Redesign of a Tree Shear

Clam Lake

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Abstract

The Vassar Company is a manufacturer of farm and ranch equipment in Perkins, Oklahoma. The company makes an economical tree shear for use by either a skid steer loader or a tractor. Recent competitors' machines introduced into the market have led Vassar to request a redesign of their current tree shear from Clam Lake Engineering. The redesign accommodated new options and reduced the number of fabricated parts. After extensive testing, computer-aided modeling, and consultation, Clam Lake Engineering (CLE) developed a new design that was cutting-edge in the tree shear market. The design satisfied all requests, and may lead to an economic boost for the company.

Acknowledgements

Jack Vassar—Vassar Farm Equipment Company, Owner

Larry Kimmel—Vassar Farm Equipment Company, Sales Manager

Dr. Paul Weckler—Oklahoma State University Biosystems & Agricultural Engineering

Assistant Professor and Senior Design Advisor

Wayne Kiner—Oklahoma State University Biosystems & Agricultural Engineering

Laboratory Manager

H. Clay Buford, P.E.—Design Consultation

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Problem Statement

A recent explosion in the number of Eastern Red Cedar trees in the region around Oklahoma has led many landowners and farmers to research different control methods against this exponential growth. Many options exist, such as controlled burning, manual removal with chainsaws, or tractor-powered tree saws. Tree shears provide an alternative to burning or sawing.

Most tree shears work with basic mechanical principles. One or two hydraulic cylinders close blades in a scissor-like motion to sever trees. Various products on the market have adapted this design for different uses, such as rotational movement, tree cutting, and tree moving. Tree shear manufacturers are being forced to increase the capabilities of their products in order to remain competitive.

Vassar Farm Equipment requested a redesign of their current tree shear from Clam Lake Engineering (CLE). The new design should be more efficient, competitive in cost, and more appealing to the consumer than the previous models. The current 10 inch capacity shear produced by Vassar Farm Equipment is shown below in Figure 1.

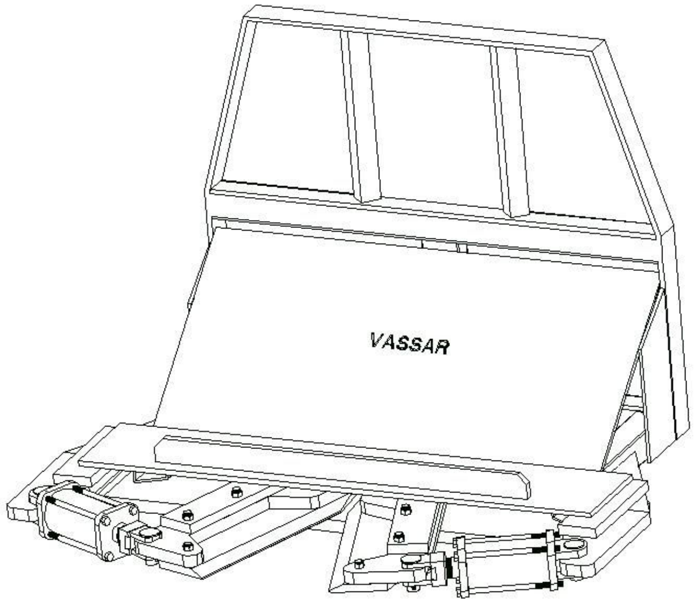

Figure 1: Current SS-4 tree shear

Statement of Work

Clam Lake Engineering contacted The Vassar Company and was provided with requirements for the new tree shear design. The new design started with a definition of the project. To help define the project parameters, CLE split the details into two sections: New Features and Limitations.

New Features

The Vassar Company communicated several new features they feel would make their tree shear competitive. These included ideas that focused on the consumers' needs, reduced the manufacturing costs, and improved the overall capabilities of the shear. After visiting with Larry Kimmel, manager, and Jack Vassar, owner, the new features of the Vassar tree shear were defined as: rotational capabilities, a more efficient frame design, and the capability to make flush cuts.

Rotation

Vassar expressed the need for rotation for the purpose of trimming large limbs. The capacity of the shear was limited to 10” because Vassar felt cutting branches over 10” in diameter would present the potential of injury from falling objects. The company also requested, but not required, that the design be manually operated, because most client vehicles operate with only one remote hydraulic circuit. Vassar did not apply any other requirements to the rotation feature. Therefore, the type of rotation was left to CLE’s discretion.

Frame Design

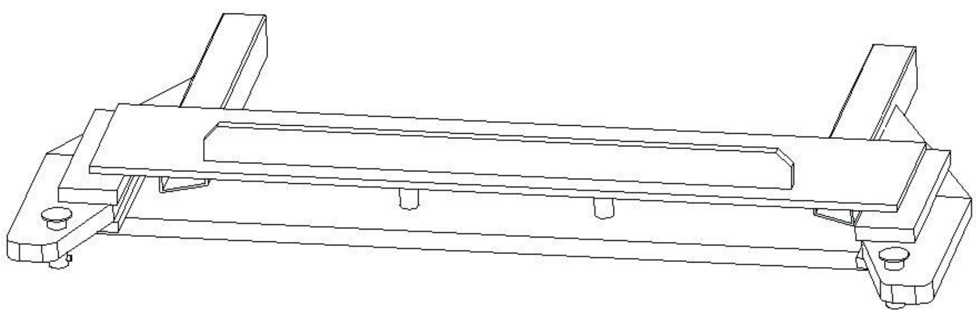

Figure 2: Vassar SS-4 tree shear frame

The Vassar Company produces the current shear frame from eleven pieces of heavy gauge steel ranging from 0.375” to 1.25” in thickness, as shown in Figure 2. The company felt that this was an excessive number of pieces, considering the production process for the frame. Therefore, the company requested that many of these pieces be merged into larger pieces. Simplifying the frame included two major changes: minimizing parts and reshaping the frame to align the cylinders with the blades. The current model placed the cutting edge of the shearing blades at a 68˚angle from the longitudinal axis of the cylinders, as shown in Figure 3. Vassar expressed the need to utilize more force produced by the hydraulic cylinders. A design to maximize the full force of the hydraulic cylinders by placing the cylinders at a right angle to the blades was suggested.

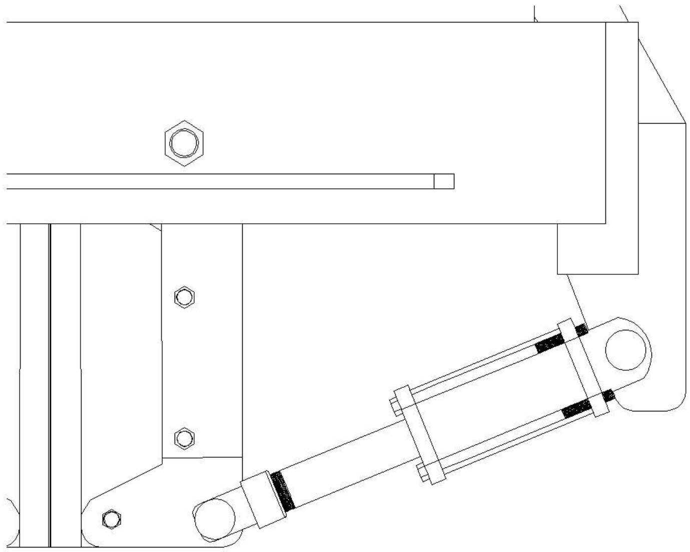

Figure 3: Ram Angle

Flush Cutting

Vassar requested the new tree shear design to incorporate flush cut capabilities. Their customers have voiced the desire for flush cut capabilities several times, so that equipment can be driven over the stump without inflicting damage upon the tires. Larry Kimmel, sales manager for Vassar, stated that the current shear allowed flush cutting, but the process included driving the shear below ground level and cutting the trunk of the tree below the ground. This disturbed the topsoil and increased wear on the implement. Allowing the blades to sit directly on the ground would enhance the appearance of the shear to the customer.

Limitations

Several factors dictated the design of the new Vassar tree shear. Clam Lake Engineering realized the limitations set forth and applied the limitations to evaluate solutions. Vassar set some of the constraints which the new design followed, along with those imposed by CLE:

- Weight of new design Model SS-4 was to be below 1200 lbs
- The new design must have a brush guard
- The new design must be competitive in cost
- Operation of the new design must be performed by one hydraulic circuit
- The shear must remain easily maintainable
- The new design must conform to the set hydraulic pressure of 2000 to 3000 psi
- Hydraulic cylinder bore should be the same as previous designs

CLE produced the list of limitations above to aid in the design process of a new tree shear. The weight limitation was set forth by the skid steer capacity. The Vassar Company asked that the total weight of the shear be no more than 1,200 pounds, which would allow the shear to be an attachment for smaller capacity skid steers.

