



Group M-3:

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CAPSTONE P-4

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OUTLINE



PROBLEM
DESCRIPTION



SCOPE OF WORK



GEARBOX CASE
SELECTION



INTERNAL
COMPONENTS



BLADES MOUNT
BASE



CONCLUSION



FUTURE
RECOMMENDATIONS



PROBLEM DESCRIPTION

- Accelerate ditch creation in Puerto Rico coffee plantation, since the process is currently been manually made.
 - Identify terrain challenges such as erosion, mountain slope and soil conditions, and how affects the design and operation of the proposed machine.
 - Consider BCS 853 tractor engine and power transmission and identify design constrains.
 - Focus on the power transmission from the tractor to an accessory.
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SCOPE OF WORK

01

Evaluate and design power transmission system from BCS 853 Tractor Power Take Off (PTO) to the blades/cutter system.

02

Low weight design to significantly decrease an impact in the BCS tractor weight and operational terms.

03

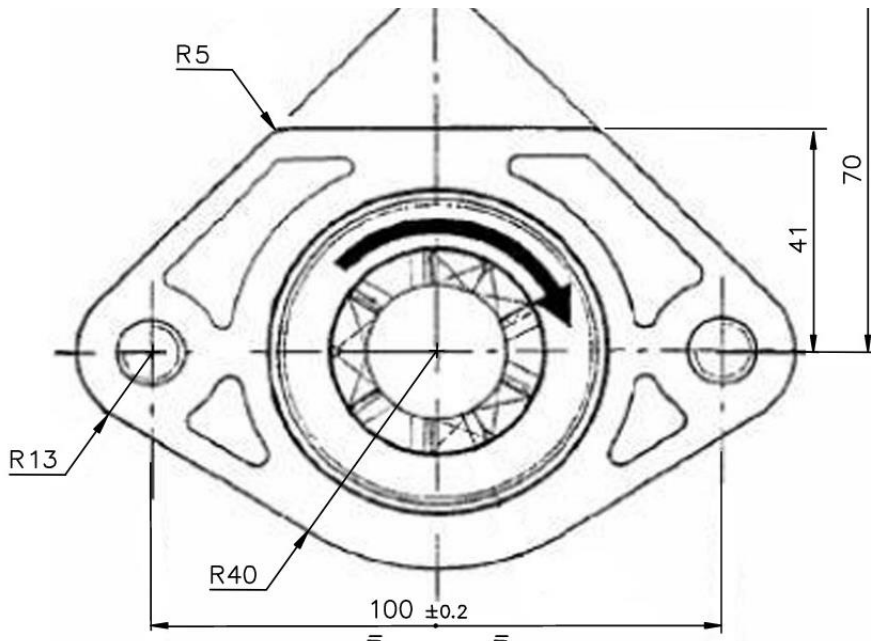
Consider soil reactive force and the require energy to perform the cutting operation.

04

Cost effective and easy to manufacture, by identifying commercial componenets.

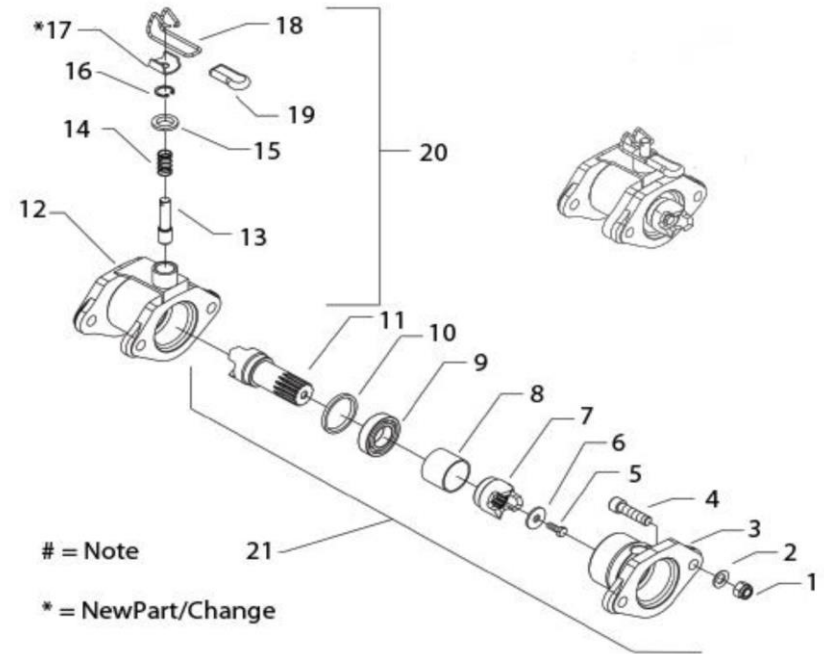
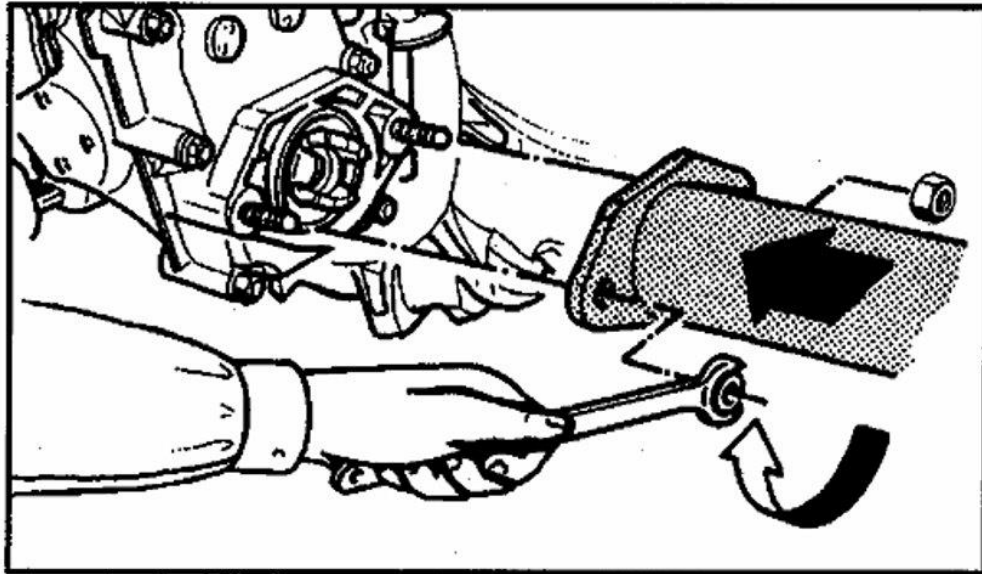
BCS TRACTOR 853

