

# **Power/Traction Assist for Amity Technology Sugar Beet Harvester**

By

Alec Bussman, Calvin Deters, and Mitch Zachman

Report

Submitted as part of the course ABEN487: Senior Design Project II

Project Advisors

Mr. Collin Miller

Mr. Blair Stoltman

Product Manager, Amity Technology  
Fargo, ND

Course Instructor

Dr. Ganesh Bora

Agricultural and Biosystems Engineering

North Dakota State University

Fargo, ND

May, 2011

# Table of Contents

Chapter	Title	Page Number
	Table of Contents	1
	List of Figures	2
	List of Tables	3
	List of Appendix	4
	Acknowledgements	5
1	Introduction	6-11
1.1	Statement of Problem	6
1.2	Rationale	8-10
1.3	Design Objectives	11
2	Literature Review	12-13
3	Methods and Methodology	14-15
4	Design Approach	16
4.1	Electric Drive System	16-17
4.2	Mechanical Drive System	17-18
4.3	Hydraulic Drive System	19-20
5	Results	21-22
	References	29

## **List of Figures**

- Figure 1.1 - (Single Rear Strut Assembly).....Source: <http://www.amitytech.com>
- Figure 1.2 - (Change in precipitation by %).....Source:<http://epa.gov/climatechange/.html>
- Figure 1.3 - (Sugar Beet Production Regions).....Source: <http://www.ers.usda.gov>
- Figure 2.1 - (ROPA Euro Tiger)..... <http://www.ctmharpley.co.uk.htm>
- Fig 4.1: Schematic for Electric Drive System.....Senior Design Team
- Fig 4.2: Schematic for Mechanical Drive System.....Senior Design Team
- Fig4.3: Schematic for Hydraulic Drive System.....Senior Design Team
- Figure 5.1 - Black Bruin Motor)..... Source: <http://www.blackbruin.com>
- Figure A.1 – 3-D model of rear strut assembly with Black Bruin Motor
- Figure A.2 – 3-D model of rear strut assembly without tire
- Figure A.3 – 3-D model of new mounting bracket designed to fit Black Bruin motor
- Figure A.4 - 3-D model of new mounting bracket designed to fit Black Bruin motor
- Figure B.1 – FEA Analysis of the mounting bracket
- Figure D.1 - (Black Bruin Load Chart)..... Source: <http://www.blackbruin.com>
- Figure D.2 - (Black Bruin Torque Output)..... Source: <http://www.blackbruin.com>

## **List of Tables**

Table 1 – FMEA.....	pg. 20
Table 2 – Bill of Materials.....	pg. 26
Table 3 – Calculations used to select Motor Size.....	pg. 28

## **List of Appendix**

Appendix A –3-D Design.....	pg:23-24
Appendix B – FMEA .....	pg:25
Appendix C – Bill of Materials.....	pg:26
Appendix D – Black Bruin Sizing Charts.....	pg:27-28

## **Acknowledgments**

Amity Technology is a company located in Fargo, ND that manufactures several lines of agricultural equipment ranging from planting to harvesting crops and commodities. It was founded by Howard and Brian Dahl, and first started as Concord, LLC later turning in to Amity Technology. Their product lines play a large role in the local economy, as well as economies worldwide. Their products are sold not only in the United States, but also in countries such as Ukraine, Russia, and China. They are currently the industry leader in sugar beet harvesting equipment, and also manufacture air seeders, and air carts.

# **Chapter 1**

## **1.Introduction**

### **1.1 Statement of Problem**

The sugar beet industry plays a major role in the Red River Valley and ensuring that a quality product is harvested is crucial to the success of the local economy. There is the issue, however, of occasionally having conditions during the harvest period that make removing sugar beets from the field extremely difficult. When there is excessive rain in the fall, sugar beet producers find themselves unable to pull the harvester through the field without losing traction.

### **1.2 Design Criteria**

Amity Technology has presented a problem that needs to be addressed of designing a power assist drive for the rear wheels of a sugar beet harvester. This is to provide a solution to the problem of harvesters getting stuck in excessively wet and muddy conditions by providing tractive support to the drive system of the tractor. The system is to be powered by the tractor and must also be able to infinitely adjust speed to match the ground speed of the tractor. The harvester must also be able to perform existing functions, meaning that the tractor must be able to supply sufficient power to perform all of the functions required to harvest the sugar beets, as well as have the ability to reverse and travel at road speeds which are much higher than working speeds. The system must be compatible with existing harvester designs with only slight design modifications to accommodate the addition of the new components. The system also needs to be able to be implemented as an accessory when a customer purchases a new harvester, while the harvester is still able to be sold without the power assist option. The optional drive is to be available on harvesters already equipped with the new single wheel option for the Model 2500 harvesters that Amity recently developed, as seen in the image below (Figure 1.1).This is