Literature Review

Clam Lake Engineering focused on patent searching and reviewing the designs of other manufacturers for the literature review portion of this project. The team found six patents and considered them before proceeding with the design process. These are available in the CLE fall progress report (Cosgrove et al, 2007)

Engineering Specifications

Based on requirements from The Vassar Company and CLE's engineering experience, the following specifications must be met by the new tree shear. For clarity, the specifications have been broken into three sections: Dimensions, Forces, and Special Considerations. The Dimensions section describes the physical shape of the tree shear and how its dimensions impact its functionality. The Forces section covers the loads imposed on the shear during the tree cutting process as well as the forces on the rotational joint from the weight of the implement. Lastly, Special Considerations includes angle of rotation, features of the rotation mechanism, and safety.

Dimensions

The new tree shear should be large enough to cut down a 10" tree, yet small enough to be mounted to a 40-60 horsepower skid-steer loader. Vassar's current SS-4 shear has a 10" capacity, determined by the distance from the tip of the blade to the blade carrier. The length of the implement should also be minimized in order to shorten the moment arm acting on the loader. If the new shear becomes too long, the center of gravity could move out far enough to tip over a small skid-steer loader. The shear must also be long enough to place a 10" tree between the blades and allow for a rotation mechanism to be placed between the blade frame and the mounting frame. The height of the blade frame should be minimized in order to save weight while remaining strong enough to withstand heavy use.

Forces

The primary forces acting on the tree shear are the shearing forces imparted on the tree by the hydraulic rams. The maximum ram forces have been estimated by multiplying the maximum rated hydraulic pressure of 3000 psi by the bore area of the 4" rams, giving a column load on the cylinder of 37,700 lbs. The resulting force on the blades was larger than the cylinder force when the moment arm the cylinder operated on was taken into account.

The force required to shear a tree was estimated using a nomograph created by Rodger Arola (1972). The specific gravity of the wood is required to use the nomograph, which was determined to be 0.48 for Eastern Red Cedar (Forest Products Laboratory, 1999). Therefore, a required shearing force of 59,000 lbs was calculated. This was less than the calculated blade force of 62,000 lbs at maximum pressure. Vassar's previous experience with this cylinder also indicated that it should be more than adequate.

Other Considerations

The mechanisms of operation, cost, and safety of the operator were incorporated into the special considerations of the new design. These also included the angle of rotation and features of the rotation mechanism.

After considering the hardware required for rotation, the members of CLE agreed that the optimum angle of rotation was 90º from horizontal. A 90º rotation simplified the mechanism required for either manual or hydraulic rotation. CLE concluded a rotation angle larger than 90º would require costly mechanisms and higher manufacturing costs.

Safety of the operator while using the shear is also a major concern to both CLE and Vassar. While considering designs CLE noted that the location of the center of gravity of the shear would be critical. Loader capacity was based on the center of gravity of a load in the bucket, so any load center of gravity deviating from the center of gravity of a load in a bucket is a safety issue. A safety consideration concerning rotation was accessibility to the rotation mechanism, particularly mechanisms requiring the operator to exit the skid steer. Entering and exiting a skid steer loader with the loader elevated was discouraged because of the possibility of accidentally engaging levers.

Preliminary Design Concept

After considering the requirements the new tree shear must fulfill, Clam Lake formulated new designs. Design considerations were based on the criteria discussed in the preceding Engineering Specifications section. CLE's solution to the problems of rotation, flush cutting, and improved frame design are discussed below.

Rotation

The main issue facing CLE was rotation. For the pivot point of the shear, CLE initially considered a shaft and bearing construction, but it was determined that large diameter bearings were too high in cost. Another proposed new idea involved using two pipes with bearings between them. The proposed idea was to utilize severed round stock or commercially produced bearings if available. After consulting H. Clay Buford, P.E., CLE considered drawn over mandrel tubing (DOM tubing) placed within another DOM tube to be a better option. CLE concluded that DOM tubing was the best option given the wide range of sizes and wall thicknesses offered.

Next, CLE focused on the mechanisms that would be needed to drive the rotation system. Initially, both hand and hydraulic actuators were considered. Through further discussion of the problem with Larry Kimmel, it was determined that a hand-move system was preferred. The hydraulic system, therefore, was put on hold while the team determined more efficient hand-move designs. After exploring several hand-move options, such as a moveable flange (Figure 6) and a worm gear, CLE elected to omit any manual rotation options due to cost and safety issues.

One option for hydraulic rotation was a rack and pinion arrangement. A hydraulic cylinder would move a straight rack horizontally over a pinion mounted to the frontal section. The idea of one large gear powered by an electric or hydraulic motor turning a small gear was also considered. Lastly, the team also proposed using a single hydraulic cylinder, connected to both the shear head and the frame. This arrangement was determined to be optimum due to its simplicity and affordability.

Flush Cutting

New concepts generated needed the ability to perform flush cuts. Flush cutting refers to the ability to shear a tree trunk flush with the ground level and leaving no portion of the stump above the surface. After modeling the system in Pro-E, CLE began to explore different options that would lower the blades. Designs generated by CLE incorporated flush cutting capabilities in two ways, depending on the shear head frame design. If the blade assembly was placed between two plates, then the blade length was limited to the portion of the blade carrier not covered by the frame, as shown in Figure 4.

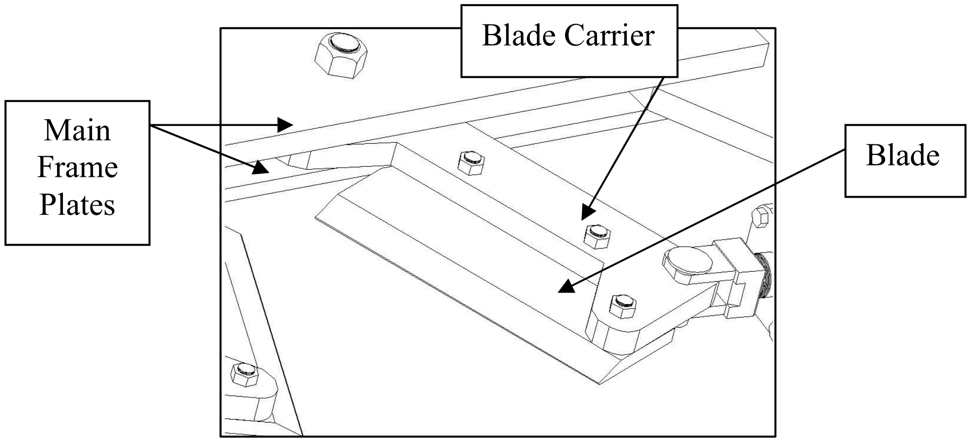

Figure 4: Flush cutting

Shortening the blade places the bottom face of the blade flush with the bottom surface of the shear, but the shear is not truly flush. The bolt heads holding the blade protrude from bottom of the shear. CLE considered countersinking bolts or threading the blades to remedy the problem, but ultimately decided the thickness of the bolt heads was negligible.

An issue also related to flush cutting was the increased torsion on the blade carriers. As seen in Figure 4, obtaining flush cut requires an increasing of the distance between the blade and the centerline of the cutting cylinders. To compensate for the increased torsion produced by this alignment, CLE increased the torsion capacity requirement of the redesigned blade carriers.

Improved Frame Designs

After analyzing the loads involved, setting the design criteria, and considering safety factors, CLE began with a collection of preliminary design concepts. CLE did not perform detailed analysis of each concept until the group decided on a final design.

The first concept, shown below in Figure 5, was a four piece frame, with the cylinders placed at a perpendicular angle from the cutting edge of the blades. Rotational ideas for this design were put on hold until all designs were considered. As seen in the drawing, the hydraulic cylinders extend lower than the bottom plane of the blades. This prevents the design from achieving a true flush cut shear as Vassar requested. For this reason, CLE moved on to alternative designs.

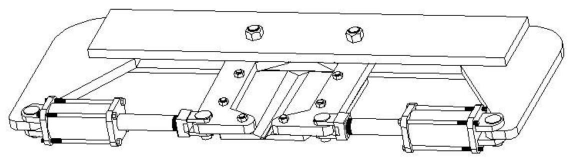

Figure 5: Initial Double Plate C-Shape Frame

Figure 6 illustrates a second design concept consisting of three shear frame pieces. As the figure shows, in the closed position the cylinders are at a perpendicular angle to the cutting edge of the blades. CLE also incorporated rotational capabilities into this design. After CLE presented the alternative design, Vassar had concerns about the angle of the cylinders. CLE was also concerned about the amount of torsion on the blade carriers. As seen in the drawing the blade carriers consist of a single plate that would be limited in torsion resistance. This alternative design was omitted due to the blade carriers and the angle of the cylinders.