PTO : TECHNICAL INFORMATION



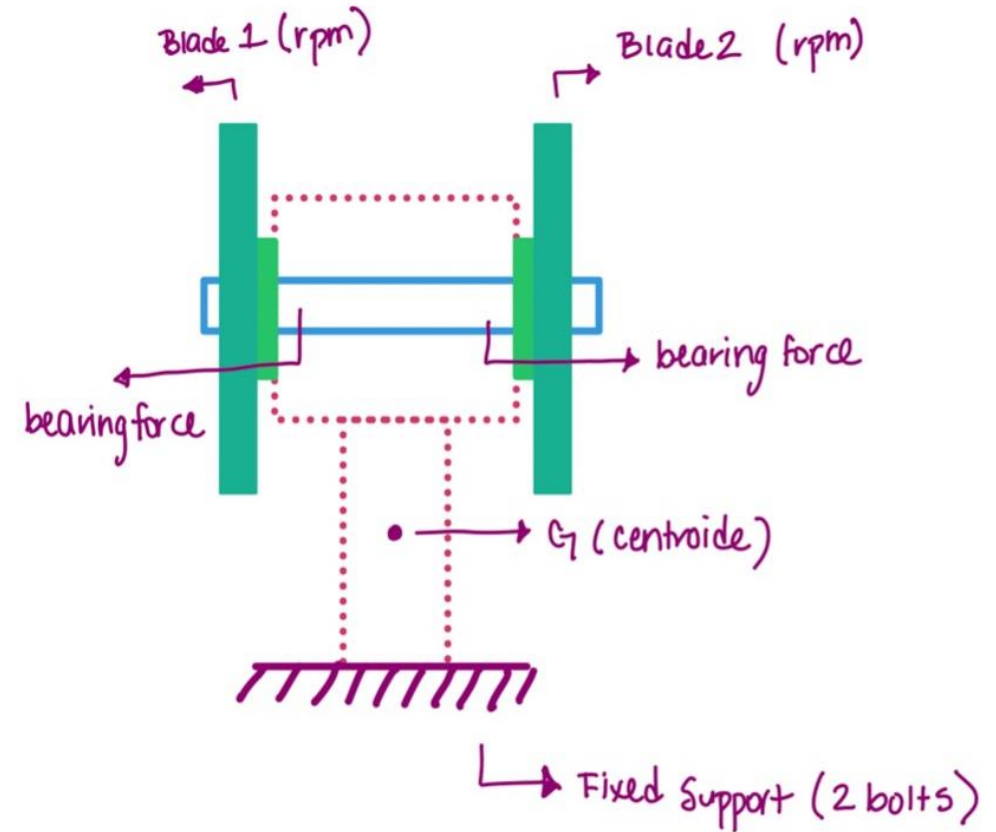
Parameter	Value
Engine Peak Power	11.7 hp
PTO Attachment	2 threaded studs/nuts
PTO Gear Ratio	3.63:1
PTO Output Torque	61.7 ft-lbs
PTO rpm	990
Forward Speed	
1st	0.8 mph
2nd	1.6 mph
3rd	2.7 mph
4th	8.3 mph