opposed to the older design that utilized two sets of smaller dual tires. Another problem that needs to be addressed is that the system used must be able to provide sufficient tractive power. Some of the features already integrated into this machine are adjustable lifting struts which aid in grabbing more of the taproot in dry field conditions and allow for less removal of mud in wet field conditions. Another design feature is an adjustable rear strut, which allows the operator to self level the machine in order to stay at the optimum digging depth. This particular harvester weighs 22,500 lbs when it is empty. When the tank is full, there is an additional 7,000 lbs of weight that needs to be distributed between the hitch and the rear wheels of the harvester. This is the leading need for power assist being integrated into a sugar beet harvester. The issue lies with the power requirements for the Model 2500 harvester. Currently, without the power assist option, the minimum tractor requirements are 200 hp, 1000 rpm PTO, 30 gpm of hydraulic capacity, and 2700psi of hydraulic pressure. This leads to the biggest problem in designing a power assist system for the harvester. Figure 1 shows a visual of the rear strut on the Model 2500 series harvester. The problem with the design shown below is that mud builds up on the tires and causes them to stop rotating freely. This can lead to the tractor having a difficult time pulling the harvester up and down the field, and possibly getting stuck as well. The idea of powering these rear wheels will keep these wheels rotating through muddy conditions, and take some of the strain off of the tractor.





Fig 1.1: Single rear strut assembly for the harvester

### **1.3 Rationale**

During the past few years, excessive rainfall has been an issue during the annual sugar beet harvest. Figure 1.2 shows that precipitation in the United States has been increasing for the past century. Figure 1.3 shows the most prominent sugar beet production areas in the United States. As shown in the figures, the areas of the country with increased rainfall, is the majority of the sugar beet production area. This added rainfall in these regions leads to traction problems with the tractor trying to pull the harvester through the field. Mud builds up on the rear tires of the harvesters, and after enough mud builds up, the wheels eventually quit rotating. The tractor then drags the harvester up and down the field with the rear wheels skidding and causing even more resistance. When the tractors get into a really muddy spot in the field and the harvester wheels are not spinning, it is probable that the tractor gets stuck. This has also been a big issue in Russia because of the narrow tires that are necessary to accommodate the narrower row spacing in which beets are planted; the tractor and harvester do not have enough traction to the ground. This costs precious time to the farmer because they then have to stop operation to get

the tractor and harvester unstuck, which often times is not an easy task. This can also be economically detrimental to farmers because if field conditions become too wet and muddy, then they subsequently must postpone sugar beet harvest until field conditions improve.

Occasionally, the rain does not stop, and field conditions do not improve. The farmer may not even be able to harvest the beets at all if the ground conditions stay too wet. This could result in the loss of the farmer's sole income for that year.

The reason for implementing a design for power/traction assist on the sugar beet harvester is to overcome this problem that is related to wet and muddy fields, which this system could give the tractor enough help to keep the wheels turning and get through the mud. By creating more traction, the operator would be able to through the wet conditions, allowing harvest to continue even through the wet conditions. As wet as the past few years have been, the market for this design has developed due to a lack of cost effective options. There is simply not a different alternative to getting through the fields when conditions are unfavorable. The goal of this design is to enable a drive system for the rear wheels of the harvester, which in turn will help the tractor push the heavy harvester through the field. This will give farmers the capabilities of harvesting sugar beets in poor field conditions which will result in less beets being left in the field, ensuring a more profitable year.