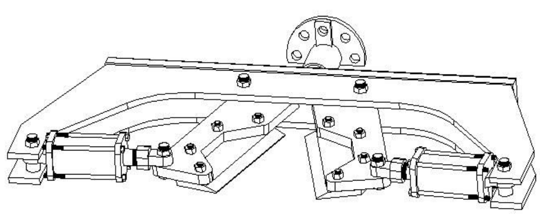

Figure 6: Double Plate Frame Design with Flange Rotation

A four piece frame design is shown below in Figure 7. As with the design in Figure 5, rotational capabilities for this concept were not considered until the group agreed on a final solution. The design met the flush cutting capabilities and reduced the number of parts. A major issue with the design was the single piece blade. As shown the hinge pins on the blade carriers in this design are supported by a single plate, creating a cantilever pin. The plate supporting the pin would require more material to increase its rigidity. Along with the increase in material, the pins would require a larger diameter to support the blade carriers. For these reasons, CLE omitted the concept from a final design.

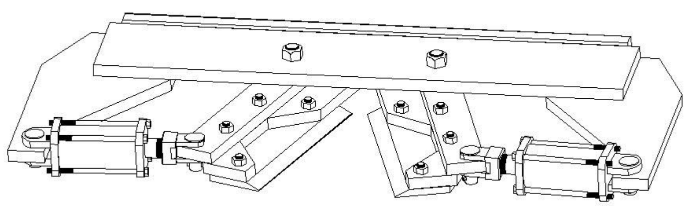

Figure 7: Single Plate C-Frame Alternate Design

A common feature among each of the preceding designs was the angle of the cylinders to the shear blades. When the blades were closed, the cylinders were at a 90º angle to the blades to maximize the force. At this point in the design process, Vassar expressed concern about the possibility of the cylinders shifting position on the blade carriers due to the angle. This concern of "locking up" furthered CLE's decision to change the possible designs to include ram angles less than 90°.

Stress Analysis

After formulating design concepts for the shear frame CLE examined each concept using a computer generated stress analysis. CLE utilized ANSYS Workbench to evaluate concepts through finite element analysis (FEA). Geometries from Pro/ENGINEER were imported directly into ANSYS. The finite element model allowed CLE to identify stress concentrations and modify the design to compensate for the high stress regions. An area on the frame that CLE was concerned with was between the hinge points of the blade carriers. The high torsion in the blade carriers transferred forces into the hinge pins of the blade carriers. The reaction forces on the bottom frame plate resulted in large tensile stresses between the hinges as shown in Figure 8.

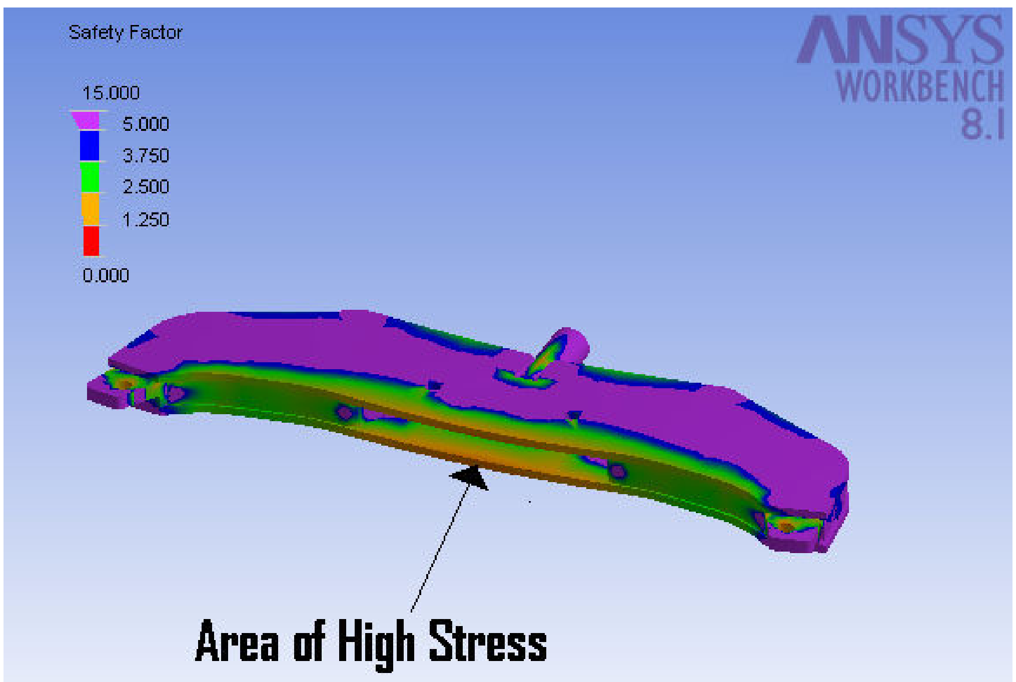

Figure 8: ANSYS frame analysis

Finite element models were analyzed in detail by CLE. Conformation of the models was done by assuming static loading. Stresses were calculated by hand at the cross sections shown in Figure 9 to confirm CLE's findings in ANSYS. These hand calculations showed that ANSYS was typically more conservative than CLE's stress estimates.

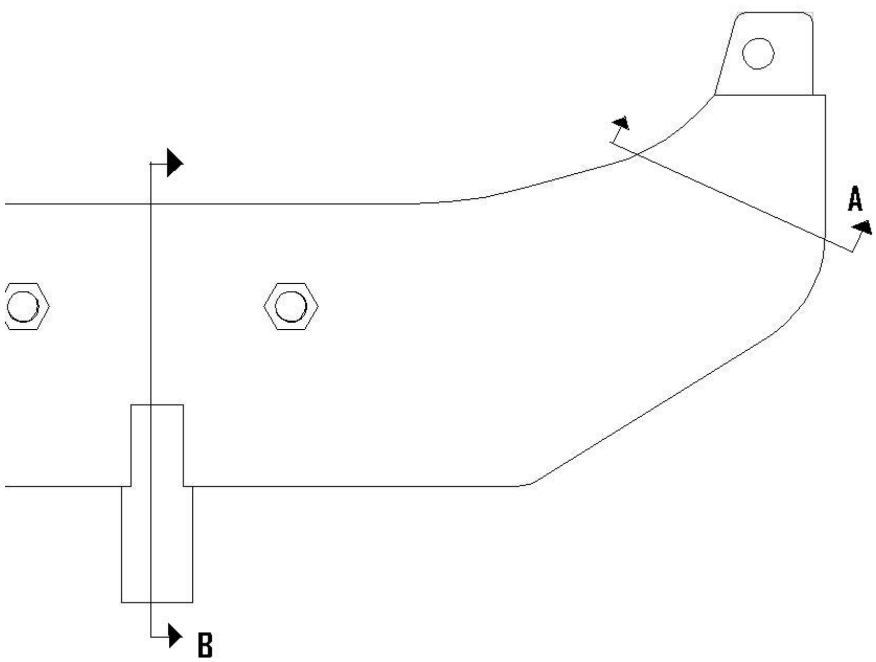

Figure 9: Hand checked FEA cross sections

Determination of Final Design

Figure 10 illustrates the final design that CLE chose. The design met the needs of Vassar. Clam Lake Engineering utilized Pro/ENGINEER to formulate these new designs. The Pro/ENGINEER drawings will also be valuable to the Vassar Company in the future, should they choose to change any aspects of the shear.

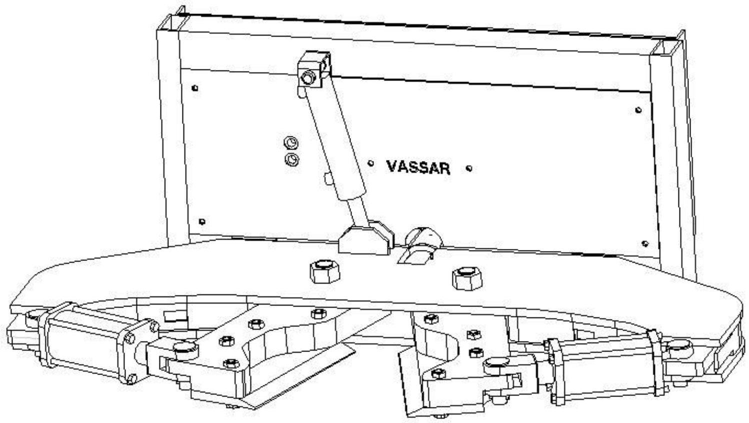

Figure 10: Redesign of Vassar SS-4 tree shear

Rotation

The rotation mechanism chosen is a 2” cylinder with an 8” stroke mounted to the frame that attaches to the right side of the shear, as seen in Figure 10. The problem of having only one hydraulic remote to run both the shears and the rotation cylinder was overcome by installing a 6-way, 2-position hydraulic valve on the back of the shear. This will enable a user to switch between the rotational cylinder and the shearing cylinders with the flick of a switch. It will also enable Vassar to offer a non-rotational tree shear option easily with the removal of the cylinder and direct welding of the shear head to the frame.

