Brush Hog
Final Project

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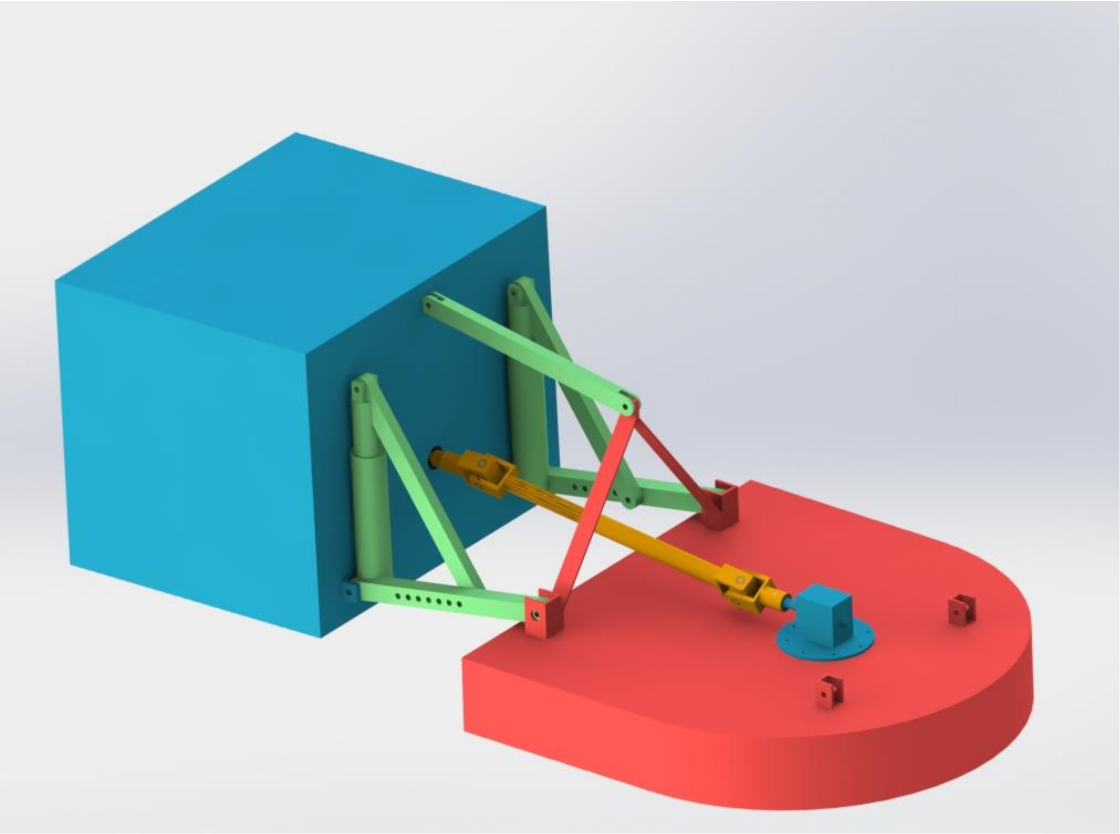
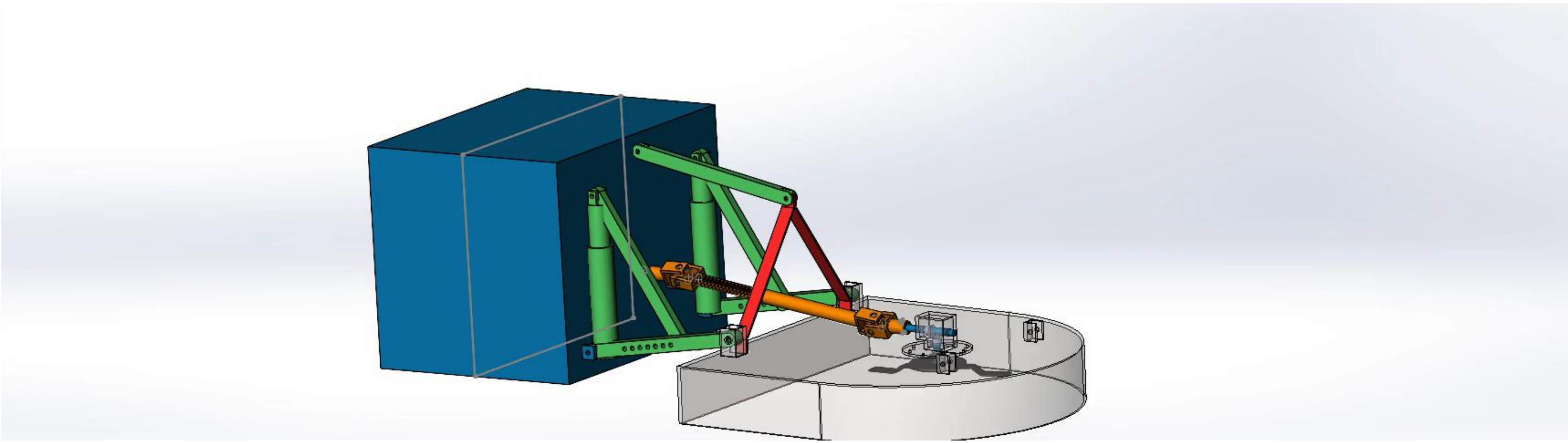
ENGR 3330

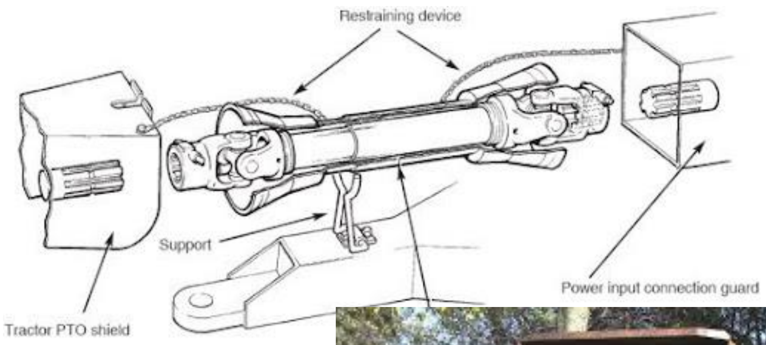
Mechanical Design



Video of Mechanisms:



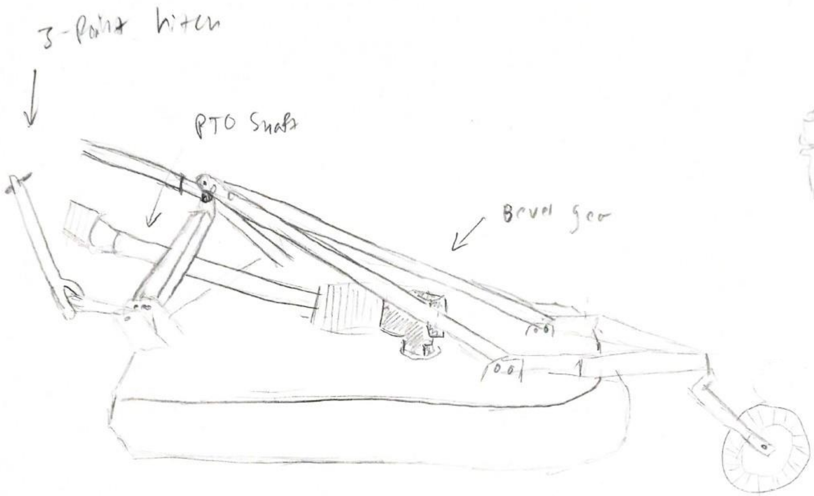
Prior Art Analysis:

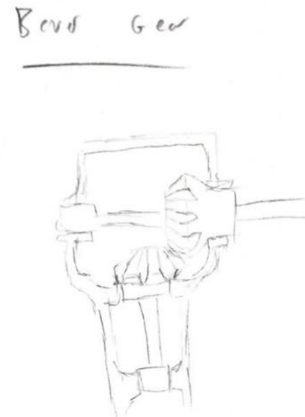


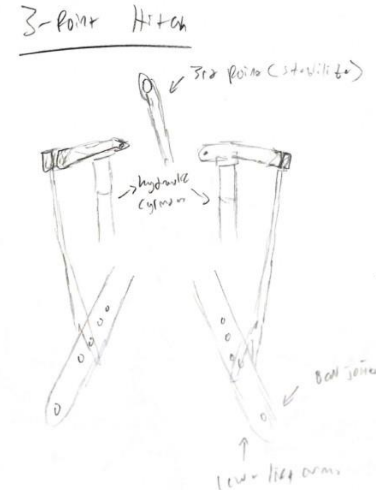
A brush hog is essentially a very powerful mower driven by a tractor. It's often used for clearing really aggressive plant species, such as blackberry brambles.

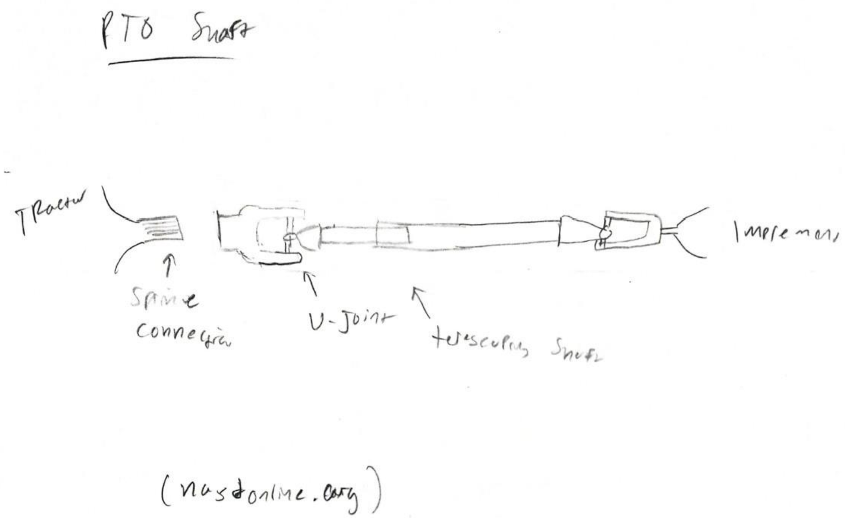
There are a few major components of a brush hog. The tractor's 3 point hitch raises and lowers the implement, and the drive train consists of a power take off (PTO) shaft that attaches to a bevel gear box, which drives a pair of blades.

Initial Sketches:



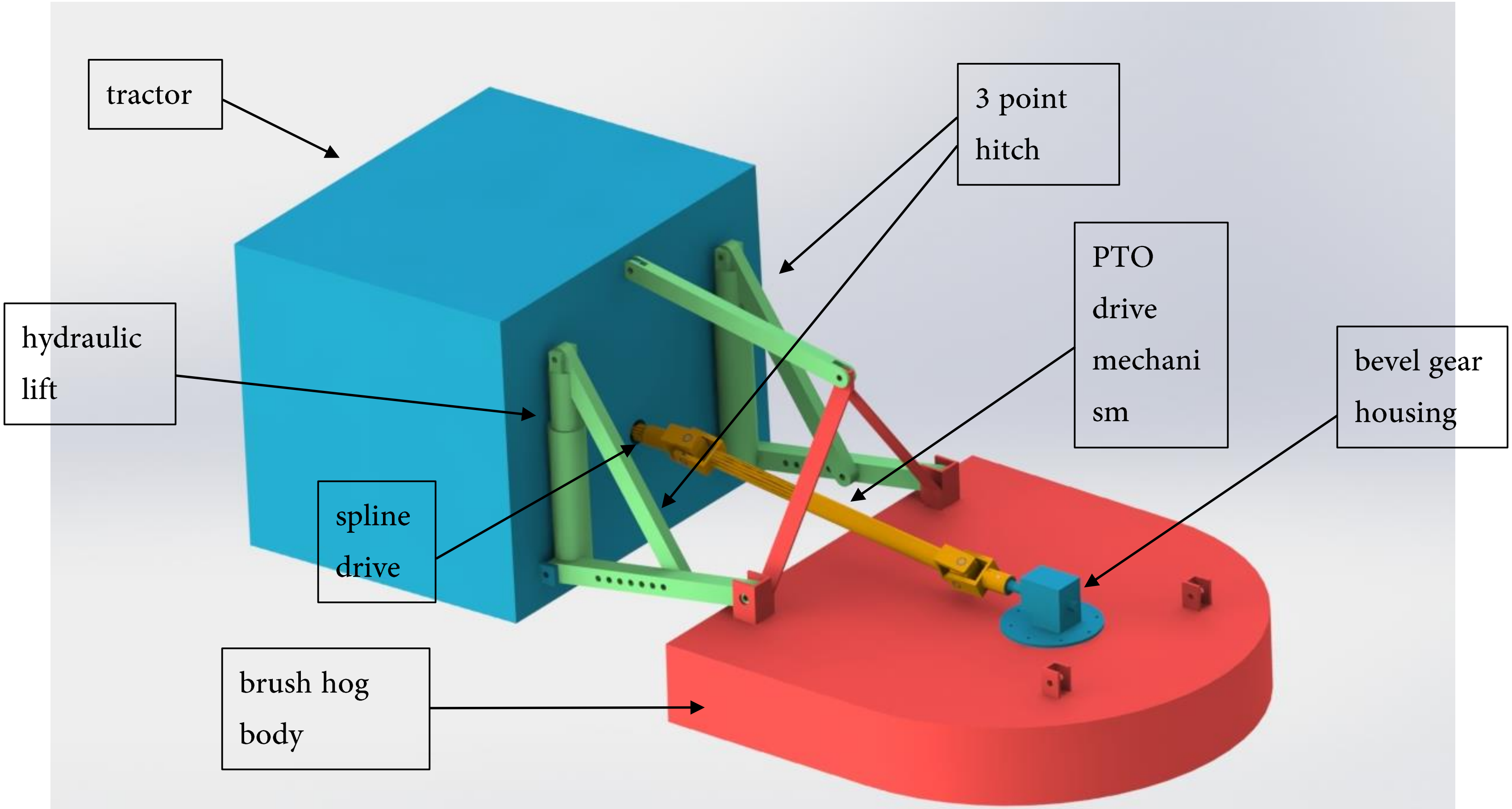






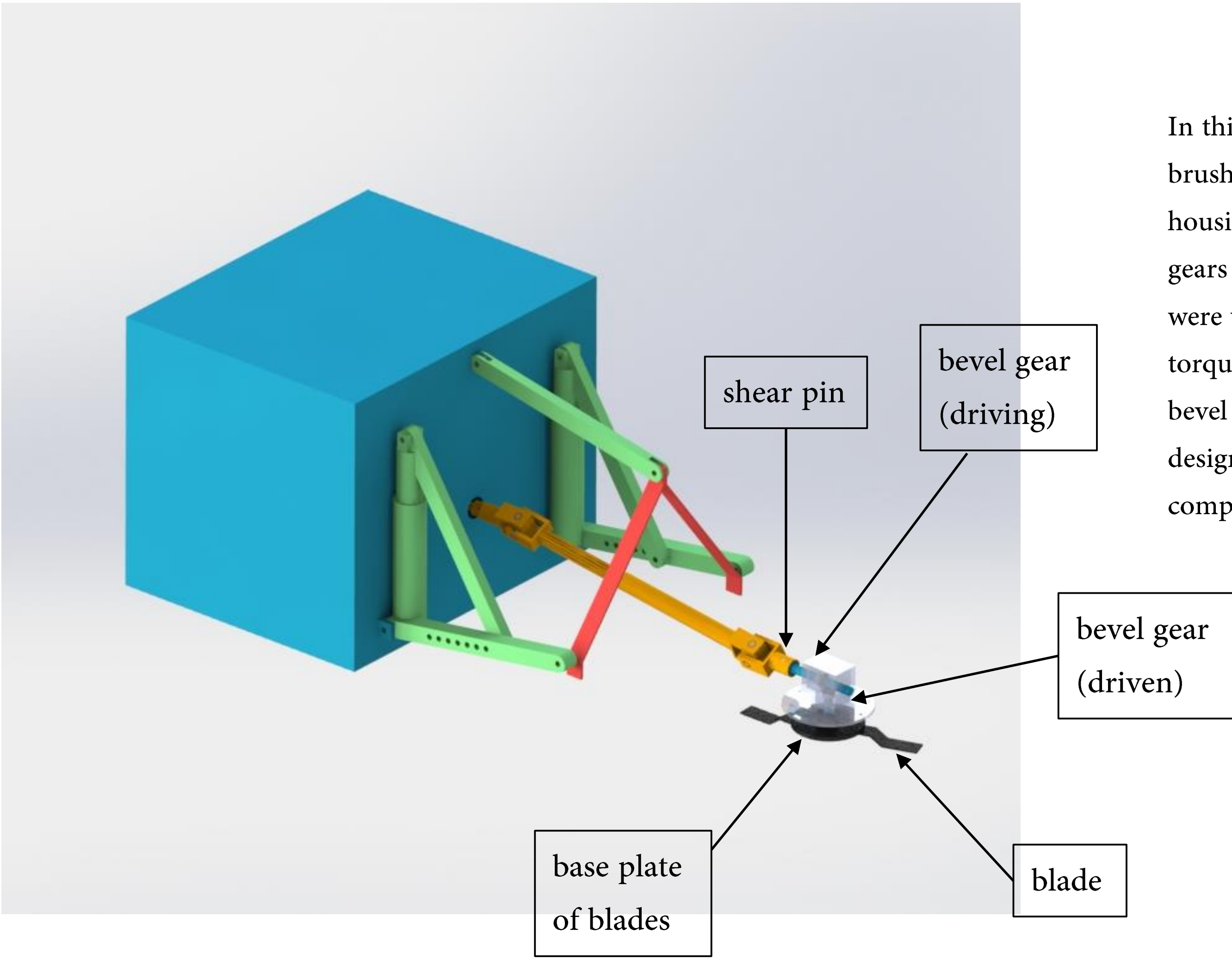
In my initial sketching and ideation phase, I explored different shapes of my brush hog model, eventually settling on using one with only one pair of blades. I then went into further depth sketching out my bevel gear box, my 3-point hitch, and my PTO shaft, attempting to understand these mechanisms before settling on dimensions and specific components.

SolidWorks Assembly of Design (Note: not every part is labeled):