QUICK CONNECT

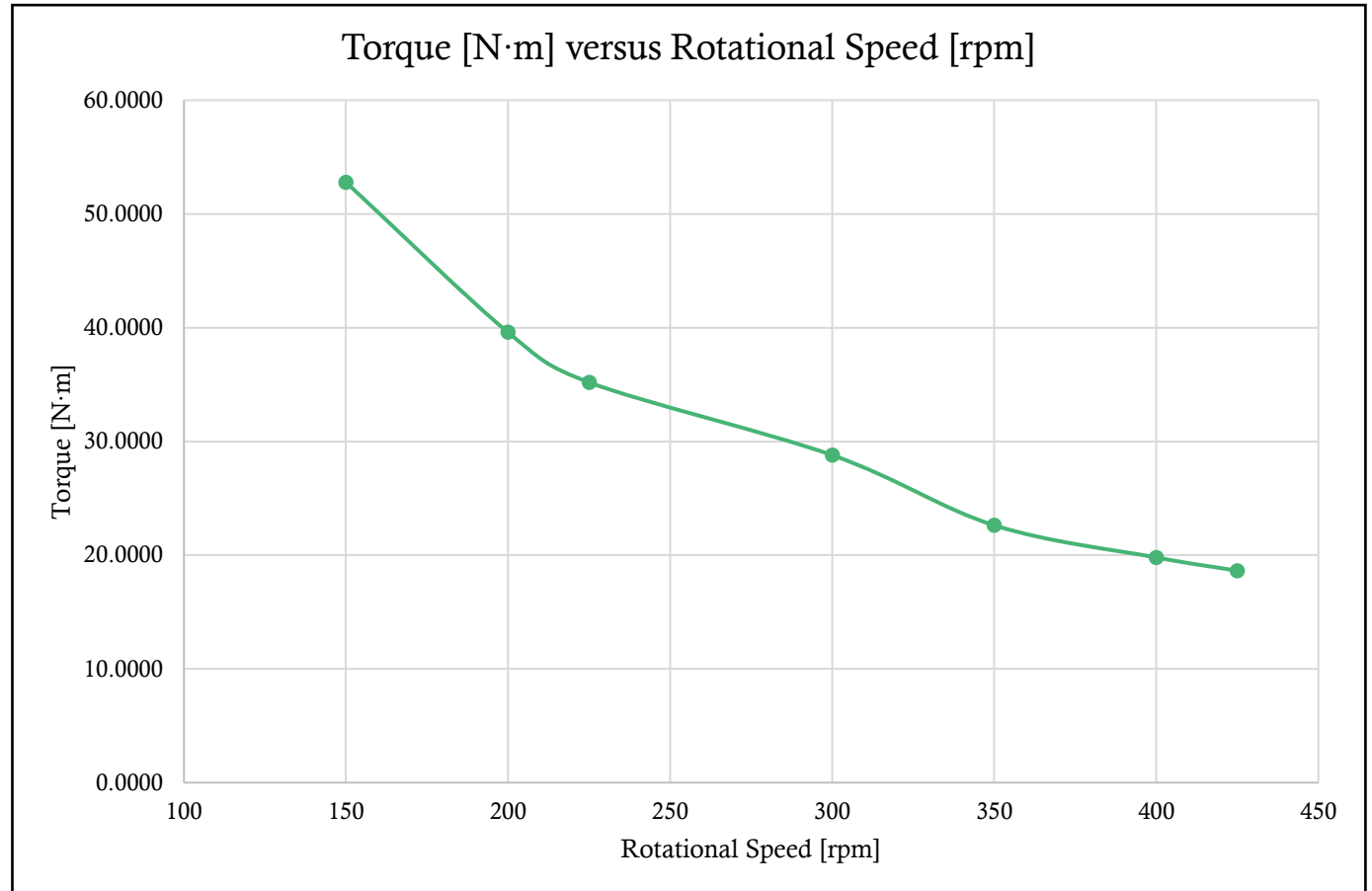


MATHEMATICAL MODEL: SPECIFIC ENERGY MODEL

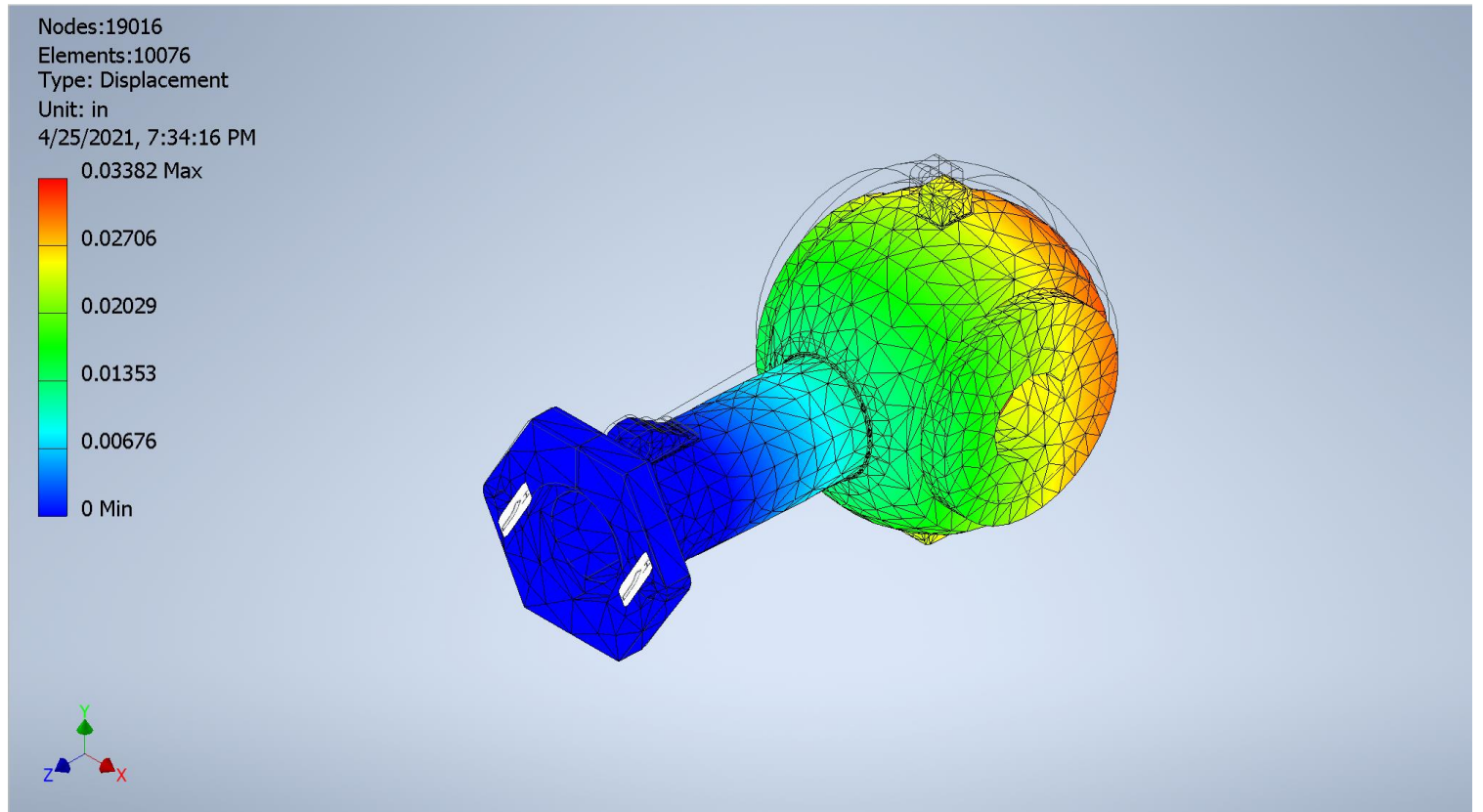
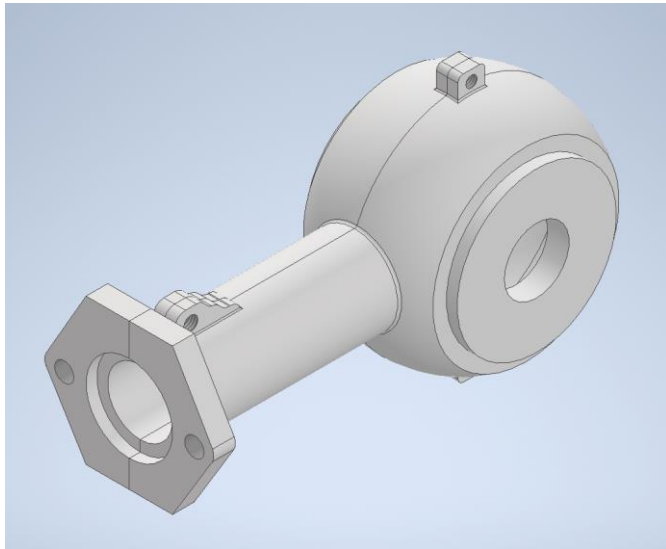
- Calculating the rotor power consumption using specific work method, formulated by Bernacki (1972).
- The SPW related the:
 - Tractor Power
 - Peripheral Force
 - Peak Torque
- Several assumptions were considered base on the known soil composition.
- Different parameters were studied within:
 - Rotor Radius
 - Rotational Speed



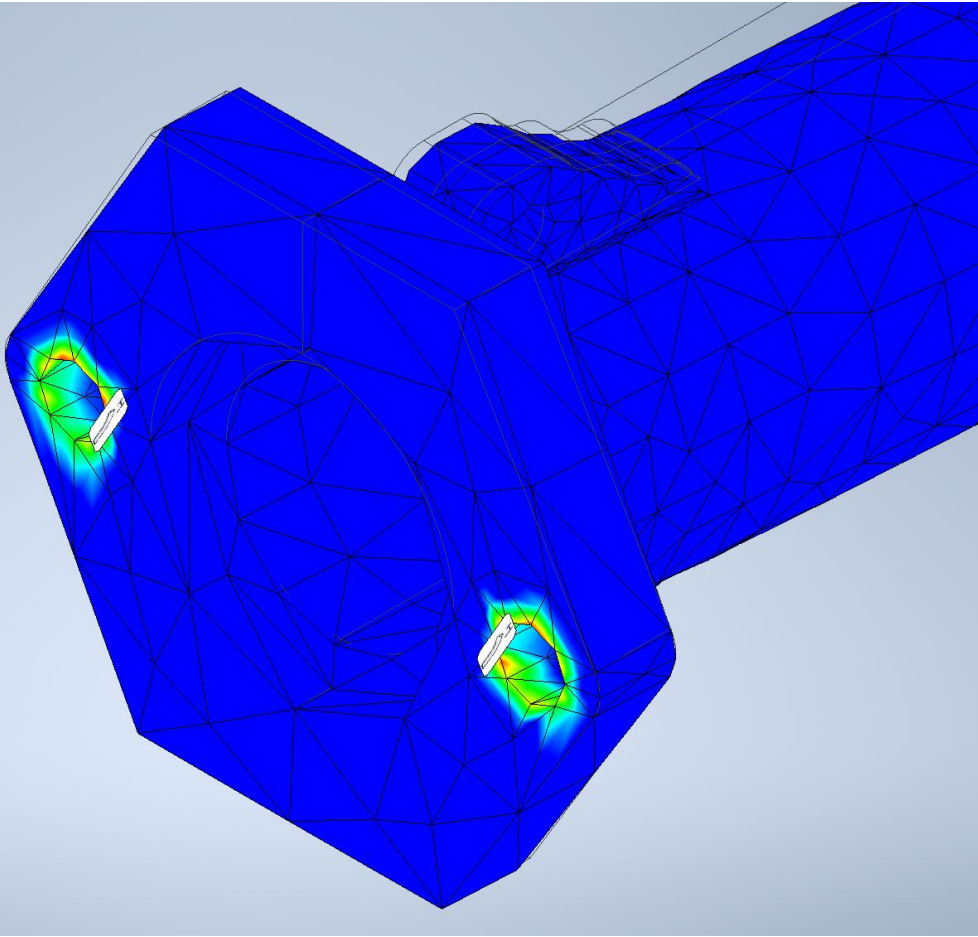
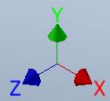
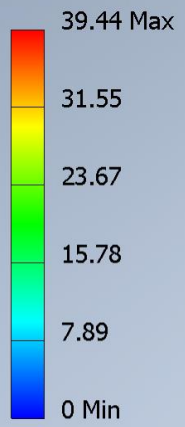
- The resultant peak torque minimize with the increasement of the rotational speed.
- For the Finite Element Analysis (FEA) the resultant torque, per blade was:
 - $N = 150$ rpm
 - $T = 52.791 \text{ N}\cdot\text{m} = 38.939 \text{ ft} - \text{lb}$
 - $T_{\text{total}} = 77.878 \text{ ft} - \text{lb}$