### Rate of Precipitation Change, 1901–2008

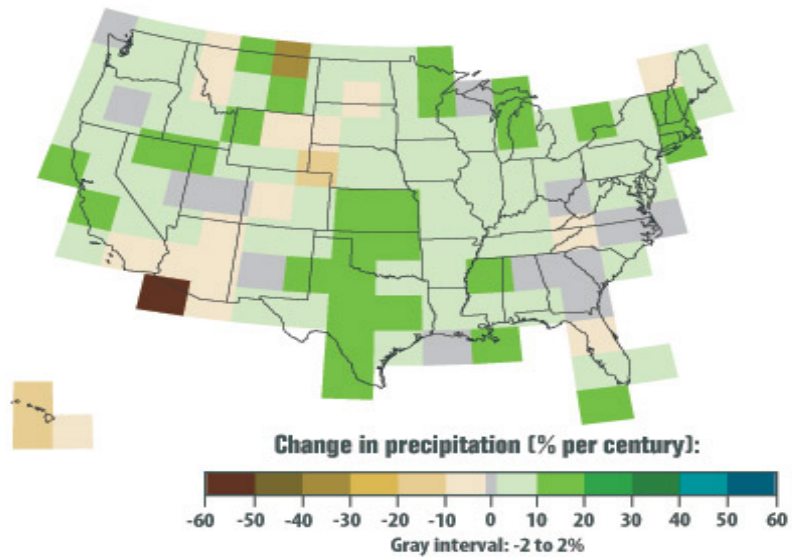


Fig 1.2: Change in precipitation by %

### Sugarbeet production regions

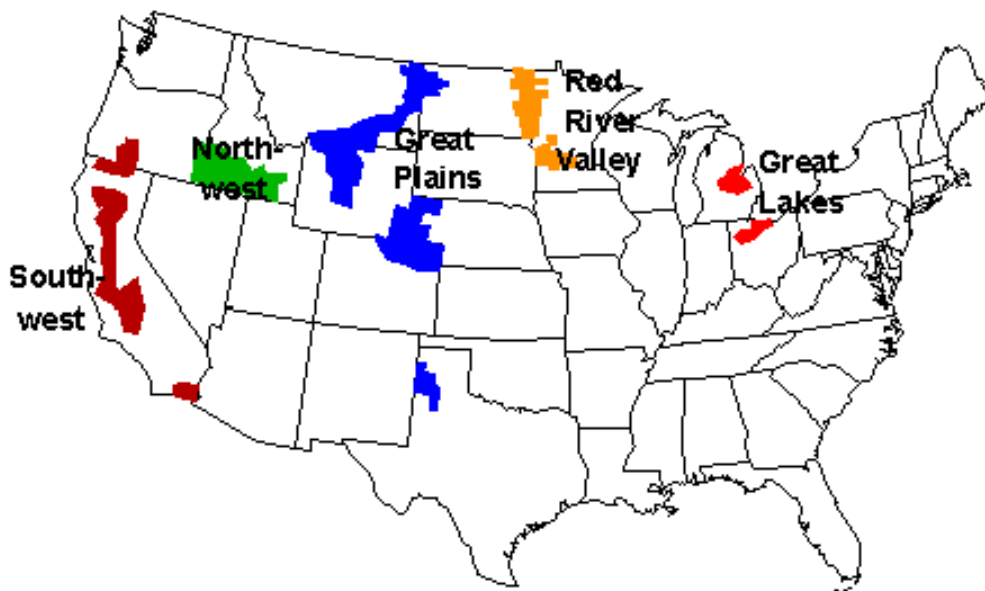


Fig 1.3: Sugar Beet Production Regions in US.

## **1.4 Design Objectives**

The main objective of the project is to design an effective power/traction assist system for the Model 2500 sugar beet harvester, using the following criteria:

1. Recommend a method to rotate the rear wheels in order to move the harvester through wet field conditions.
  - a. Evaluate alternative sources to power the rear wheels of the harvester based on:
    - i. Power requirements
    - ii. Cost
    - iii. Adaptability to the current design

## **Chapter 2**

### **2 Literature Review**

Other designs or models of power assist systems for sugar beet harvesters haven't been developed yet. There are currently no available power/traction assist pull-type sugar beet harvesters in the market. There are a few different types of implements that have power assist capabilities, but nothing that comes close to the complexities of a sugar beet harvester. The only other design similar to this idea is a self-propelled harvester produced called a ROPA Euro Tiger.

This unit, shown below (Figure 2.1), is a self-propelled harvester that defoliates and lifts the sugar beets all with one machine. The defoliation unit rides in front of the machine, and the lifting unit is directly behind the defoliation unit. The beet tank on this machine can carry approximately 20 to 26 tons of beets, as compared to the three ton beet basket on most pull type machines. The Euro Tiger utilizes a 604hp engine and is incorporated with a load sensing hydraulic system that triggers different torque and horsepower output required for the weight of the beets in the tank. This ensures the highest possible traction at all times and through any conditions. The drivetrain of this machine utilizes a continuous hydrostatic propulsion system with 2-gear drive and all wheel switching. First gear on this machine is rated to speeds of 0-13.5km/hr, and second gear is rated from 0-20km/hr. This machine essentially completes every step of removing the beets from the ground. Due to the advanced design, this machine is very expensive. As a result, this machine is produced and used mainly overseas where farms are much larger and operated by large scale corporations. These machines are not practical for the average farmer to purchase for small to medium scale farming operations. With this being the only current option for any sort of power assisted sugar beet harvester, the proposed design would give an option for a cheaper more practical power assisted harvester.



Fig2.1:Ropa Euro Maus Self-Propelled Harvester

## **Chapter 3**

### **3 Methods and Methodology:**

It is important to the collaborators and customers that the design of the harvester requires minimal changes. They feel that the current lifting linkage design of the 2500 that is currently used is optimal for the consumer needs and also feel that excessive change would be detrimental to current sales. One important reason minimal implement modification is important is that this system is be offered as an optional accessory and is not be standard on all machines. The harvesters are going to be sold without this power/traction assist, but it is possible to purchase this as an option if the customers feel it is beneficial to their operation. Due to this option, it needs to be available for purchase as an aftermarket part that can be easily assembled to the harvester as the customer needs it. This allows for versatility with different models as well as older models of harvesters that will be able to utilize this design. This may be achieved by developing different bracket packages that are compatible with all different models of harvester.

It was suggested to the collaborator by the design team that a hydraulically operated system be used because it will avoid the majority of the problems that result from a mechanical drive system would be eliminated by a hydraulic drive system. The plan to achieve this is to purchase an aftermarket hydraulic radial piston motor that would be able to achieve an output of at least 42 hp based on power demand requirements calculated from machine weight and wheel size; as well as develop a system to mount to the current strut design of the harvester. One issue that needs to be overcome with this design is how to match the harvester wheel speed and tractor speed. Currently, Amity's 12 row harvester comes

equipped with GPS capabilities, and it can be purchased as an option for the 2500 as well. This system could be tied into this GPS system to match the ground speed, but this would require the purchase of the GPS capabilities if the customer wants this power/traction assist feature. After reviewing other possible options for this design, it was found that a hydraulically operated system was the best solution given the specifications and guidelines given by the collaborator. This decision was based on the difficulties of speed matching and mechanical complexity of the mechanical drive design and the inability of the adequate power supply for an electrical system.

