\text{in}}{\frac{12\text{in}}{\text{ft}}} \right) \\ x &= 694\text{lbs} \end{aligned}$$

*INTERNAL FORCES OF TOOL*



Figure 12 Triangle to be used in FBD

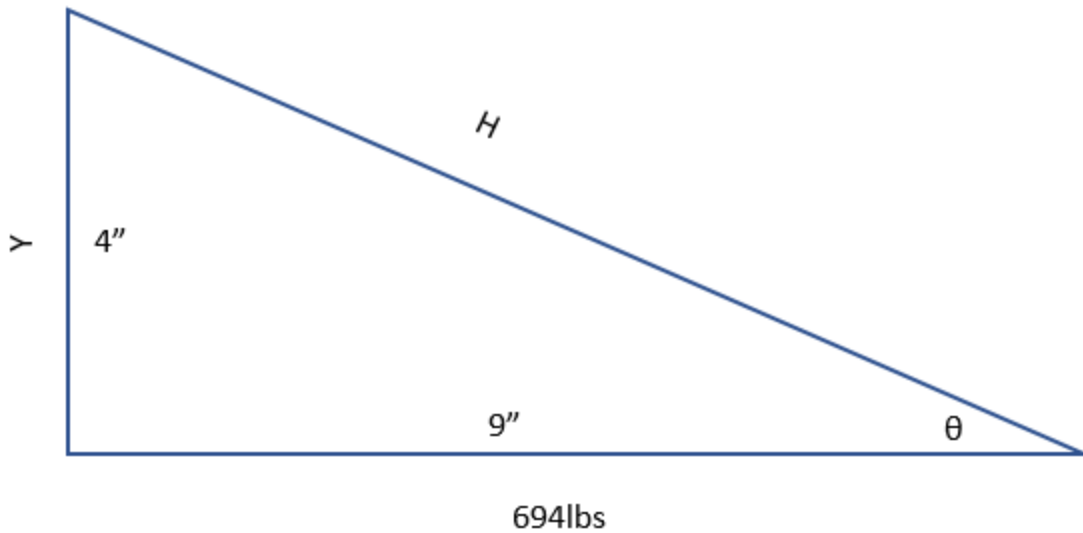


Figure 13 FBD of forces on tool

$$\tan\theta = \frac{4}{9}, \quad \theta = 24^\circ$$

$$\cos(24^\circ) = \frac{694lb}{H}, \quad H = 760lb$$

$$Y = 694lb * \tan(24^\circ), \quad Y = 309lb$$

### ***BENDING FORCES IN HANDLE***

$$\sigma_{max} = \frac{MC}{I}$$

$$I = \frac{b * h^3}{12} = \frac{.75in * .75in^3}{12} = .026in^4$$

$$C = b * h = .75in * .75in = .375in^2$$

$$\sigma_{max} = \frac{MC}{I} = \frac{79.5ft * lbs * \left(\frac{12in}{1ft}\right) * .375in^2}{.026in^4} = 137600psi$$