GEARBOX CASE

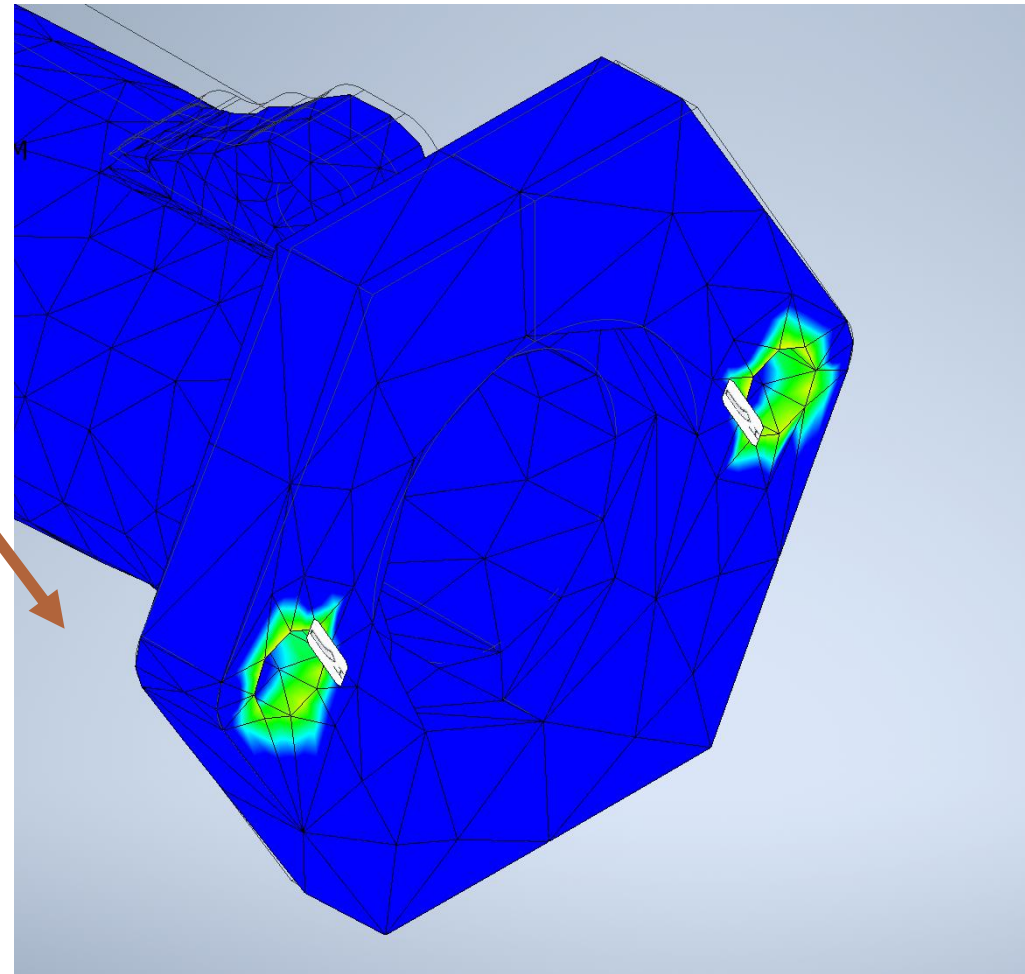


Nodes:19016
Elements:10076
Type: Von Mises Stress
Unit: ksi
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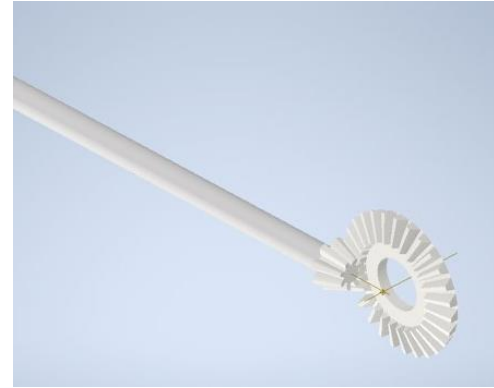
☐ **Result Summary**

Name	Minimum	Maximum
Volume	39.9779 in ³	
Mass	10.3267 lbmass	
Von Mises Stress	0.00351885 ksi	39.44 ksi
1st Principal Stress	-8.96877 ksi	45.9579 ksi
3rd Principal Stress	-42.1005 ksi	6.91086 ksi
Displacement	0 in	0.0338202 in
Safety Factor	2.78749 ul	15 ul
Stress xx	-17.2252 ksi	10.9272 ksi
Stress XY	-4.88708 ksi	4.81199 ksi
Stress XZ	-17.1058 ksi	17.3639 ksi
Stress YY	-11.5614 ksi	11.4765 ksi
Stress YZ	-12.92 ksi	15.7932 ksi
Stress ZZ	-33.1396 ksi	39.876 ksi
X Displacement	-0.0001469 in	0.000141792 in
Y Displacement	-0.0338201 in	0.0000358855 in
Z Displacement	-0.0109281 in	0.0108115 in
Equivalent Strain	0.000000176452 ul	0.00206264 ul
1st Principal Strain	-0.000000267867 ul	0.00237594 ul
3rd Principal Strain	-0.00219845 ul	-0.0000000976827 ul
Strain XX	-0.000413209 ul	0.000380223 ul
Strain XY	-0.000363517 ul	0.000357931 ul
Strain XZ	-0.00127239 ul	0.00129158 ul
Strain YY	-0.000523522 ul	0.000387092 ul
Strain YZ	-0.00096103 ul	0.00117475 ul
Strain ZZ	-0.00155849 ul	0.00190155 ul
Contact Pressure	0 ksi	16.0372 ksi
Contact Pressure X	-3.46326 ksi	3.68065 ksi
Contact Pressure Y	-3.29574 ksi	3.55318 ksi
Contact Pressure Z	-15.7341 ksi	5.71139 ksi

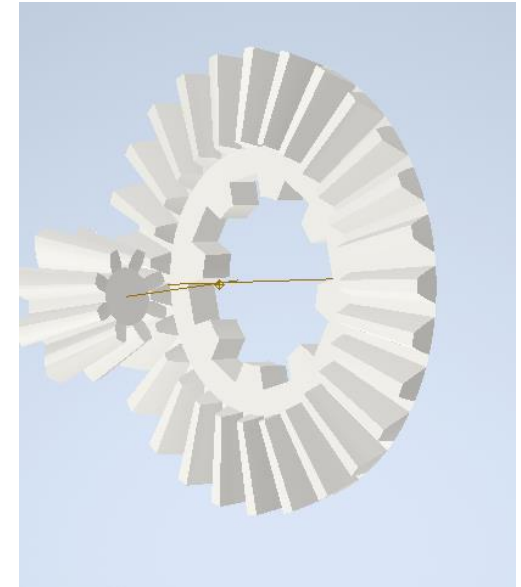


INTERNAL COMPONENTS

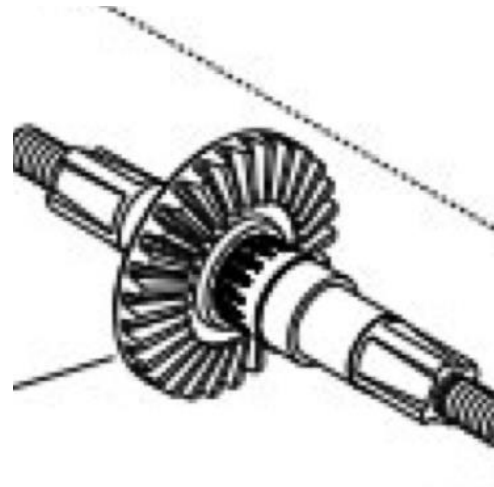
- Recommended to use the existing components provided by the BCS gear box case.
- Gear change is possible but will require increased price, manufacturing, and validation.
- Data provided is the gear components of OEM tiller gearbox.