Another issue with this design is to decide whether or not to power the motors from the tractor's hydraulic system or to integrate a self-contained hydraulic system powered by the tractor's power take-off (PTO). This decision is based off of the hydraulic capabilities of the tractor that is going to be used for this design. Some tractors may not have the hydraulic capabilities to operate this system directly from the self-contained hydraulic system. This may cause problems if the customer desires this feature, but doesn't own a tractor capable of operating it, and doesn't desire to purchase a new bigger tractor. Due to this complication, it would be beneficial to offer two methods to provide power to the hydraulic motors; one which will run off of the tractors hydraulic power directly, and one which will have a self-contained pump and reservoir mounted on the harvester itself which is powered by the PTO. Amity currently has optional equipment that includes a self-contained hydraulic system that operates the scrub and unloading chain separate from the tractor hydraulics. This system could be modified by implementing a replacement pump that would be able to produce the enough hydraulic pressure to meet the demands of the wheel mounted motors.



## **Chapter 4**

### **4 Design Approach:**

Through the brainstorming process, the team was able to narrow down probable solutions to three ideas. One idea was using an electric motor gear and chain system to drive the rear wheels. Another idea was to design a mechanical drive system using a chain and gear system that is powered directly from the tractors PTO. The third design involved a hydraulic motor connected to each of the rear wheels. These three ideas were presented and were then further researched to develop the most optimal design to meet the collaboration specifications. The team then evaluated these ideas on design for safety, ease of use, portability, durability and strength, use of standard parts, and cost.

#### **4.1 Electric Drive System:**

The first idea involved is utilizing electric motors attached to the rear drive wheels by a gear box and chain system. Two electric motors are required, one to drive each wheel. The power to run the motors is generated by the tractor pulling the harvester. The wiring is strung along the frame of the harvester from the motors up to the tractor. The motor is designed to be mounted to the harvester and the gear box would have to share space with the automatic depth control hydraulic cylinder on the struts. One issue with this design is that the gear box used would have to be able to handle very high torque situations, and this could be very expensive to the project.

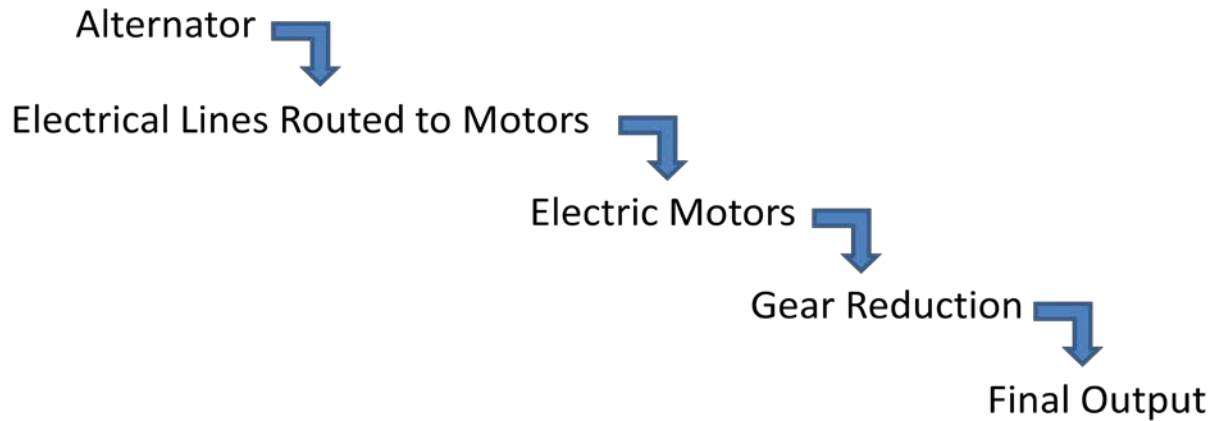


Fig 4.1: Schematic for Electric Drive System

When evaluating the electric motor idea, a problem concerning the power source arose. It was determined that the tractor could not generate enough electrical power to drive the electronics of the tractor and two high-torque electric motors for the harvester. In order to produce the 42 hp needed to drive each wheel would require 2600 amps delivered to each motor at the standard 12V electrical system used by current equipment. The idea was then contemplated of using a separate generator driven by the PTO of the tractor to develop enough power to allow the motors to run efficiently enough to assist the tractor in pulling the harvester. This would work, but it would require a design of a generator and housing compatible with running off the PTO requiring time and money. Also, finding space on the already clustered harvester would pose a challenge. Electrical components are also expensive and can be more complicated to maintain and service as well as less resistant to the harsh field conditions.