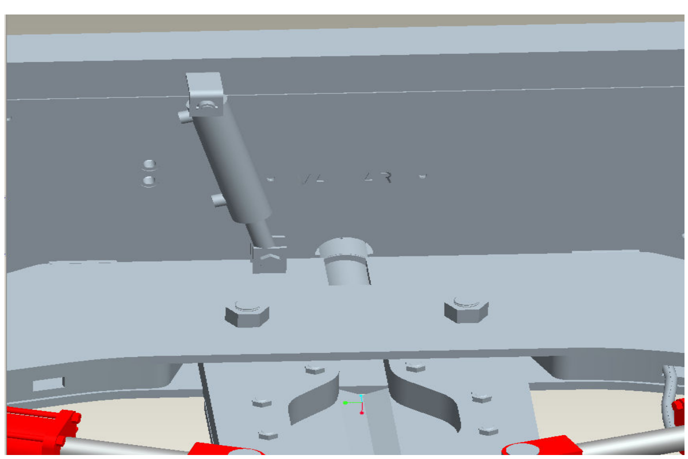

Figure 11: Rotation Cylinder

CLE intended to use DOM tubing for the prototype of the final design. When visiting with Vassar, Mr. Kimmel informed the team the company uses 4.5” O.D. seamless pipe with a 0.5” wall. Due to the small quantity of DOM tubing required for the prototype, the seamless pipe Vassar had in-house was used as the collar for rotation. The shaft for rotation was formed from a solid piece cold rolled carbon steel (Figure 12). For production purposes, DOM tubing would be used in place of the seamless pipe and solid round stock.

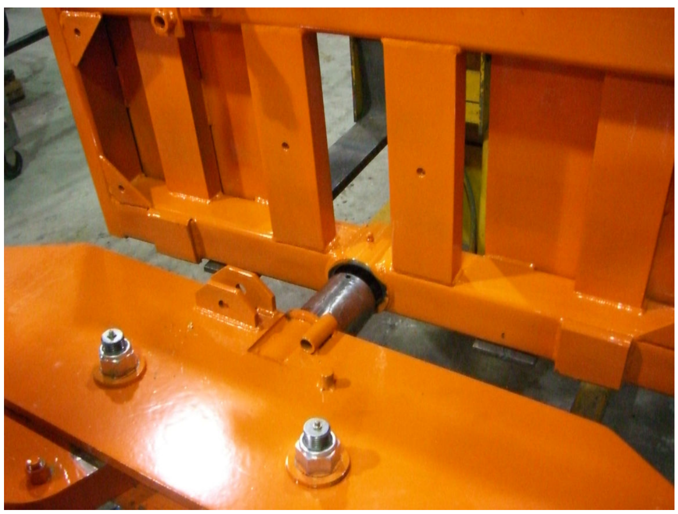

Figure 12: DOM Tubing for Rotation

Frame

After analyzing the possible designs, a frame design was chosen. The frame design utilizes two parallel C-shaped plates with the blades and hydraulic cylinders between them (Figure 13).

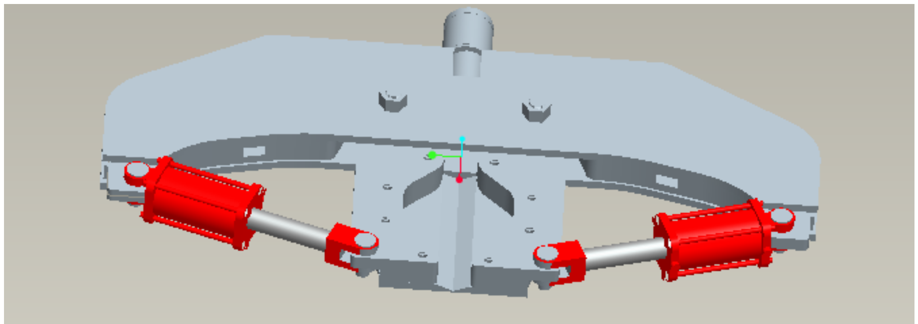

Figure 13: Double Plate C-Frame Final Design

Modeling was conducted in ANSYS software to determine the amount of strain being placed on the plates. Although the group attempted to use ½" thick plates for the final C-Frame, the design was returning a safety factor of only 1.25 on the lower plate and at areas close to the cylinders on the top plate in the software. The shear was then upgraded to ¾" material to increase durability and to give satisfactory safety factors. Also, the placement of the cylinders was reduced slightly from a 90^{o} angle to a 70^{o} angle to decrease the stress being placed on the cylinder mounts. This will also prevent the cylinders from locking on the blade carriers by reversing the arc that is intended for travel.

Flush Cutting

Flush cutting was achieved by attaching one end of the hydraulic cylinders to a one-piece cylinder mount that is welded to the frame. The clevis-end of the cylinder attaches to a one-piece blade carrier with the blades bolted to the bottom. The company prefers making these pieces out of one part because it increases the simplicity of making the part while maintaining a greater strength as well.

Manufacturing

Figure 14: Assembled Tree Shear

The frame pieces, blade carriers, blades, name plate, and skid steer mount were all cut out using the Vassar Company's flame table in Perkins (Figure 15), while all welding was performed at the Biosystems Lab. The Vassar Company also provided the two shear hydraulic cylinders and bolts. Painting was also done at the Biosystems Lab.

Figure 15: Blade Carrier Being Cut Out on Vassar Flame Table

Issues

A difficult aspect of construction of the tree shear was forming the 3/8" metal for the frame. It had to be welded in place and then bent to shape along the contour of the frame. Also, the holes for the shears were drilled slightly off center on the frame, so the blade carrier holes were drilled approximately ¾" off of the original plan to compensate for the misaligned holes.

Costs

A breakdown of the estimated costs of manufacturing and materials is shown in Table 1. Testing costs were not included in this table because they were one time costs that would not affect the retail price of the machine.

Table 1: Cost Breakdown

Item	Cost
Hydraulic Cylinders	$300
Control Valve	$182
Fabrication	$450
Metal	$1000
Misc. Small Parts	$500
Total	**$2,432**

Testing

Testing of the tree shear was performed at the Biosystems Laboratory on the Oklahoma State University campus, at the farm of Robert Harshman, and at the OSU ARS Hydraulic Lab. The first trial run of the tree shear was conducted on April 10, 2007. A machine stand was constructed for the purpose that enabled the team to use 5 ½" diameter treated lumber posts for the demonstration. The post was sheared cleanly, as seen in Figure 16.

Figure 16: Cut test post

On April 11, CLE traveled to the farm of Mr. Harshman with a rental skid steer for more extensive testing on Eastern Red Cedar trees and dense Blackjack Oaks. A problem was soon encountered when the rotation cylinder was actuated. The cylinder extended too quickly, resulting in the shear head rotating almost instantaneously and striking the floor of the Biosystems Lab. After the shear was returned to the original position, CLE discussed the problem with Mr. Kimmel from the Vassar Company and Dr. Weckler from the Biosystems program. They concluded that the cylinder needed orifices at the ports, but none were available at the lab so the team proceeded to conduct the tests without rotating the shear head. Figures 17 and 18 illustrate the operation of the shears in the standing timber at the farm.

Figure 17: Testing Shear on Blackjack Oak

Figure 18: Testing Shear on Eastern Red Cedar

On April 20, 2007, CLE performed a test on the rotation capabilities of the tree shear with a 0.032" orifice installed on the hydraulic cylinder inflow line. The orifice was sized with the following equation taken from a fluid power designer's manual.

Equation 1: Pressure drop across an orifice

$$\Delta P = \left(\frac{GPM}{23.5 * A} \right)^2 \quad \text{(Womack, 1999)}$$

The cylinder successfully rotated the shear head at a controllable speed. The shear head was able to rotate 90 degrees in approximately 3 seconds. As Figure 19 shows, CLE did not encounter any problems rotating the shear head and using the hydraulic valve to operate the blades while the shear was rotated. A second orifice was installed to further slow rotation.

Figure 19: Testing Shear Rotation

Final Recommendations

Consultation with the Vassar Company following testing resulted in CLE offering the following final recommendations for commercial production of the tree shear:

- Modify the angle of the skid steer mount
- Change the cover plate to increase blade visibility
- Shorten or reroute the hydraulic lines to prevent line pinching
- Offer a non-rotational model utilizing the same frame
- Shield the hydraulic lines

While the redesigned tree shear is currently fully functional, Clam Lake Engineering believes that the implementation of these design suggestions would further enhance the usefulness and durability of the implement. Overall, the prototype produced by Clam Lake has met and exceeded the Vassar Company's expectations.