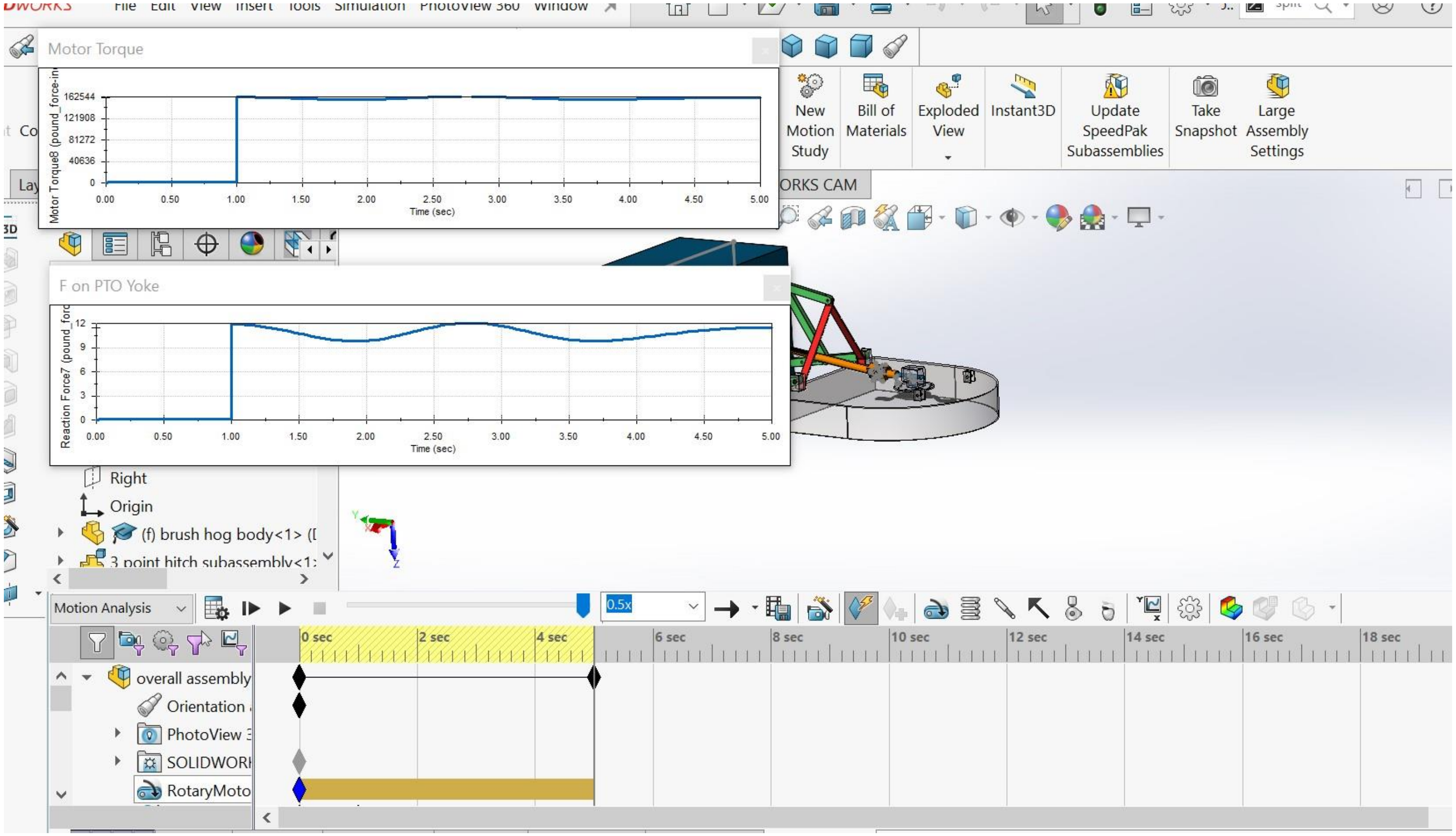
There are two major mechanisms necessary to operate the brush hog: the lifting mechanism, which lifts the brush hog to the desired height, and the driving mechanism, which drives the blades from the tractor's engine. The lifting mechanism employs a hydraulic lift and a 4-bar linkage to raise and lower the implement. The driving mechanism uses a spline drive leading from the tractor's engine to transmit power to a PTO shaft, which uses universal joints and a telescoping mechanism to drive a set of bevel gears. These in turn drive the blades.

SolidWorks Assembly of Design (Bevel Gears and Blades):



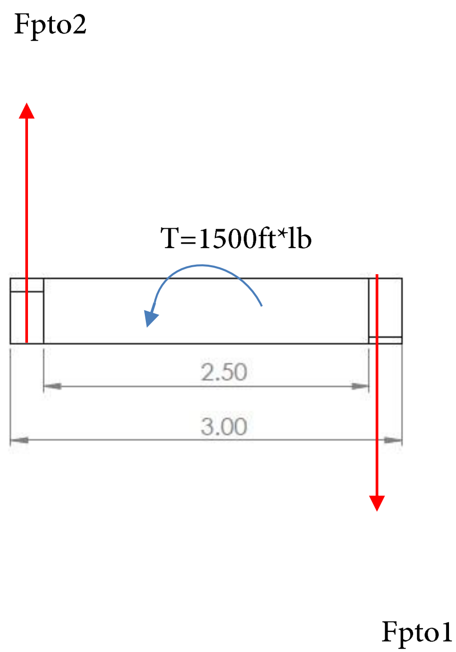
In this view, I hid the body of the brush hog and made the bevel gear housing transparent so the bevel gears and the blade subassembly were visible. A shear pin transmits torque from the PTO shaft to the bevel gear subassembly, and is designed to fail before any other component.

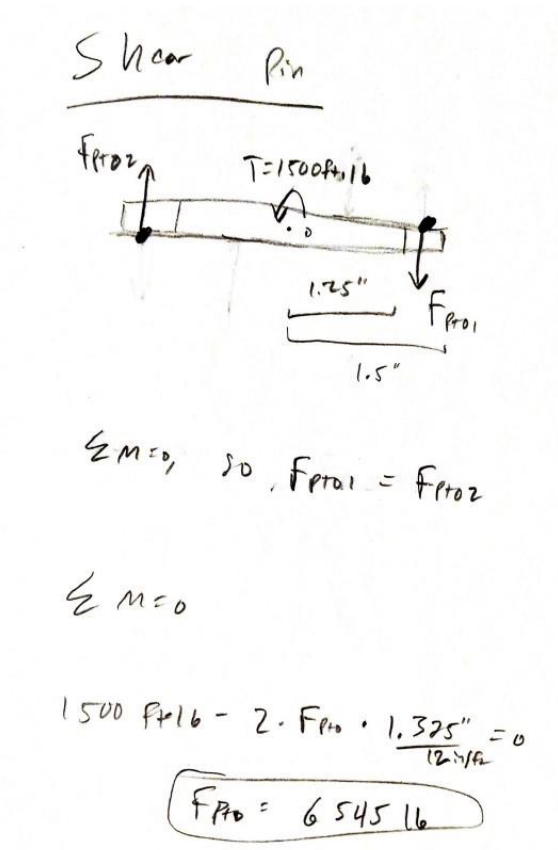
Attempt at Motion:



I fiddled with SW Motion until the PTO shaft successfully spun the blades with a resistance torque being applied to the blades, such as if they had hit a rock or tree stump, but did not get expected results. The expected motor torque was magnified by about 10x expected torque, and the component reaction forces were miniscule, such as the force on the PTO shaft yoke. I assume that SolidWorks motion had trouble with my U-joint, and decided to move forward with hand calculation analysis, assuming that a constant torque of 1500ft*lb was being transmitted through the drive train.