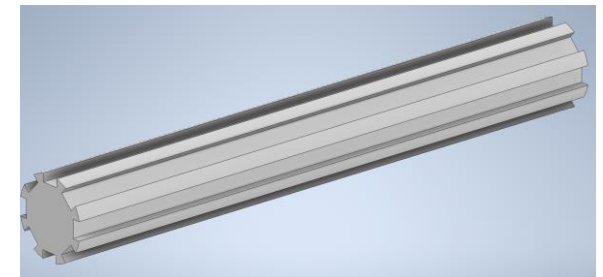
A. PTO shaft to tiller gear assembly.



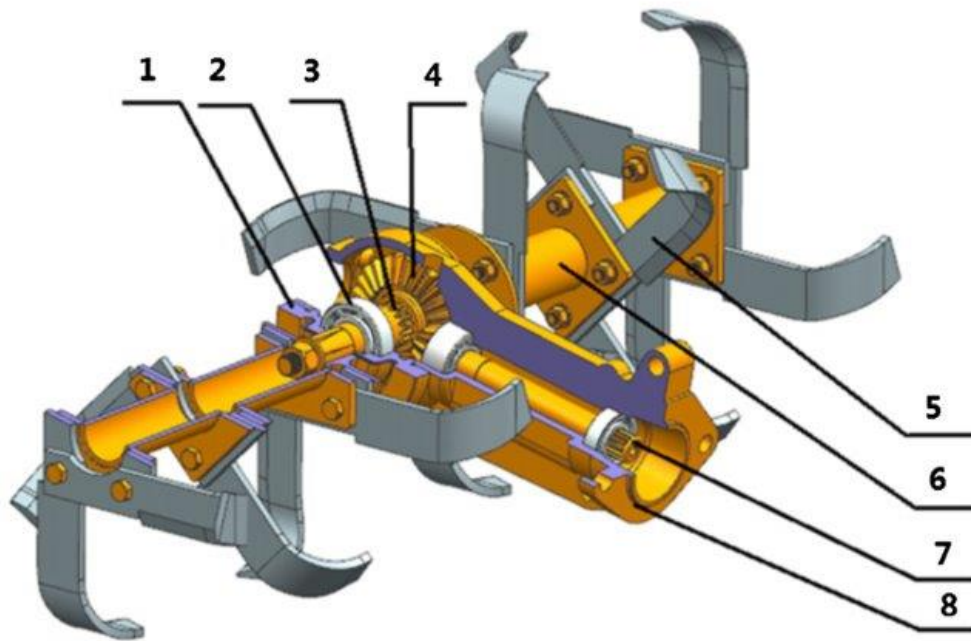
B. Gears for gearbox.



C. Gear shaft to blade mount



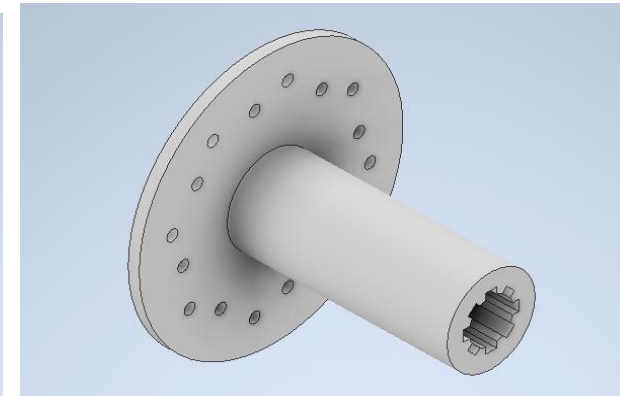
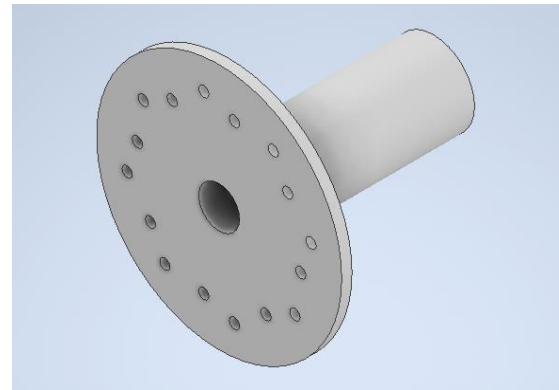
TILLER GEARBOX: TECHNICAL DAT



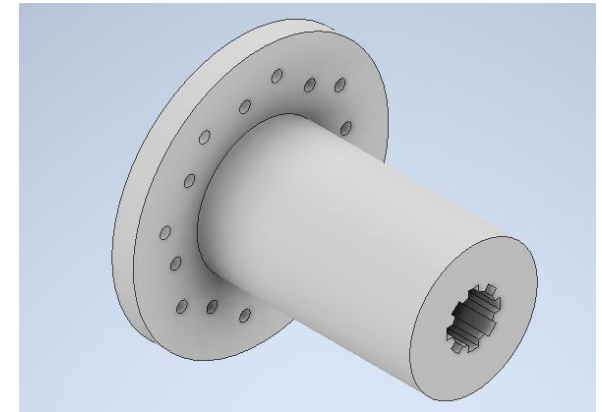
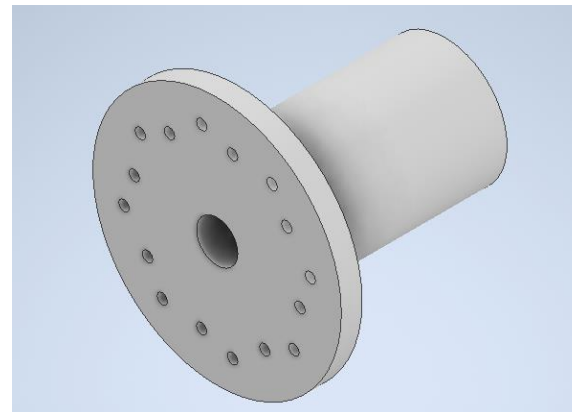
Data	Value	Size
Bevel Pinion Z8 Teeth (146 mm)	8	.957in
Crown Gear with Shaft Z27 Teeth Flange	27	2.632 in
Gear Ratio	3.38:1	n/a
Accessory Gearbox Output	293 rpm	n/a
Output Torque after gearing	207 ft-lb	n/a

BLADES MOUNTS

- New mounts compose of a thinner circular face to add attachment points for blade disk.
- Overall dimensions keep the same but thinner overall and lighter.
- Mounting hardware will be high grade bolts, washer and nylon nuts to secure blades.