References

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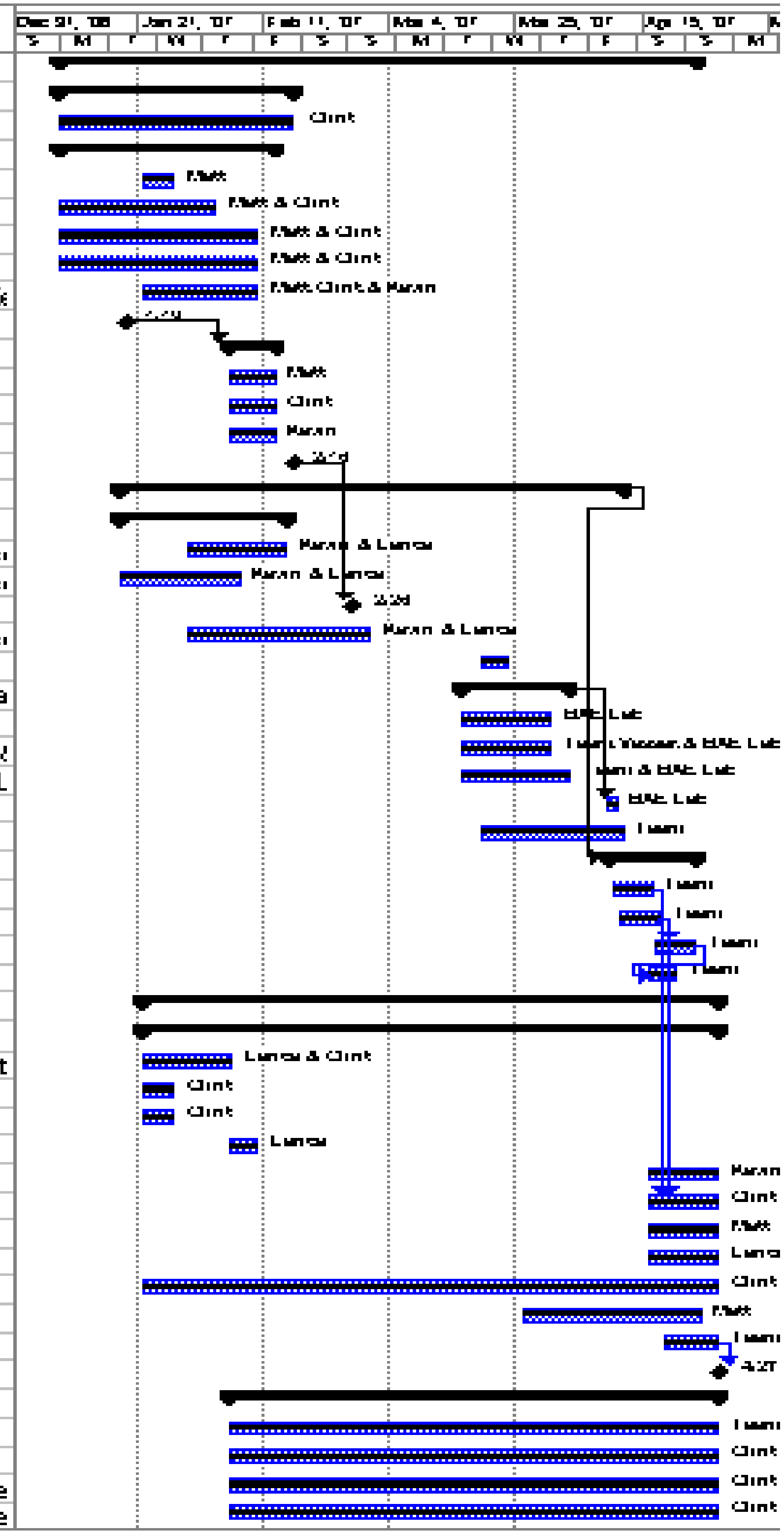
Appendix A. Gantt Chart

Task Name	Duration	Start	Finish	Predecessors	Resource Names
Finish Tree Shear	76 days	Mon 1/8/0	Mon 4/23/0		
Finalize Design	29 days	Mon 1/8/0	Thu 2/15/0		
Route Hydraulic Lines	29 day	Mon 1/8/0	Thu 2/15/0		Clint
Set Dimensions	26 days	Mon 1/8/0	Mon 2/12/0		
Ram Angles	5 day	Mon 1/22/0	Fri 1/26/0		Matt
Pin Diameters	20 day	Mon 1/8/0	Fri 2/2/0		Matt & Clint
DOM Tube Thickness	25 day	Mon 1/8/0	Fri 2/9/0		Matt & Clint
Frame Width	25 day	Mon 1/8/0	Fri 2/9/0		Matt & Clint
Rotation Mechanism	15 day	Mon 1/22/0	Fri 2/9/0		Matt, Clint, & Ke
Meeting With Vassar	0 day	Fri 1/19/0	Fri 1/19/0		Team
Make Drawings	6 days	Mon 2/5/0	Mon 2/12/0	10	
Rotation	6 day	Mon 2/5/0	Mon 2/12/0		Matt
Blades	6 day	Mon 2/5/0	Mon 2/12/0		Clint
Frame	6 day	Mon 2/5/0	Mon 2/12/0		Kevin
Deliver Drawings to Vassar	0 day	Fri 2/16/0	Fri 2/16/0		Team
Build Prototype	60 days	Thu 1/18/0	Wed 4/11/0		
Find Bought Parts	20 days	Thu 1/18/0	Wed 2/14/0		
Hydraulic Rams	13 day	Mon 1/29/0	Wed 2/14/0		Kevin & Lanc
Flow Splitter Valve	14 day	Thu 1/18/0	Tue 2/6/0		Kevin & Lanc
Deliver Drawings to BAE Lat	0 day	Mon 2/26/0	Mon 2/26/0	15	Team
Order Parts	23 day	Mon 1/29/0	Wed 2/28/0		Kevin & Lanc
Spring Break	5 day	Mon 3/19/0	Fri 3/23/0		
Assemble Parts	12 days	Fri 3/16/0	Mon 4/2/0		Team & Vassa
Frame	11 day	Fri 3/16/0	Fri 3/30/0		BAE Lab
Blades	11 day	Fri 3/16/0	Fri 3/30/0		Team, Vassar, &
Rotation	12 day	Fri 3/16/0	Mon 4/2/0		Team & BAE L
Paint	2 day	Mon 4/9/0	Tue 4/10/0	23	BAE Lab
Final Assembly	18 day	Mon 3/19/0	Wed 4/11/0		Team
Test Prototype	10 days	Tue 4/10/0	Mon 4/23/0	16	
Bench Testing	5 day	Tue 4/10/0	Mon 4/16/0		Team
Field Testing	5 day	Wed 4/11/0	Tue 4/17/0		Team
Make Alterations	5 day	Tue 4/17/0	Mon 4/23/0	31	Team
Retest Prototype	5 day	Mon 4/16/0	Fri 4/20/0	32	Team
Report and Presentation	70 days	Mon 1/22/0	Fri 4/27/0		
Write Report	70 days	Mon 1/22/0	Fri 4/27/0		Team
Expand Task List	11 day	Mon 1/22/0	Mon 2/5/0		Lance & Clint
Refine SOW	5 day	Mon 1/22/0	Fri 1/26/0		Clint
Customer Requirements	5 day	Mon 1/22/0	Fri 1/26/0		Clint
Look Over Lit Review	5 day	Mon 2/5/0	Fri 2/9/0		Lance
Design Specs	10 day	Mon 4/16/0	Fri 4/27/0		Kevin
Testing	10 day	Mon 4/16/0	Fri 4/27/0	30,31	Clint
Design Changes	10 day	Mon 4/16/0	Fri 4/27/0		Matt
Recommendations	10 day	Mon 4/16/0	Fri 4/27/0		Lance
Gantt Chart	70 day	Mon 1/22/0	Fri 4/27/0		Clint
Parts Book	22 day	Mon 3/26/0	Tue 4/24/0		Matt
Write Presentation	7 day	Thu 4/19/0	Fri 4/27/0		Team
Give Presentation	0 day	Fri 4/27/0	Fri 4/27/0	46	Team
Web Page	60 days	Mon 2/5/0	Fri 4/27/0		
Layout	60 day	Mon 2/5/0	Fri 4/27/0		Team
Home Page	60 day	Mon 2/5/0	Fri 4/27/0		Clint
Members	60 day	Mon 2/5/0	Fri 4/27/0		Clint & Lance
Photo Gallery	60 day	Mon 2/5/0	Fri 4/27/0		Clint & Lance