## 4.2 Mechanical Drive System:

The second idea involved is developing a mechanical drive system to power the wheels. Chains and gears could be calculated to run off of the PTO and housings would need to be developed. Lubrication options would need to be planned and clutching would also be needed to help keep the speed of the rear wheels matching the tractor's speeds. A problem with this design is that it would add many extra moving parts to the already complicated sugar beet harvester. As common, the more moving parts that there are, the higher risk for failure. This system also needs to be able to move up and down as the struts act as an automatic depth control for the sugar beet harvesters. This means that the strut has a cylinder attached that moves it up and down, so developing a chain and gear system that allowed this motion would be very difficult. With this in thought, it is important to keep the design as simple as possible.

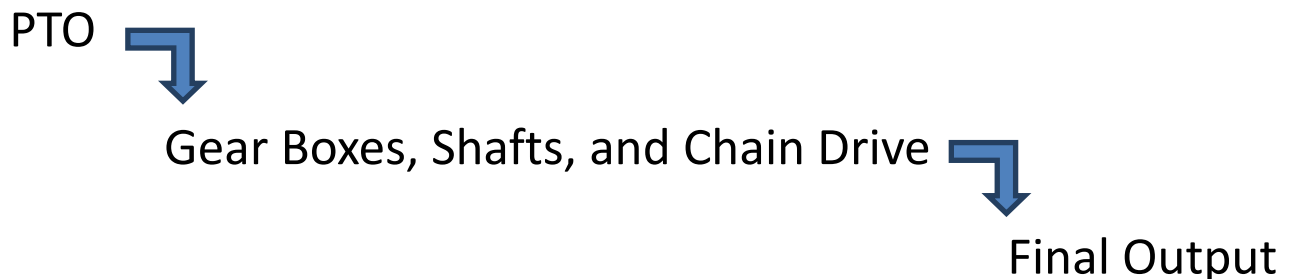


Fig 4.2: Schematic for Mechanical Drive System

After evaluating the mechanical drive system, the challenge came in trying to get from PTO power on the machine to route into the wheels in the back. The amount of material needed to develop this system would be costly and not easy to design. The housings for the chains and gears are a must to keep debris out. Another challenge would be matching the speed of the tractor; this would require use of a sort of clutching. The use of clutching would require needed

maintenance and have a greater possibility of failure while in use. A clutch system would also be more inefficient as more power is wasted and lost to heat energy. The gears and chains used in this process would also require a more meticulous lubrication and maintenance regimen and are also prone to failure and breakage.

### 4.3 Hydraulic Drive System:

The third and final idea involves using two hydraulic motors to power the rear wheels. The motors would need to work with the cylinder on each strut that controls the depth similar to the electric motor gear box idea. Hydraulic flow needed to power these two motors could be provided by the hydraulic system of the tractor, or a hydraulic pump and reservoir mounted on the harvester already provided as an option to the 8 row harvester by Amity. The lines could be run along the frame and attach to the motor down on the strut. The motor could mount either on the frame and a gear box would be used to deliver power to the wheel, or the motor could be attached directly to the hub of the wheel and the frame of the strut.

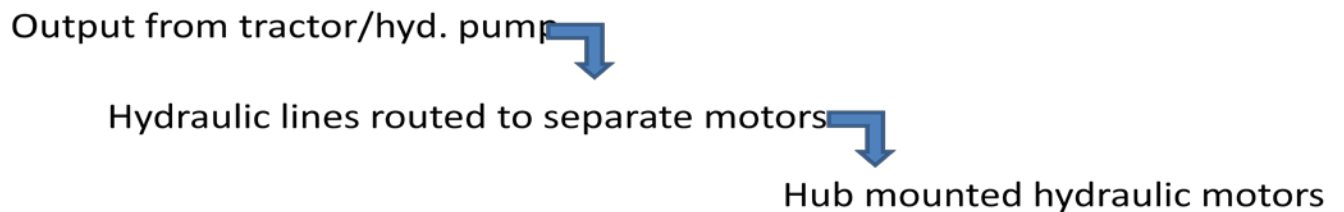


Fig4.3: Schematic for Hydraulic Drive System.

Finally, the hydraulic motor idea was assessed. This idea was low maintenance and practical. The lines for the hydraulics could be easily routed along the harvester and the motor could be mounted in multiple ways. This idea ranked high in the ease of use by having the option of getting hydraulic power from either the tractor or the on-board tank. These options brought the

cost of the project down, the motor being the most costly item within this whole system. This design seemed to fit most of the collaborators specifications as it was the most cost efficient. It utilized the current design of the harvester without requiring too many additional modifications, and it allowed for the simplest design that is easiest to integrate with the design of the current harvester.

The hydraulic motor idea was presented to the collaborator and it was decided that this would be a suitable option to solve the traction problem in wet field conditions. They also agreed it would be an option to buy motors that are available in market to be used in the project, due to the cost and difficulty of developing a custom free-wheeling hydraulic motor. Amity will also be in charge of deciding what method they choose to power the hydraulic motors.