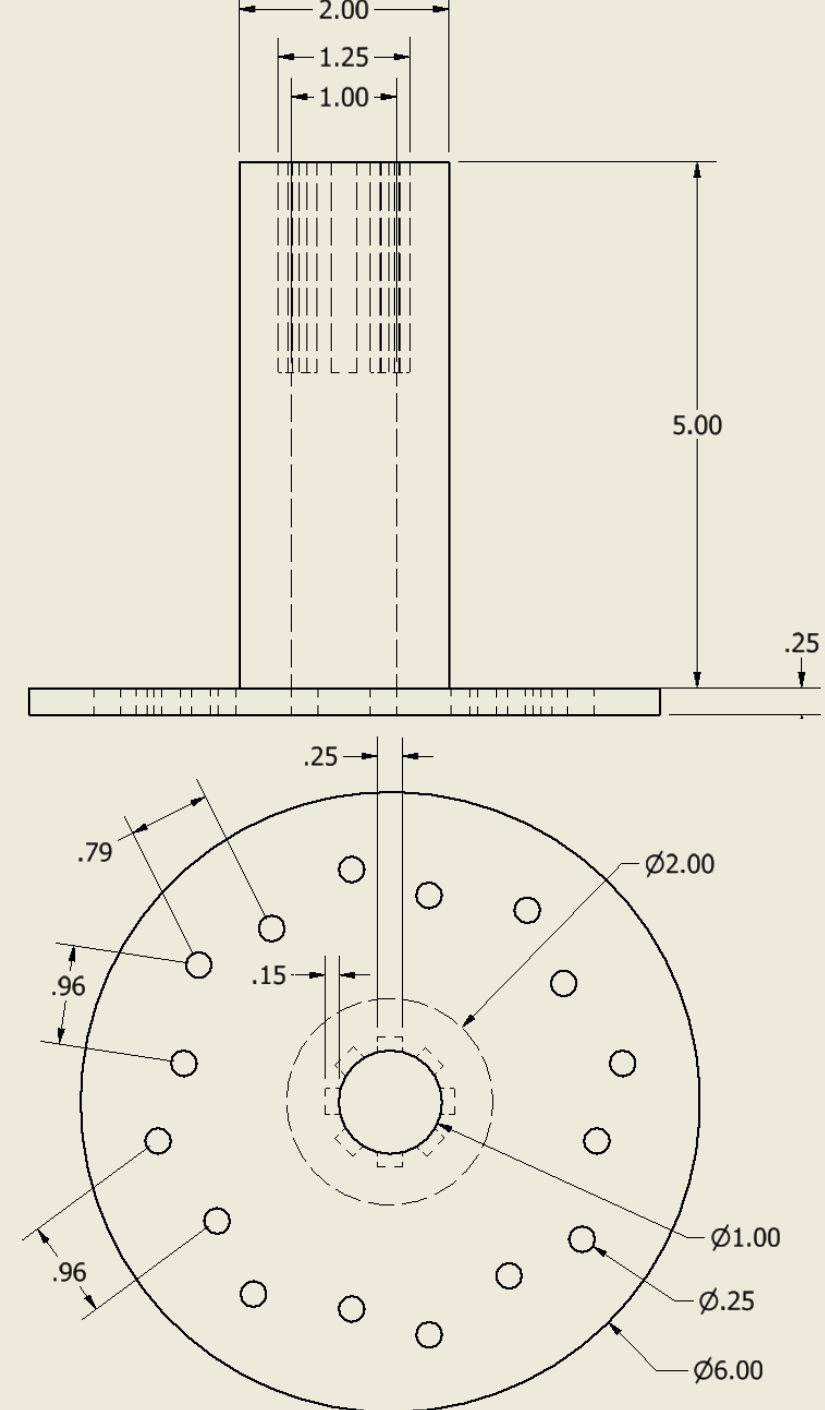
B. Updated mount



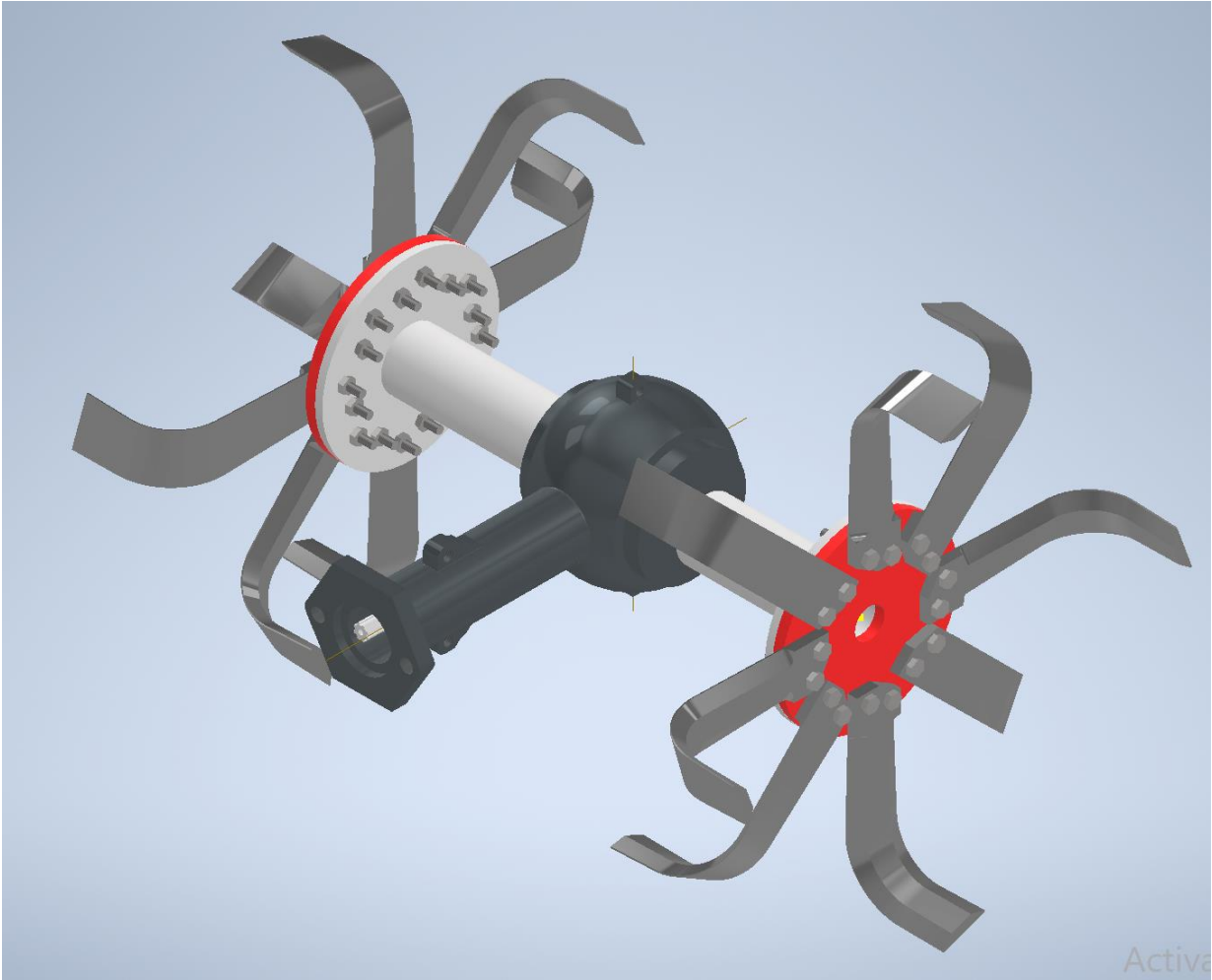
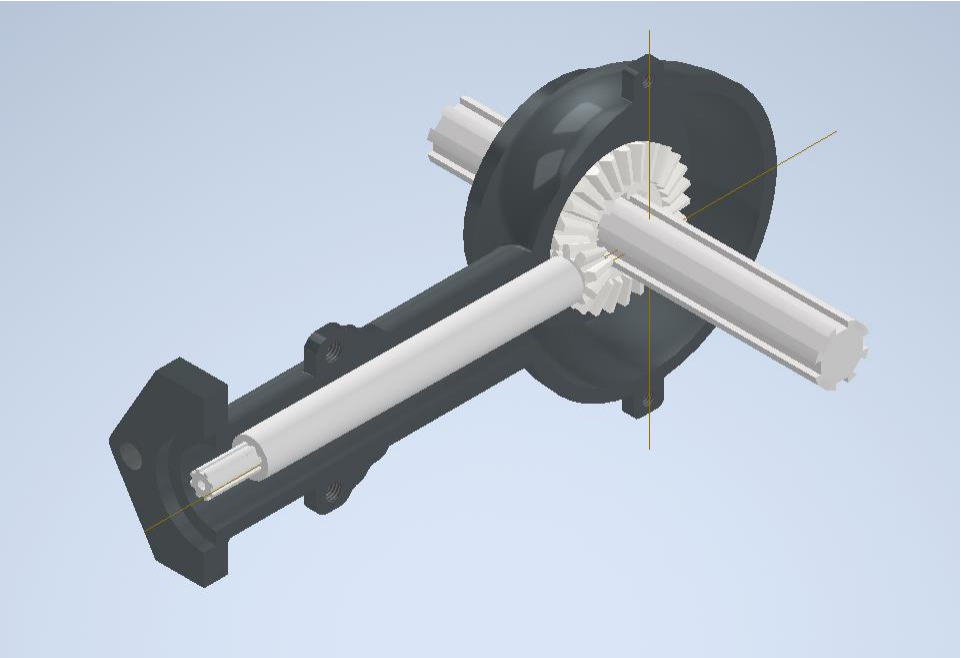
A. Previous mount