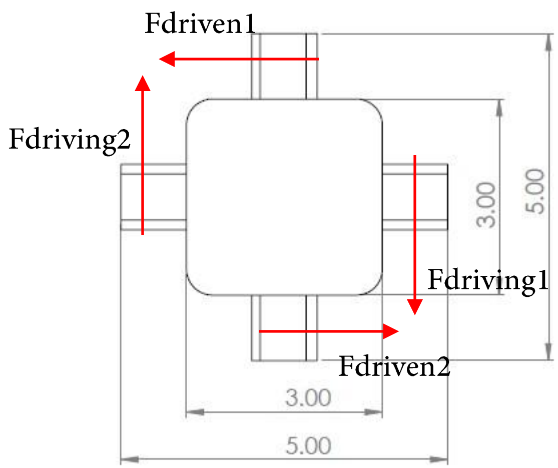
FBD of shear pin:





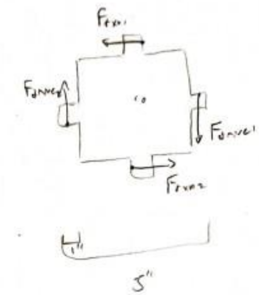
Fpto=6545lb

FBD of PTO yoke:



Yoke of PTO Shaft

Torque = 1500 ft·lb



Assume $F_{drive1} = F_{drive2}$, and $F_{rxn1} = F_{rxn2}$

$1500\ ft \cdot lb = 2 \cdot F_{drive} \cdot 2.25'' / 12\ in/ft$

$F_{drive} = 4000\ lb$

$\Sigma M = 0$

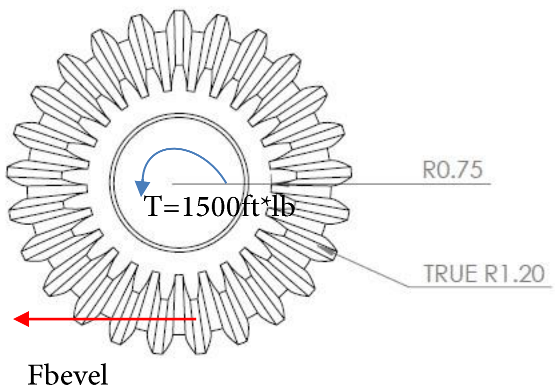
$2 \cdot F_{drive} \cdot r_{out} = 2 \cdot F_{rxn} \cdot r_{out}$

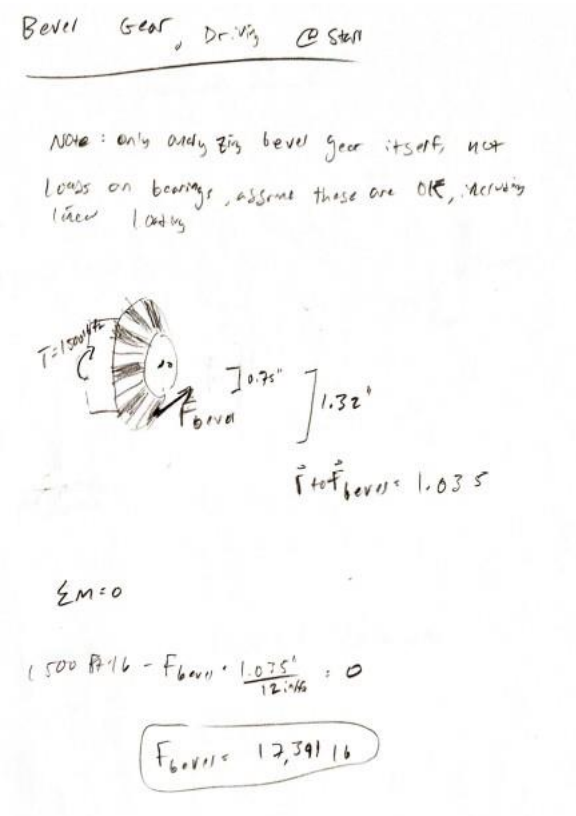
$F_{drive} = F_{rxn}$

$F_{rxn} = 4000\ lb$

Fdriven=Fdriving=4000lb

FBD of bevel gear (initial):

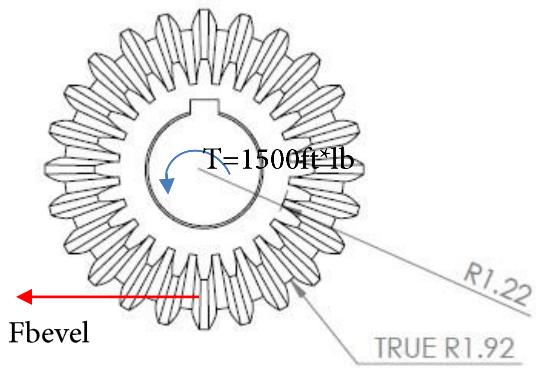




Fbevel=17,391 lb

Note: while normally the key of the bevel gear would fail before the tooth, my bevel gear part is modeled as an extruded shaft and is very well supported, so the tooth would definitely fail before the shaft failed, allowing me to do a simpler FBD and FEA analysis. This is true for both the initial and the redesigned bevel gear. In actual manufacturing, a different manner of attaching the bevel gear to the shaft would have to be considered. A square drive shaft might be a good idea, for instance.

FBD of bevel gear (redesign):



After my FEA analysis of the initial bevel gear (see below) failed before my shear pin did, I redesigned to have a larger bevel gear, allowing the load on the tooth to be smaller, given the increased radius to transmit torque, and allowing the bevel gear's individual teeth to be larger and able to support more load.