Table 1. FMEA Results

Criteria	Weight %	Electric		Mechanical		Hydraulic	
		Score	Points	Score	Points	Score	Points
Safety	5	8	40	7	35	8	40
Ease of Use	20	8	160	4	80	8	160
Portability	5	9	45	9	45	9	45
Durability	20	7	140	6	120	9	180
Standard Parts	15	5	75	9	135	9	135
Cost	15	3	45	8	120	7	105
Probability of Successful Function	20	3	60	3	60	8	160
<b>Total Points</b>	<b>100</b>		<b>565</b>		<b>595</b>		<b>825</b>

## **Chapter 5**

### **5 Results:**

The hydraulic power assist design consists of two hydraulic motors, one attached to each strut, fed by a series of hoses and valves to drive the harvester wheels (shown in figures A.1, A.2). The group is recommending hydraulic motors that are available in the market for Amity to use. This is because it would be very expensive to create a new design for a free-wheeling hydraulic motor, not to mention that Amity doesn't currently have the capabilities at the current time. The motors will attach to the wheels and strut and be able to provide assist to the tractor pulling the harvester. The lower, pivoting portion of the strut containing the axle will be replaced at the pivot point with a new rower strut section. This new strut section will still contain all of the necessary brackets for the mounting of the hydraulic cylinder, but it will replace the axle with a plate to which the hydraulic motor is mounted. A rim with the necessary bolt pattern to match the hydraulic motor is also required. The hydraulic lines will be routed off to either the tractor or the optional reservoir, whichever Amity decides. By using the given weight on the rear wheels of the fully loaded harvester and the tire size, we were able to calculate the amount of torque that is required to move the weight. We then designated that the system should be able to provide enough power to move 20% of the load. We determined that 4550 ft-lb of torque is required given these parameters; and assuming a maximum operating speed of 7.5 mph, 42 hp is required per axle.

While looking more into using hydraulic motors the group came across the Black Bruin hydraulic freewheeling motor (shown in figure 5). The preliminary assembly is shown on page seventeen. Black Bruin has a history of producing high quality' durable hydraulic motors and

rotors for applications such as this, which should have no problem being strong to power the rear wheels. Black Bruin offers mechanical freewheel with shift-on-the fly capabilities allowing the machine to operate at multiple field operation speeds or towed at highway speeds at a price of approximately \$3000 per motor, depending on quantity and time of purchase.

The design is to be constructed using the Black Bruin motor (Figure 5.1) acting as the hub for the wheel and attaching the other side of the motor to the strut using a flat circular plate with the correct bolt pattern (shown in figures A.3, A.4). This motor mount apparatus will replace the existing lower portion of the lift linkage. A FEA model was ran with this mounting bracket to ensure that the design would hold up under high torque loads (FEA results shown in appendix B). The motor will bolt to the circular plate, and the wheel will be attached to the opposite side allowing the motor to act as both a propelling device as well as the wheel's hub. To meet the required demand of 42 hp necessary at each of the rear wheels, the BBC-03 motor was selected since the specs of this motor most adequately meet necessary design parameters. The parameters for selecting the right motor are shown in appendix D. The hydraulic lines running to the motor will need to be flexible hoses to allow for vertical movement of the lower portion of the strut which provides the height adjustments of the machine.