BLADES MOUNTS: TECHNICAL DRAWING:

- Measurements are based of similar mounts from other tiller machines.
- Materials: A36 Steel plate with round bar to complete the intended shape.



FINAL ASSEMBLY



ESTIMATE COST ANALYSIS: BLADE MOUNT

Component	Raw material	Cost
Mount face	¼ " 6"D Steel Circle Plate-A36 qty (2)	\$8.50each (qty 2)= \$17.00
Cylinder	A36 Steel Round Bar 2"x12" qty (1)	\$23.69
Hardware	¼ "-20 Nylon lock nuts grade 8 coarse qty (50)	\$7.60
	¼ " Structural flat washers qty (50)	\$5.10
	¼ " 20x2 Grade 8 Hex bolts qty (50)	\$13.45
Total price:		\$66.84

ESTIMATE COST ANALYSIS: GEARBOX CASE

Component	Cost
BCS Tractor Tiller Gearbox Case	\$300.00
Quick Hitch Female (includes hardware)*	\$80.00
Quick Hitch Male (includes hardware)*	\$85.00
Total price:	\$465.00

*If necessary

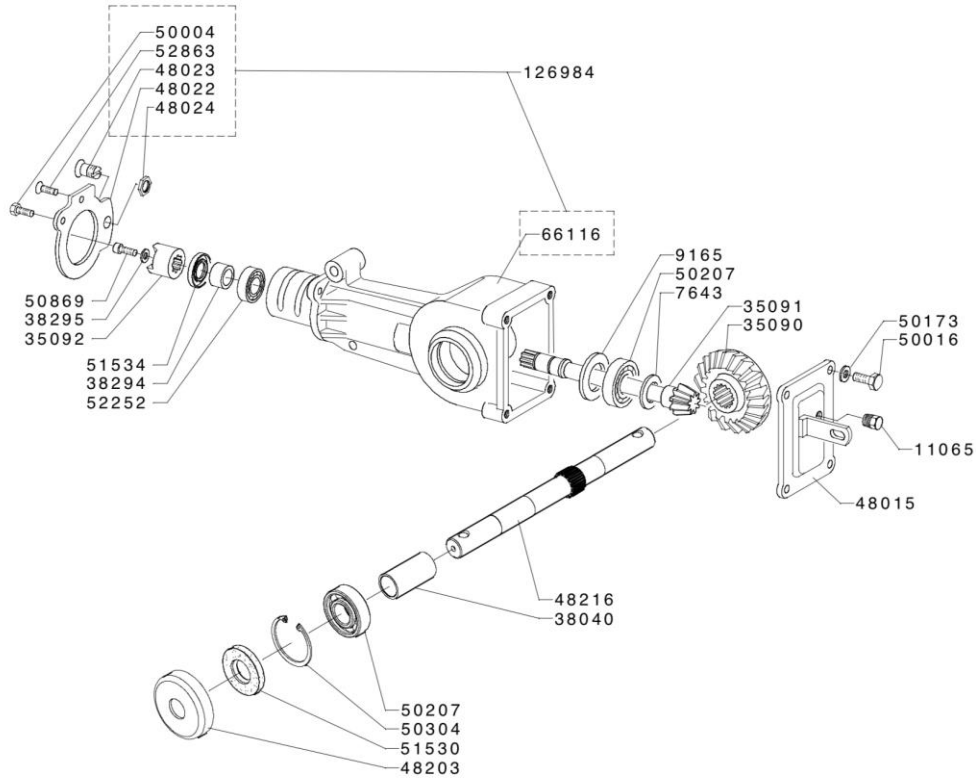
CONCLUSION

- Using the already implemented PTO system the blades could receive a torque of 207 ft-lbs and 293 rpms after gearing, which would be sufficient for the task at hand.
 - After conducting a Finite Elements Analysis to the gearbox case and the bolts that connect it to the quick connect adapter, it was determined that the components should not fail under the operation conditions considered.
 - Considering the dimensions of the blades, different mounts from the existing ones will have to be manufactured which would cost approximately \$66.84.
 - If different internal components (gears) would be implemented inside the gearbox case, the gearbox case must be manufactured with an added cost of approximately \$465.00. Price may change for modifications of extend pto shaft.
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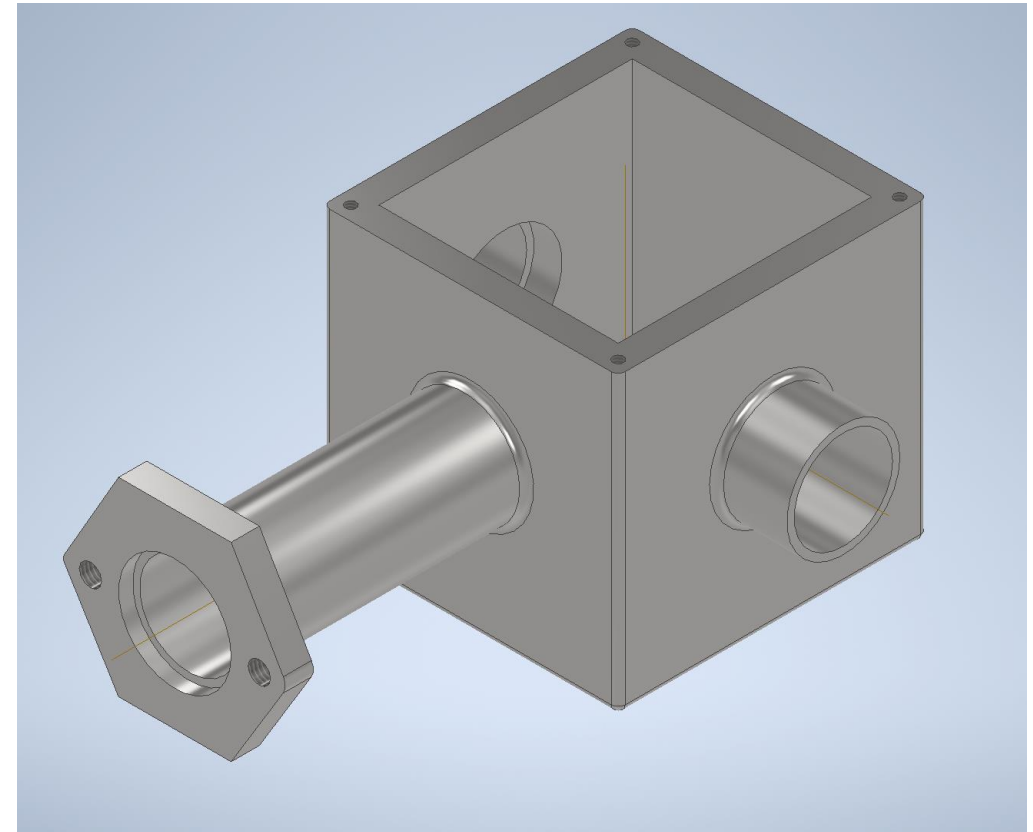
FUTURE RECOMMENDATIONS