Clam Lake
Engineering

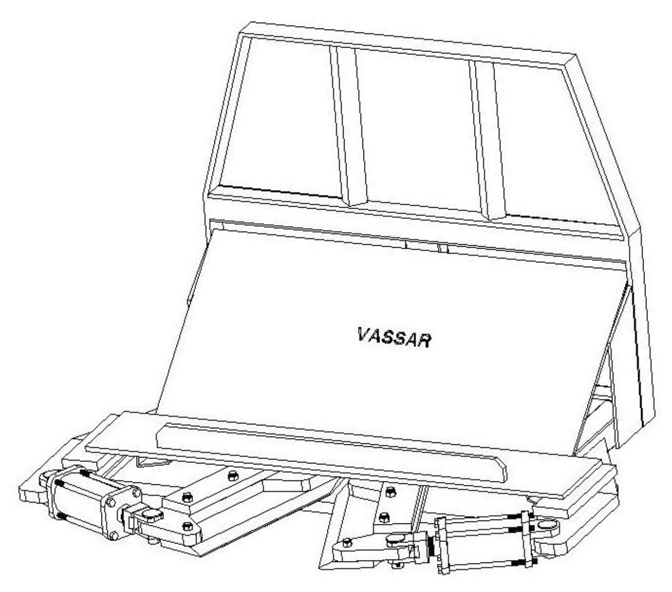
Vassar Tree Shear Project

Clam Lake
Engineering

CL — Clint Cosgrove
Am — Matt Lemmons
La — Lance Klement
Ke — Kevin Taylor

Current Design

- 7, 10, 12, & 16" Shears Currently Available
- Main focus is on 10" (SS-4)
- Frame is stacked steel plates
- No rotational capability
- Blades not flush with ground



Customer Requirements

- Rotation
- Flush Cutting
- Fewer Frame Parts
- More Cutting Force
- Must Retain Brush Guard

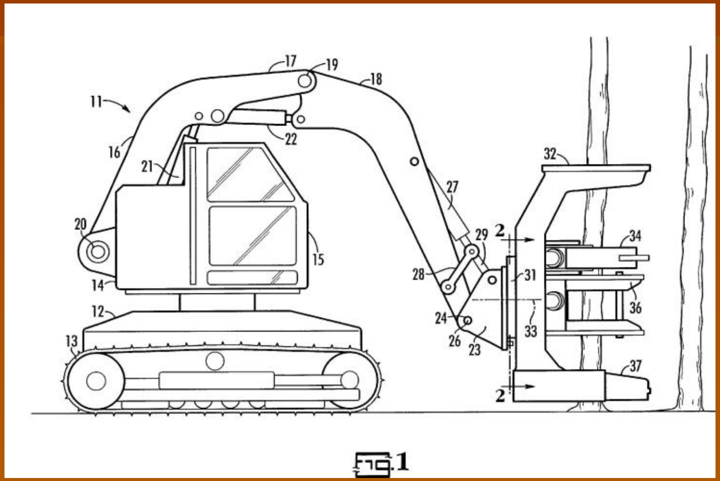
Engineering Specifications

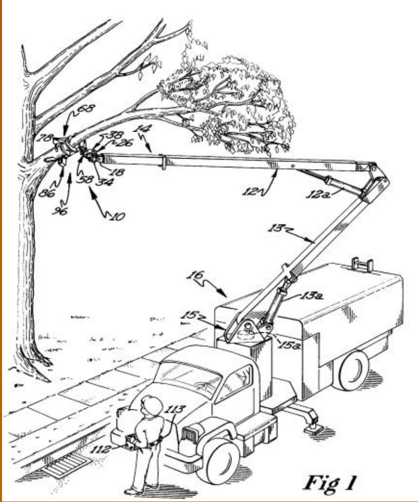
- 1100 lb Maximum Weight
- 3000 psi Maximum Pressure
- 10” Shearing Capacity
- Minimize Overall Length

Patent Searches

Industrial Logging

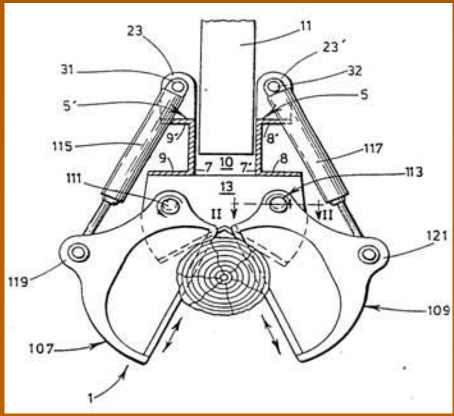
- Focused on Grapple
- More Complex Systems





Other Shears

- “Loppers”
- Oscillatory Motion



The Competition

<u>Grace Manufacturing</u>

- Frame is not curved
- Cylinders Angle Near 45º
- No rotation

<u>Skid Steer Solutions</u>

- Only uses one shear blade
- Hydraulic Rotation
- Inefficient Cylinder Angle

Rotation Selection Criteria

- Low Rotational Speed
- Must Support Shear Weight
- Minimize Cost
- Ease of Manufacturing
- Utilize Only Existing Hydraulics

Rotation Design Options

- Bearings
  - Expensive
  - Require Low Tolerances
- Drive Rollers
  - Low Strength
- DOM Tubing
  - Almost Unlimited Variation in Sizes
  - Appropriate Wall Thickness
  - Cost Effective

Rotation Design Options

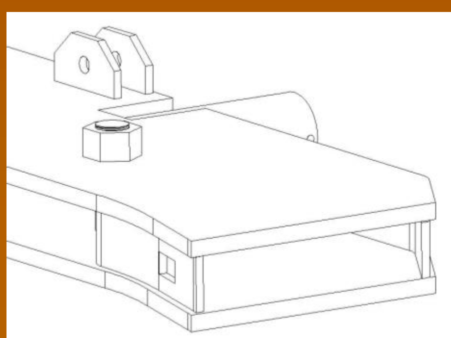
- Manual vs. Hydraulic
- Orifice
- Pressure Relief Valve
- Selector Valve

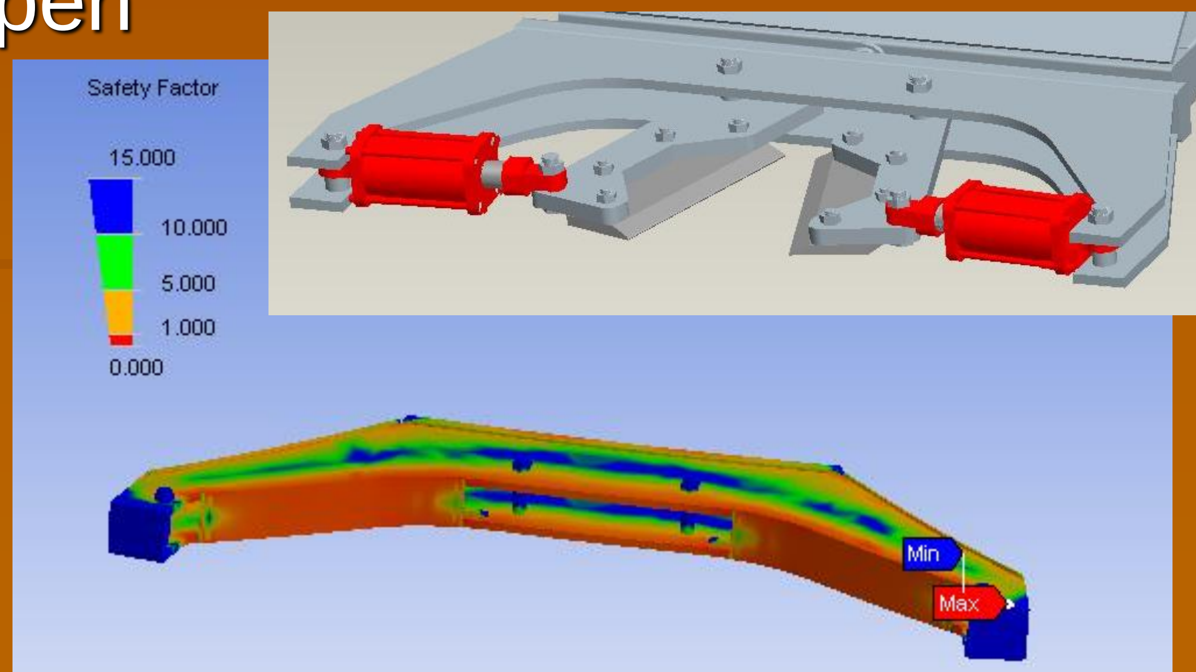
Frame Design Criteria

- Safety Factor Above 1.5
- Fewer Parts
- Minimize Weight
- Minimize Manufacturing Time

Frame Design Options

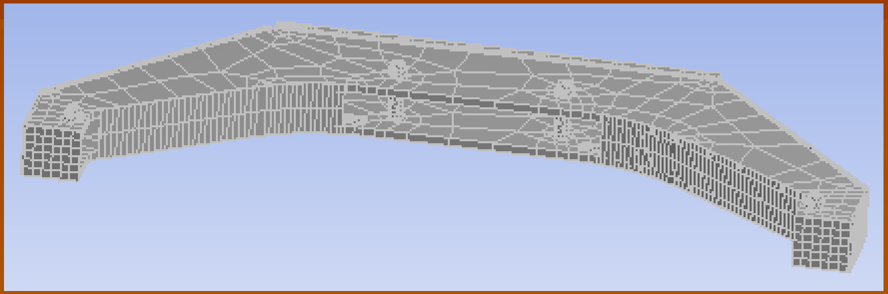
- Ram Angle
- Smooth or Angled Edges
- Boxed or Open