Fig 5.1: Black Bruin Hydraulic Free-wheeling Motor

## Appendix A



Figure A.1 – 3-D model of rear strut assembly with Black Bruin Motor



Figure A.2 – 3-D model of rear strut assembly without tire



## Appendix A

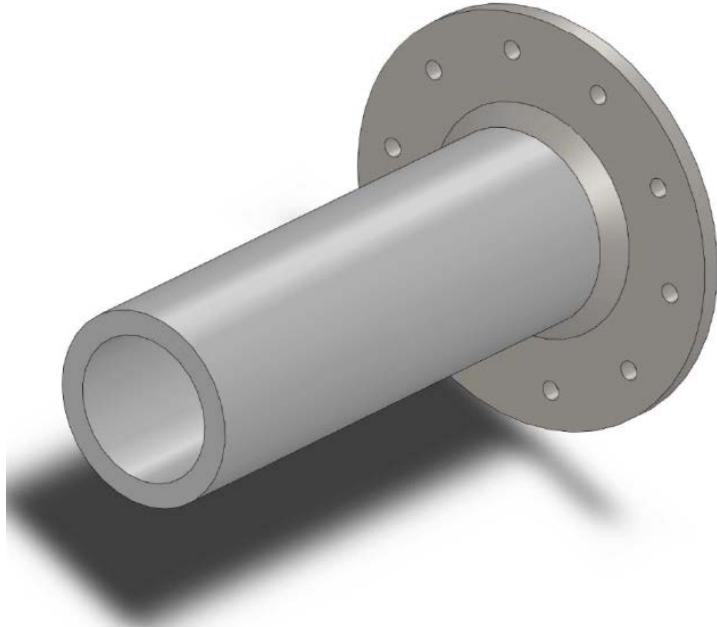


Figure A.3 – 3-D model of new mounting bracket designed to fit Black Bruin motor

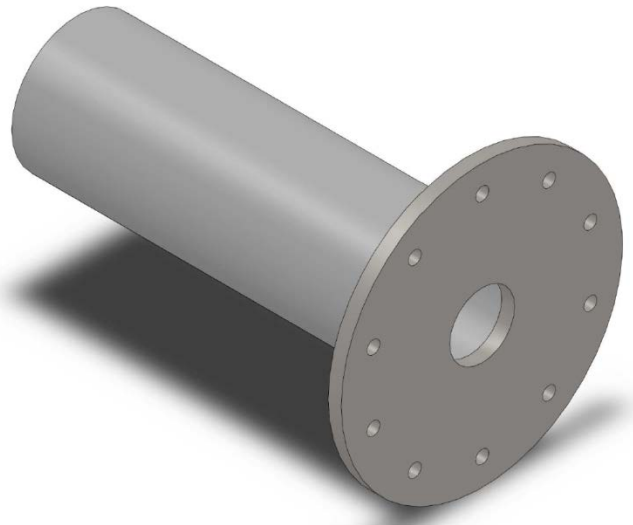


Figure A.4 - 3-D model of new mounting bracket designed to fit Black Bruin motor

## Appendix B

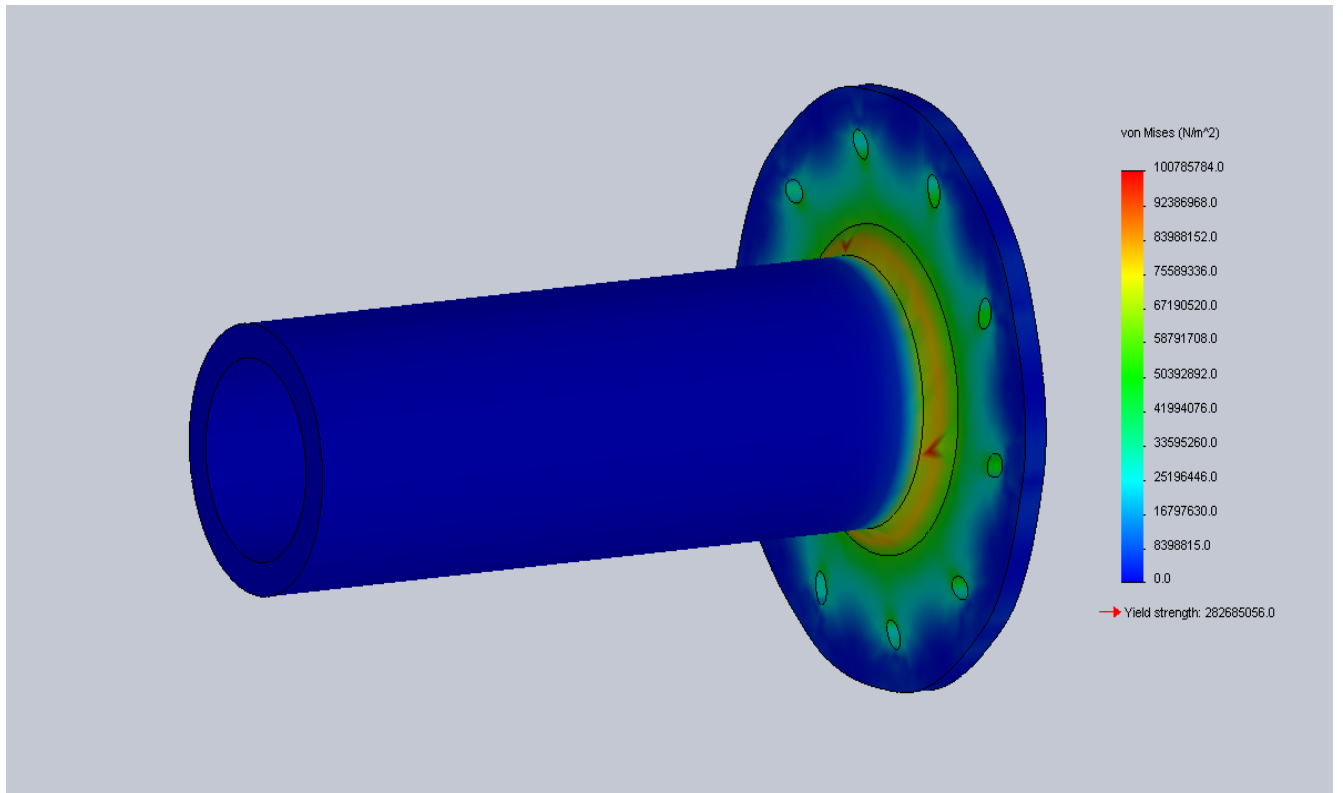


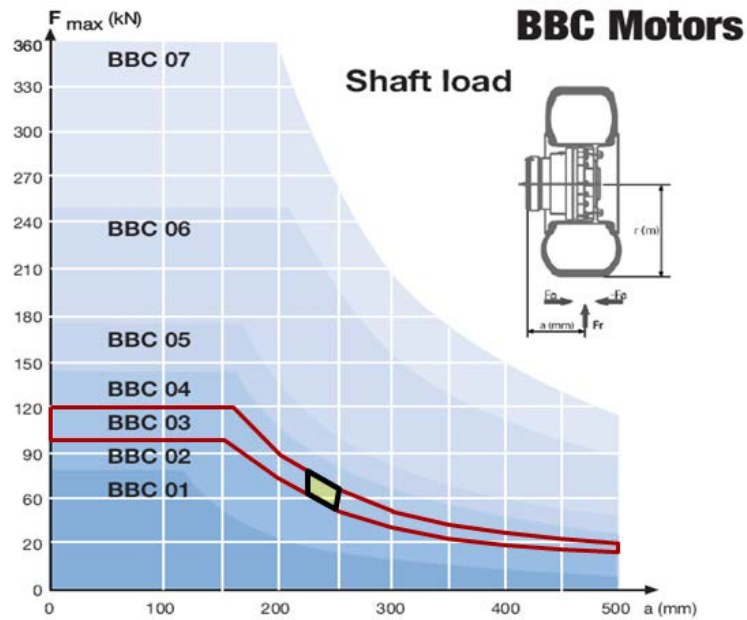
Figure B.1 – FEA Analysis of the mounting bracket