- Perform a dynamic analysis considering vibration from the internal components and different weather scenarios and compare performance.
 - Research with further detail the dimensions of the different BCS tractor accessories, considering contacting a third-party vendor or a known customer.
 - Visit the plantation where the machine will be working in order to have a better understanding of its environment. This includes taking a sample of the soil to have a precise parameter of the actual force that it will exert on the blades.
 - Include the capacity to increase/decrease the rotational speed to add additional accessory such as a lawn mower.
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FUTURE RECOMMENDATIONS

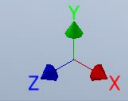
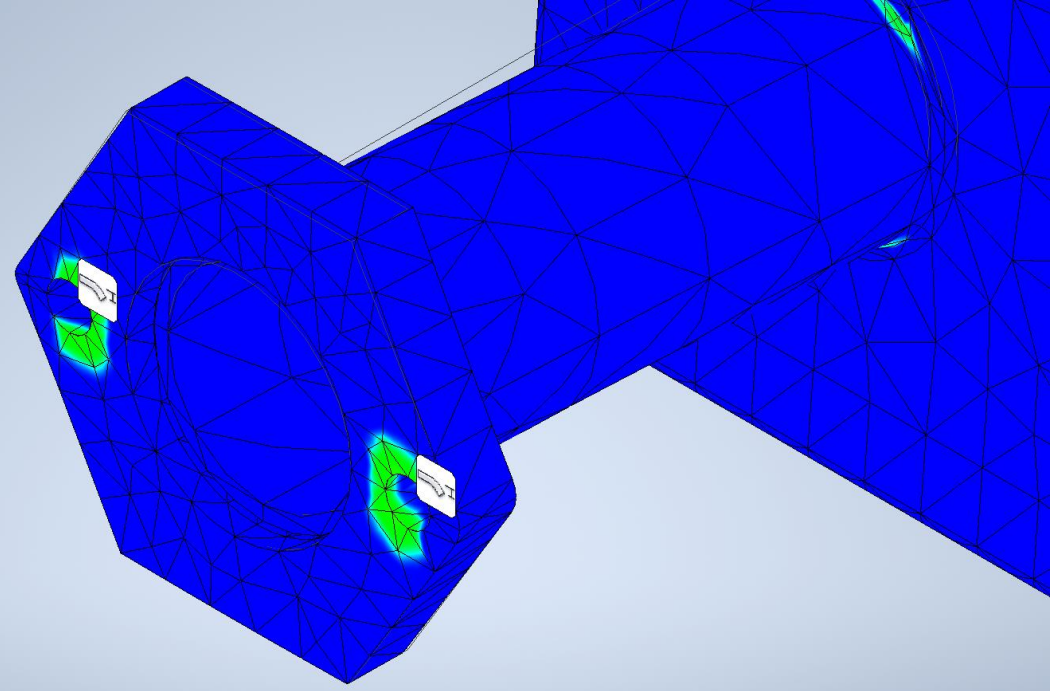
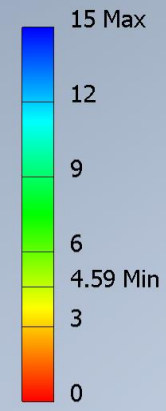


Grillo Tiller Gearbox Case

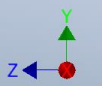
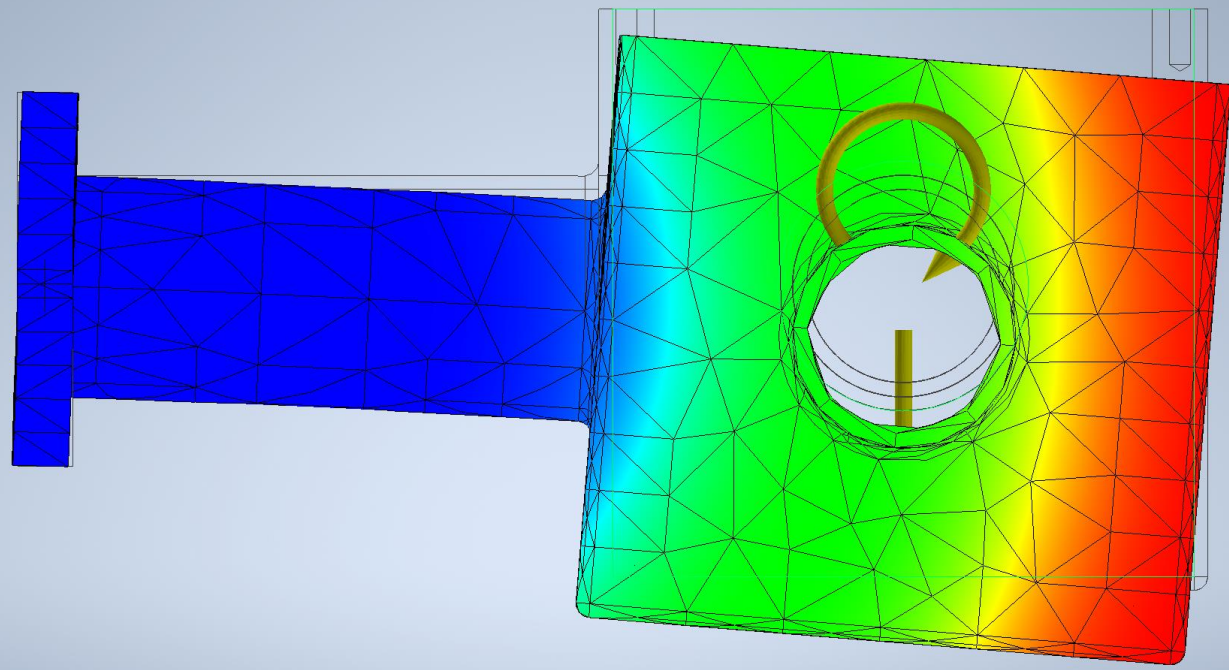
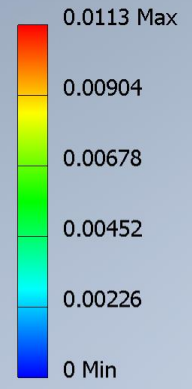


Snapper Gearbox Case Adaptation

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Unit: in
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**FUTURE
RECOMMENDATIONS**

REFERENCES

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- J. Mahapatra, V. Kashyap, and K. Sharma, "A Theoretical Method for Efficient Design of Power Tiller Rotavator Satisfying Multiple Objectives", *Current Journal of Applied Science and Technology*, vol. 39, no. 12, pp. 107-115, 2020, doi: 10.9734/CJAST/2020/v39i1230668.
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