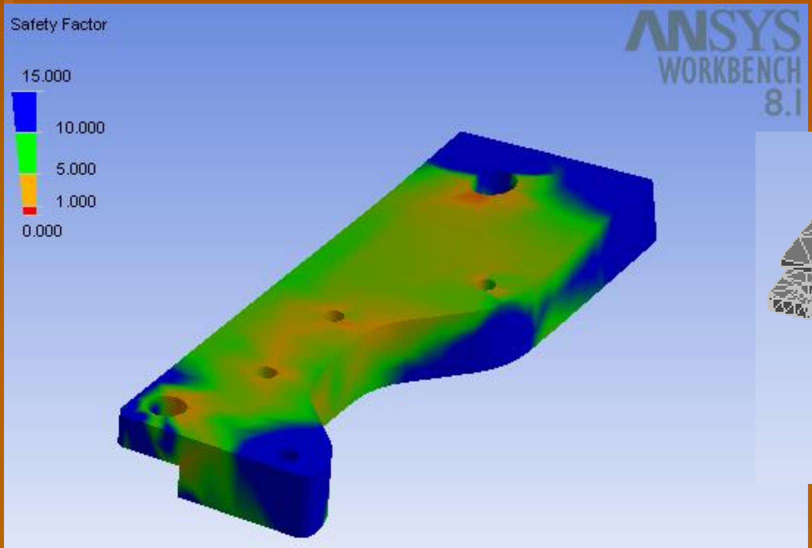


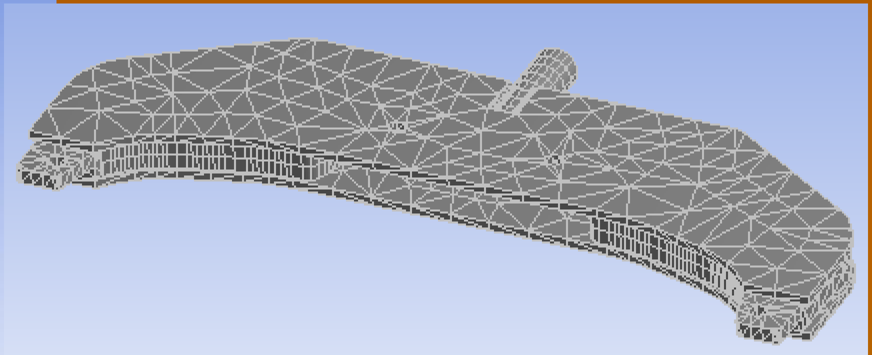


Frame Design Options

- Plate Thickness
- Frame Width
- Cut vs. Welded Parts





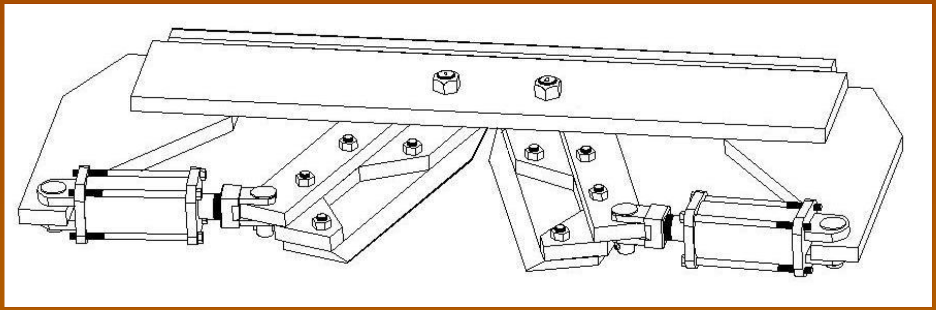


Flush Cut Design Criteria

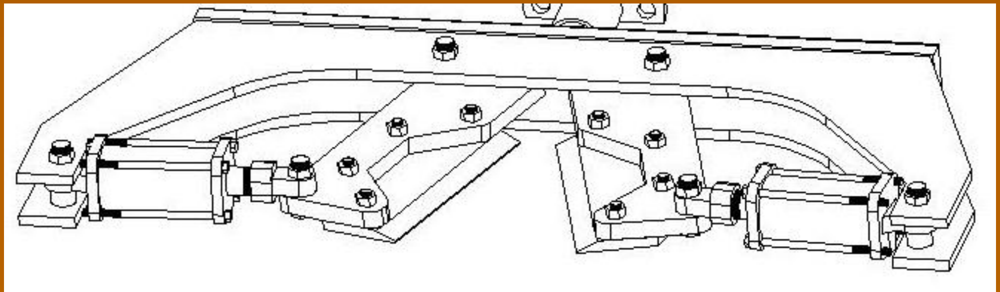
- Blades Flush With Ground Level
- Minimize Cost
- Provide a Smooth Cut

Flush Cut Design Options

- Remove Bottom Frame Plate



- Cut Shorter Blades

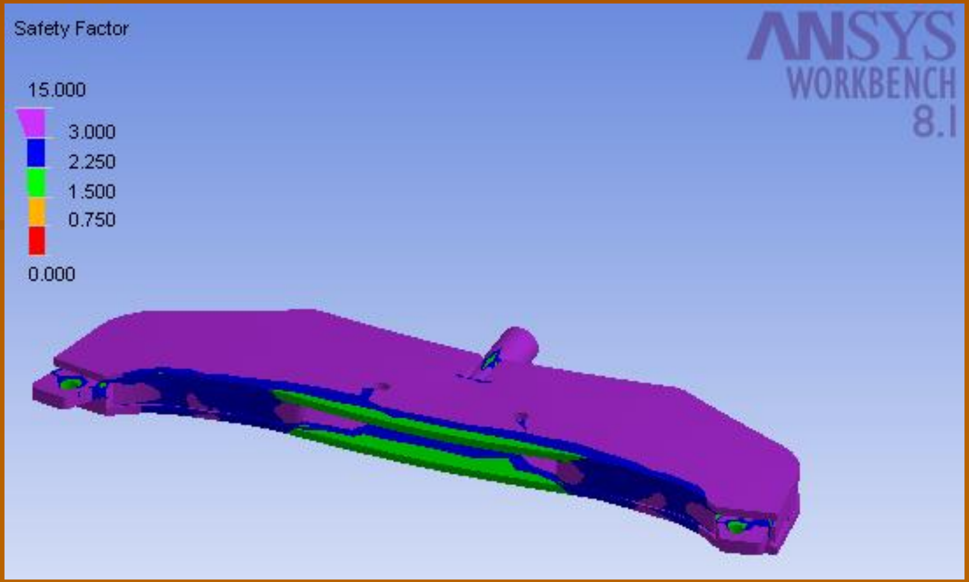


Conclusions

- Rotation
  - Hydraulic
  - DOM Tubing
  - Orifice Flow Control
- Flush Cut
  - Shorter Blades
  - Thicker Blade Carriers

Conclusions

- Frame
  - Boxed Frame
  - 0.75” Plates, 0.375” Sides
  - Smooth Curves



Testing

Lab Testing

Field Testing

Testing

Cost

Projected

Item	Cost
Hydraulic Cylinders	$300
Control Valve	$125
Metal & Fabrication	$3400
Misc Small Parts	$200
Total	**$4,115**

Actual*

Item	Cost
Hydraulic Cylinders	$300
Control Valve	$182
Fabrication	$450
Metal	$1000
Misc Small Parts	$500
Total	**$2,432**

*Minus Testing Costs

Recommendations

- Reroute Hydraulic Lines
- Increase Blade Visibility
- Offer Non-Rotating Model
- Shield Exposed Hydraulic Lines

Acknowledgements

- The Vassar Company
- Larry Kimmel and Jack Vassar
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- Dr. John Solie
- H. Clay Buford, P.E.
- Wayne Kiner
- Ron Dahlgren
- Pioneer Equipment Rental
- BAE Lab Staff
- Robert Harshman

Questions

Vassar Company Tree Shear Redesign

Proposed By Clam Lake Engineering

Team Members:

Clint Cosgrove

Matt Lemmons

Kevin Taylor

Lance Klement

Table of Contents

Introduction to the Problem

A recent explosion in the number of Eastern Red Cedar trees has led many landowners and farmers to research different control methods against this exponential growth. Many options exist, such as controlled burning or tree saws. Tree shears provide an alternative to burning or sawing.

Most tree shears work with basic mechanical principles. One or two hydraulic cylinders close blades in a scissor-like motion to sever trees. Various products on the market have adapted this design for different uses, such as rotational movement, tire cutting, and tree moving. Tree shear manufacturers are being forced increase the capabilities of their products in order to remain competitive.

Statement of Work

The Vassar Company of Perkins, Oklahoma requested Clam Lake Engineering (CLE) redesign their current tree shear. Clam Lake Engineering (CLE) contacted The Vassar Company and was provided with requirements for the new tree shear design. The new design starts with a definition of the project. To help define the project parameters, CLE split the details into two sections: New Features and Limitations.