## Appendix C

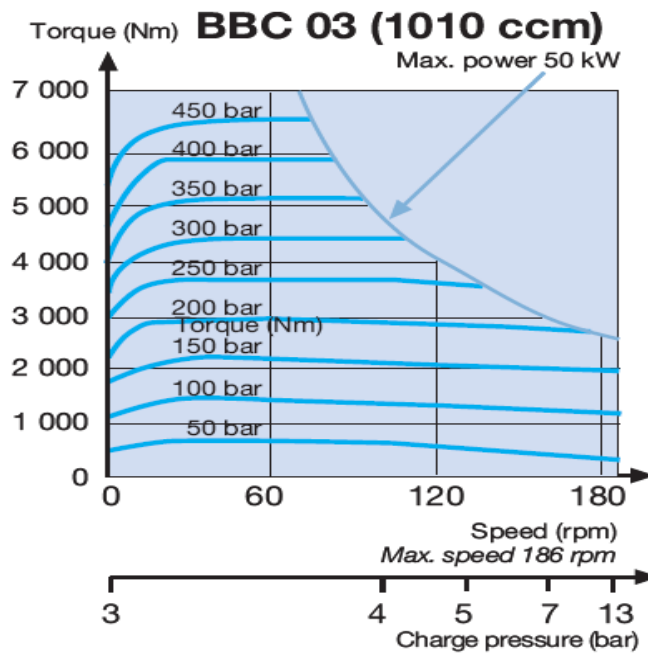
Table2: Bill of Materials

Bill of Materials					
#	Part	Quantity	Source	Price	Total
1	Black Bruin Hydraulic Motor	2	Sampo Hydraulics Inc.	\$ 3,000.00	\$ 6,000.00
2	Hydraulic Hose	100 ft	Discounthydraulichose.com	\$ 4.03/ft	\$ 403.00
3	Fittings	4	adaptersinc.com	\$ 13.50	\$ 54.00
4	Steel for new mount plate	2	Amity Technologies	\$ -	\$ -
				<b>Total Costs</b>	<b>\$ 6,457.00</b>

## Appendix D



FigD.1: Black Bruin Shaft Load Chart



FigD.2: Black Bruin Torque Output Chart

Table3: Calculations used to select Motor Size.

<b>Motor Class Size</b>	<b>BBC 03</b>					
<b>Percentual Displacement</b>	%	90	100	110	120	130
<b>Displacement</b>	gpm	0.24	0.27	0.29	0.32	0.35
<b>Peak Pressure</b>	psi	6525	6525	6525	6163	5800
- Peak Torque	ft-lb	4421	4911	5402	5568	5675
<b>Intermittent Pressure</b>	psi	5800	5800	5800	5438	5075
-Intermittent Torque	ft-lb	3930	4365	4804	4911	4967
<b>Power</b>						
-Max. Displacement	HP	67				
-1/2 Displacement	HP	44				
<b>Max. Speed</b>						
-Working	MPH	32	29	26	24	22
-1/2 Displacement	MPH	45	40	37	34	31
-Freewheeling	MPH	93				

## References

Amity Technology." [www.amitytech.com](http://www.amitytech.com). Amity Technology, 2010. Web. <<http://www.amitytech.com/>>.

"Black Bruin Hydraulic Motors." Black Bruin. Sampo Hydraulics Ltd., 2009. Web. <<http://www.blackbruin.com/en/home/>>.

"CTM-Harpley Engineering Limited." ROPA Euro Tiger Sugar Beet Harvester. N.p., 2011. Web. <<http://www.ctmharpley.co.uk/company.html>>.

"Minibooster." *General Specifications*. N.p., 03 Dec 2010. Web. <[http://www.minibooster.com/version\\_english/01\\_products/general\\_specifications\\_uk.htm](http://www.minibooster.com/version_english/01_products/general_specifications_uk.htm)>

"National Weather Service." NOAA's National Weather Service. N.p., 2 May2011. Web. 2 May 2011. <<http://www.weather.gov/>>.

"ROPA." ROPA Sugar Beet Harvesting Systems. N.p., 2011. Web. 2 2011. <<http://www.ropanorthamerica.com/index.php>>.

"USDA Economic Resource Service." [webadmin@ers.usda.gov](mailto:webadmin@ers.usda.gov) , 28 Apr 2011. Web. <<http://www.ers.usda.gov/>>.