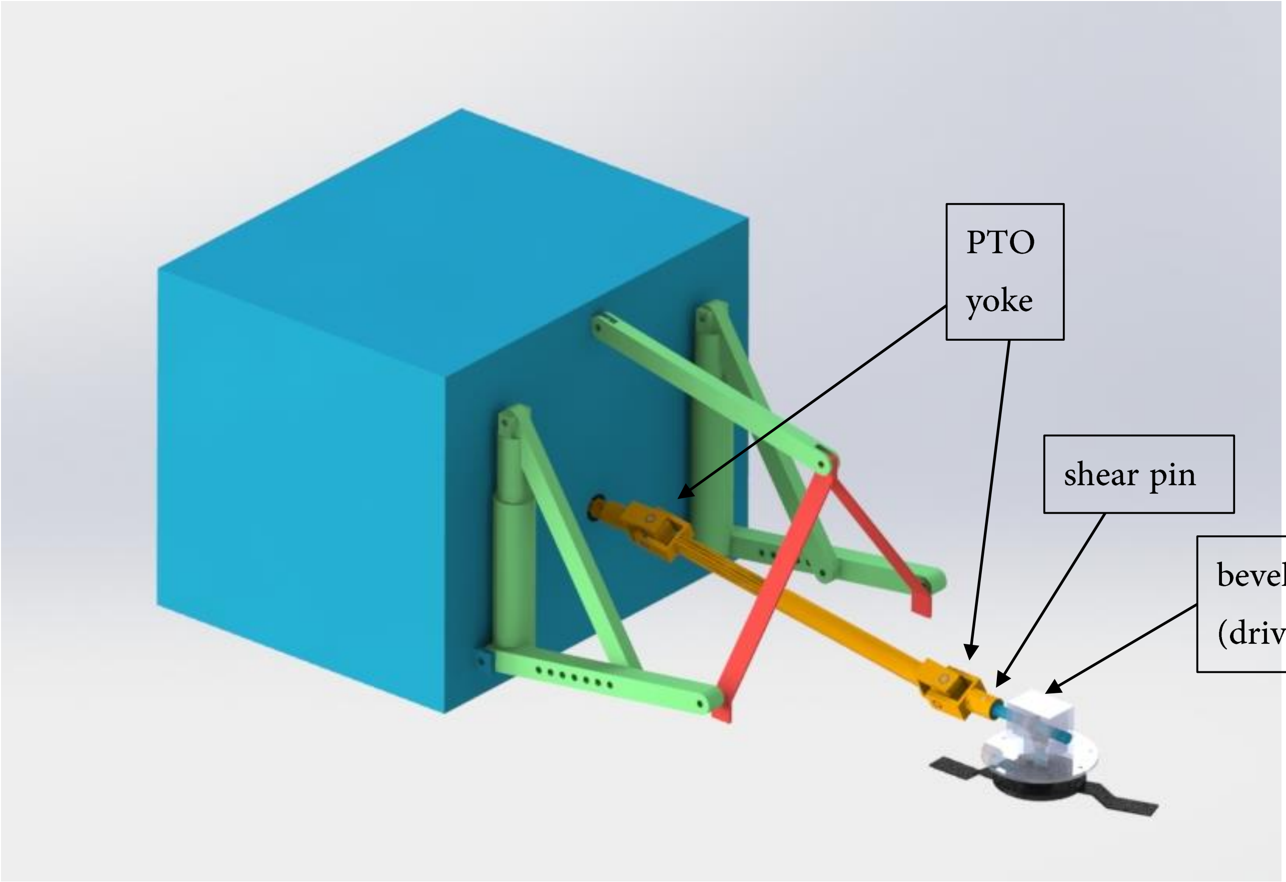
Similar to calculations on the previous page:

$\Sigma M = 0$

1500ft*lb-Fbevel(1.57/12ft)=0

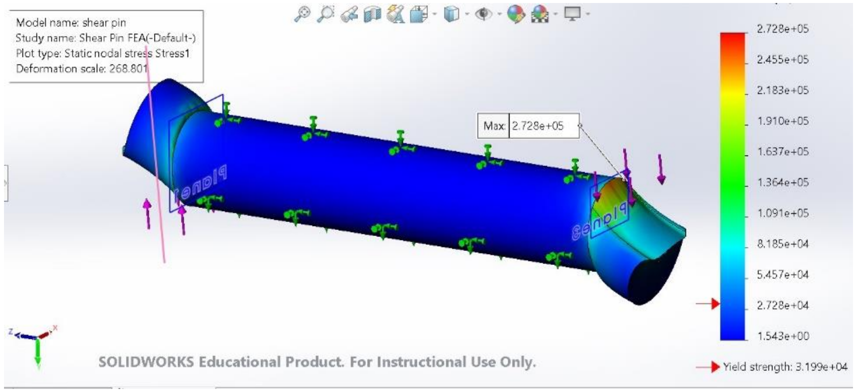
Fbevel=11,465lb

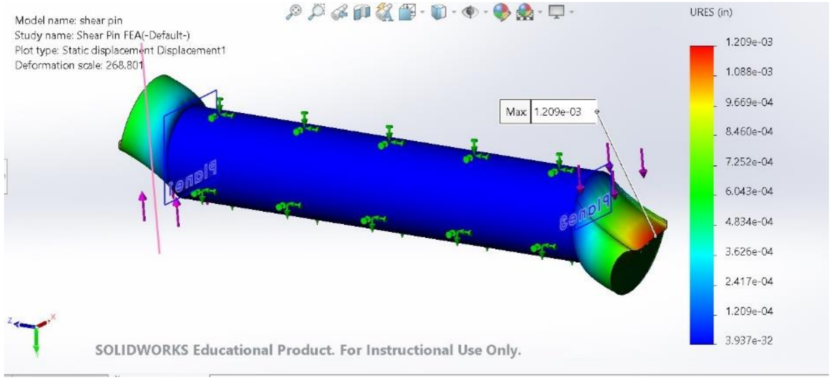
Heavily Loaded Parts:

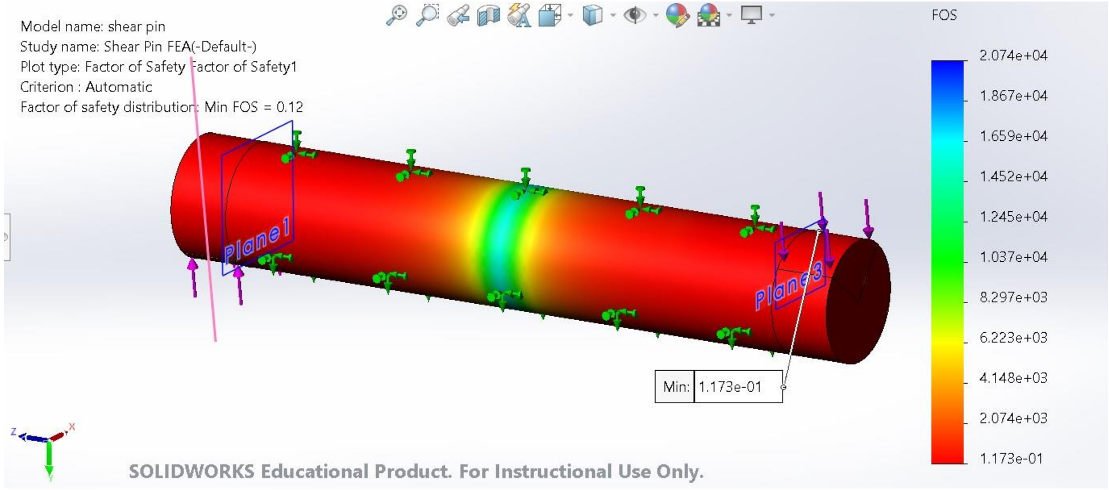


On these parts, I applied a torque (1500 ft lbs) that would cause any of my most heavily loaded parts to fail, with the intension of analyzing which parts failed more easily, so I could see which part would fail first. The hope was that the shear pin would fail before any other component of the transmission, so that it could be replaced without the rest of the transmission being destroyed.

FEA of shear pin:

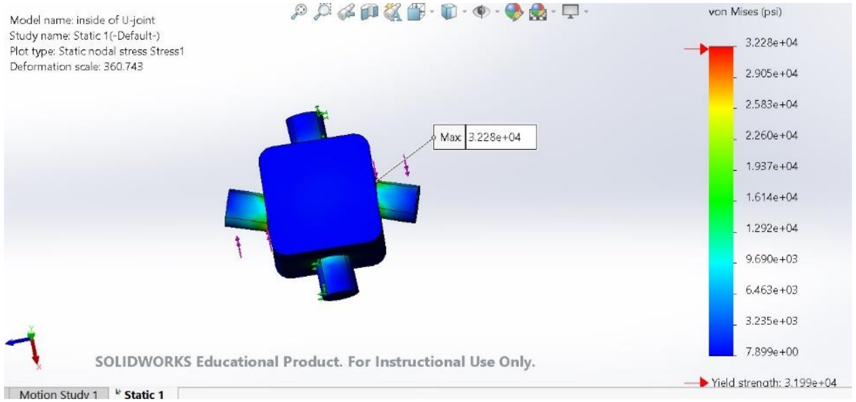


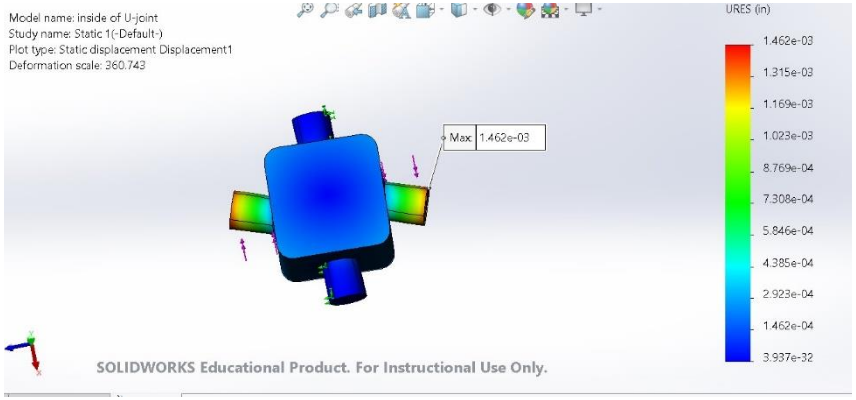


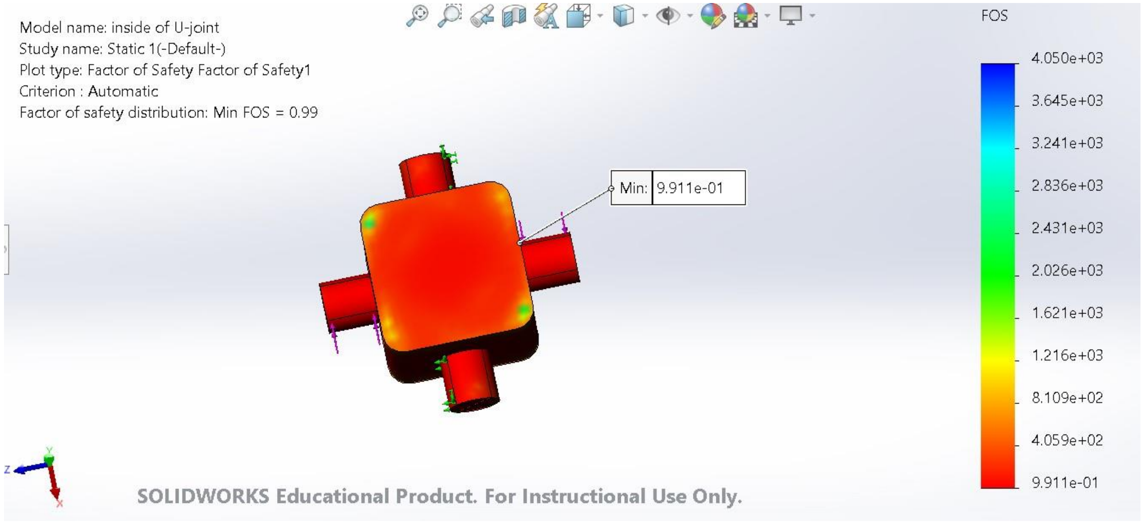


The shear pin's lowest factor of safety ended up being 0.12. It definitely fails.

FEA of PTO yoke:

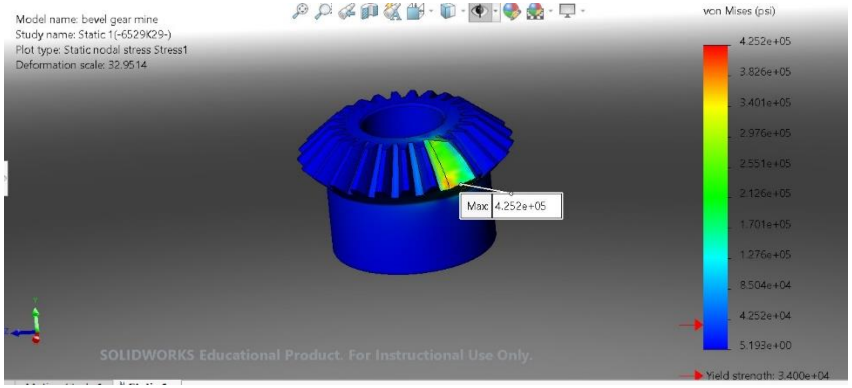


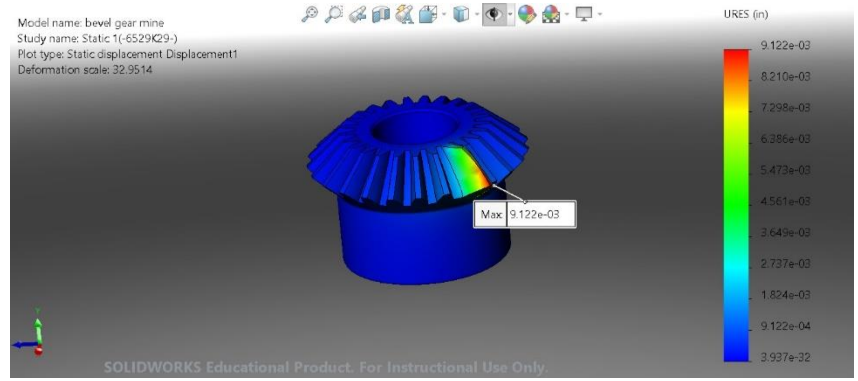


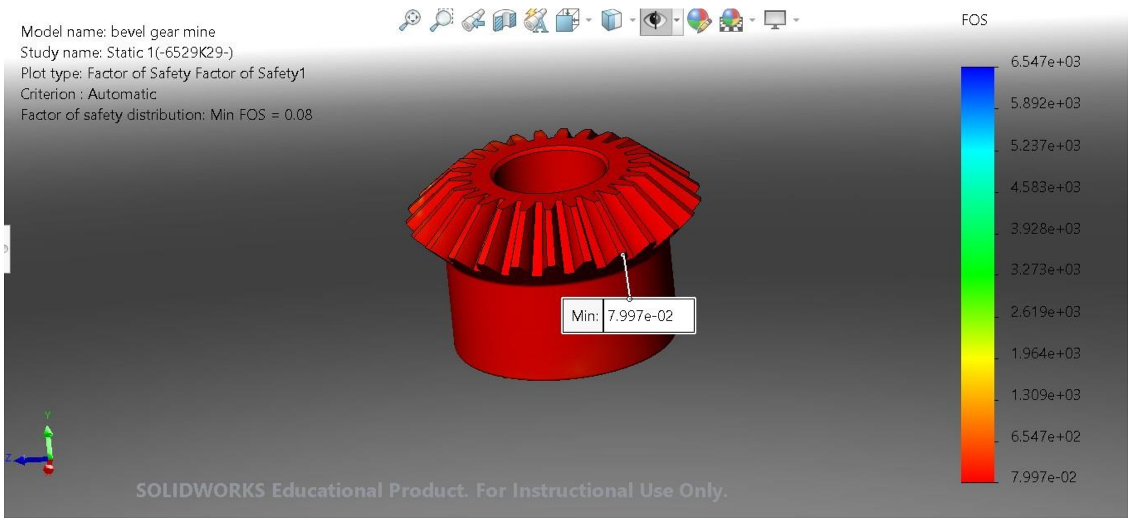


The PTO yoke's lowest factor of safety is 0.99, so this part potentially fails under this load, but only barely. It fails much less easily than the shear pin, which is great.

FEA of bevel gear (initial):

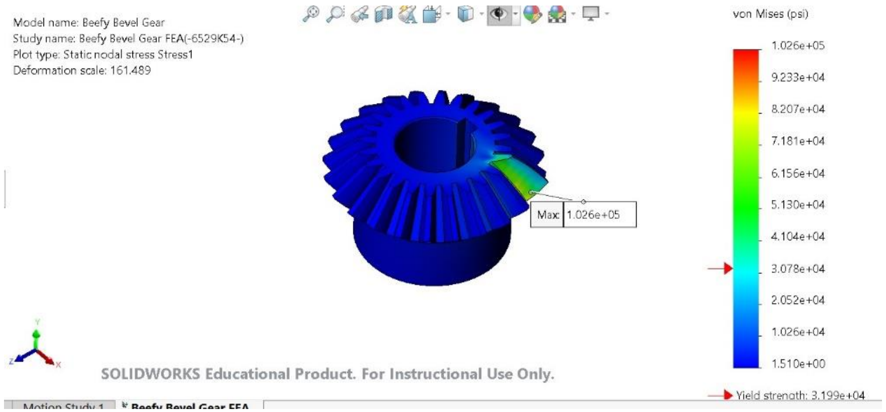


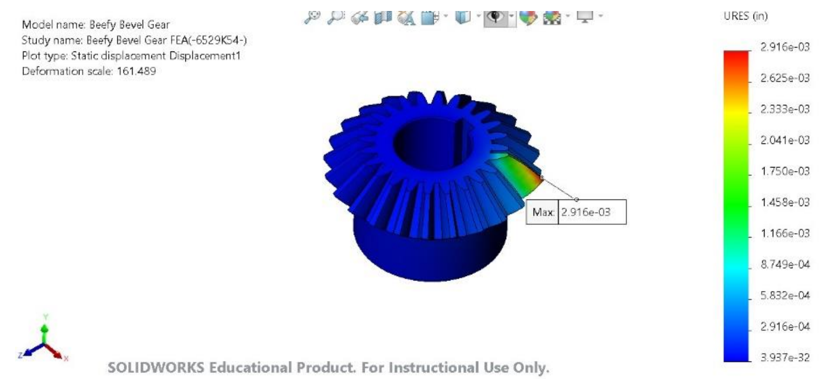


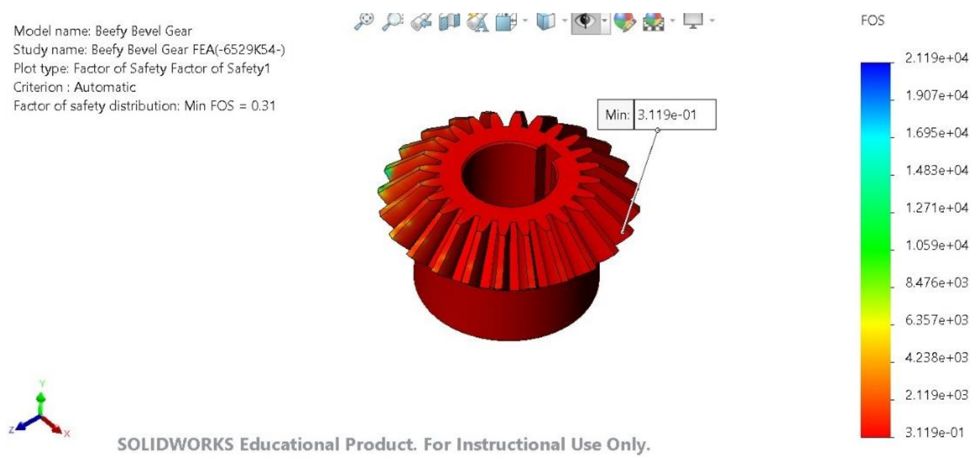


The initial design of my bevel gear had a factor of safety of 0.08, indicating that it would fail before my shear pin, assuming the full load was taken by one tooth. To prevent it failing, I redesigned to use a larger bevel gear.

FEA of beefy bevel gear (redesign):







The redesign of my bevel gear had a factor of safety of 0.31, meaning it comfortable fails after the shear pin does. However, an even larger bevel gear might be considered for actual design.

Course feedback:

It took me roughly 20-30 hours to do this assignment.

Here are three potential ways to make this assignment better for students:

1. It might be interesting to change the wording of the assignment. Suggesting including a cam or a linkage as opposed to requiring it would allow for more creativity, and is already pretty much what you mean. It would allow for more creativity in the design process.
2. I love the timeline of this project, involving loose check-in dates that keep the project moving along. I wish the other projects could have timelines like this, too. I felt like I really had the opportunity to dig into my model and learn about how a brush hog functions.
3. I want more cookies in class always.