New Features

The Vassar Company communicated several new features they feel would make their tree shear competitive. These features include ideas that focus on the consumers' needs, reduce the manufacturing costs, and improve the overall capabilities of the shear. After visiting with Larry Kimmel, manager, and Jack Vassar, owner, the new features of the Vassar tree shear are comprised of three major changes: rotational capabilities, a more efficient frame design, and the capability to make flush cuts.

Rotation

The Vassar Company requested a rotational feature on the new tree shear design prior to CLE's site visit. The Vassar Company currently produces a Model SS-4 shear with a 10" diameter cutting capacity. The company specified that rotation of Model SS-4 shear for shearing limbs would be preferred. The size of the shear is a main reason for wanting rotation on the model specified. Safety concerns arise with applying a rotation feature to a larger capacity shear. Vassar felt cutting branches over 10" in diameter presents the potential of injury from falling objects. The company also requested that the design be manually operated, because most client vehicles operate with only one remote hydraulic circuit. Vassar did not apply any other requirements to the rotation feature. Therefore, the type of rotation is left to CLE's discretion.

Frame Design

During the site visit to The Vassar Company, they informed CLE that they are seeking a new frame design. Currently, the Vassar Company produces the basic shear frame from eleven pieces of heavy gauge steel. Considering the production process for the frame, eleven main components is an excessive number of pieces. Many of these pieces can be merged into single larger pieces. Simplifying the frame entails two major changes: minimizing parts and reshaping the frame to align the cylinders with the blades. The current frame model places the shearing blades at an acute angle from the cylinders. Frame design placing the cylinders at a right angle from the blades maximizes the full force the hydraulic cylinders can produce on the tree. A redesigned frame could be applied to every model of the Vassar tree shears.

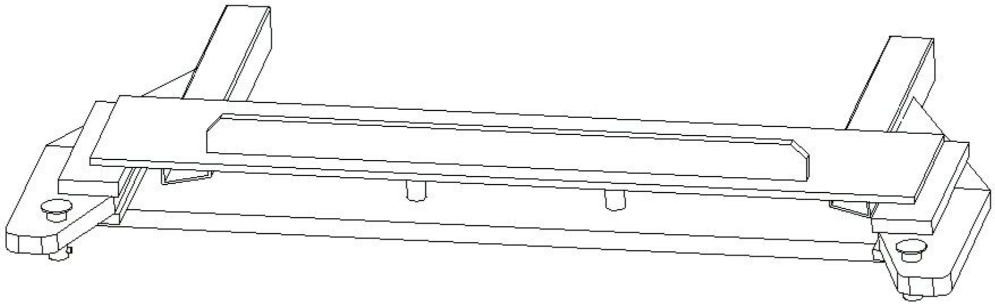

Figure 1 .Wireframe drawing of Vassar SS-4 tree shear frame

Flush Cutting

Vassar stated that the new tree shear design requires flush cut capabilities. Their customers have voiced their desire for flush cut capabilities many times. A flush cut allows the user to drive over the stump later without damaging equipment. Manager of The Vassar Co., Larry Kimmel, stated that the current shear allows flush cut, but the process includes driving the shear below ground level and cutting the trunk of the tree below the ground. Allowing the blades to sit directly on the ground will enhance the appearance of the shear to the costumer. Mr. Kimmel stated that seeing the blades sitting directly on the concrete at a farm show would work to Vassar's advantage.

Limitations

Many factors limit the design of the new Vassar tree shear. Clam Lake Engineering realizes the limitations set forth and intends to apply the limitations to evaluate solutions. Vassar set some constraints which the new design must follow, and some inferred by CLE. Below is a list of limitations known to CLE at this time:

- Weight of new design Model SS-4 is to be between 1000-1100 lbs
- The mounting hardware and brush guard must remain the same as the old design
- The new design must be competitive in cost
- Operation of the new design must be performed by one hydraulic circuit
- The shear must remain easily maintainable
- The new design must conform to the set hydraulic pressure of 2000 to 3000 psi
- Hydraulic cylinder bore should be the same as previous designs

CLE produced the list of limitations above to aid in the design process of a new tree shear. During the visit to Vassar, Mr. Kimmel requested the weight of the new tree shear to remain in the range of 1000-1100 lbs. The weight limitation is assumed to be set forth by the skid steer capacity. By remaining under a set weight limit, customers owning a smaller size skid steer would be able to use the implement. The limitation of maintaining the same design on the rear portion of the shear was set by Vassar. A new tree shear containing many advanced features may seem appealing, but cost must stay competitive. Vassar prefers to remain as cost effective as possible. A limiting factor on the equipment Vassar targets for use of its shear is the number of hydraulic circuits. Clam Lake Engineering favors using only one hydraulic circuit for operating the newly designed tree shear because many smaller skid steer loaders only have one auxiliary hydraulic circuit. Vassar mentioned the preference of retaining the same cylinder size for the new shear. Operating pressure should only be an issue if CLE realizes potential for making the tree shear more cost effective by downsizing the hydraulics.

Research Plan

Research for the Vassar tree shear project will be comprised primarily of modeling, simulation, and literature review. Some physical experiments may need to be done, but none have been foreseen at this time. The Vassar tree shear's basic design has been thoroughly field tested by Vassar and is satisfactory. The scope of this project is to optimize Vassar's existing product without compromising its quality. CLE feels that no initial physical testing will be required to meet Vassar's needs. CLE will instead focus on literary research and concept generation during this phase of development.

Modeling

CLE believes that a computer model of Vassar's current tree shear will aid us in redesigning it. A ProEngineer model of Vassar's ten inch tree shear has been developed from measurements of a tree shear the team has on loan from Vassar. All measurements were taken in the BAE lab using lab equipment such as measuring tapes and Vernier calipers. Now that CLE has an accurate model, the team can make changes to it and predict the system impact the changes might have. This allows for a much more interactive design approach.

Figure 2 . ProE model of Vassar SS-4

Simulation

Clam Lake Engineering will simulate the effects of our modifications using computer simulations. Since the team will be designing in ProEngineer, the natural choice for simulation software is Mechanica. CLE can import our models directly into Mechanica and apply virtual loadings to them. The team will attempt to simulate the loads placed on the system by both shearing and running into trees. This data will assist us in optimizing the Vassar tree shear. Input data for our simulation will be developed from information provided by Vassar about the operating conditions of their tree shears. CLE will require the use of university vehicles to travel to and from Perkins for meetings and to procure a working model of the current tree shear.

Literature Review

Clam Lake Engineering chose to focus on patent searching and reviewing the designs of other manufacturers for the literature review portion of this project. After several weeks of searching, the team found six patents and three manufacturers. Below are brief descriptions of each and an explanation of their relevance to the Vassar project.

Patent Number 6,435,235

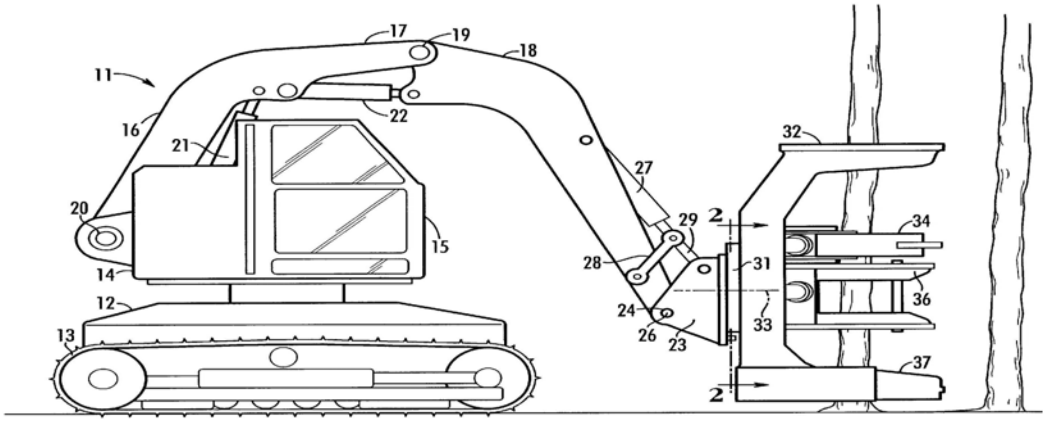

Figure 3. Image of patent number 6,435,235

The US Patent number 6435235 is for a rotation system for a forestry tree shear consisting of a large diameter ball bearing and an internal actuator for rotating the feller head on the end of a boom (Hicks, 2002). Rotation design also includes a spring actuated, hydraulic release disk brake. The bearing consists of two races. One race fits inside the other race and a groove is formed on the inner surface of the outer ring and outer surface of the inner ringforming a guide for the spheres of the bearing. The outer race is attached to the feller head while the inner race is bolted to the boom. Outside the outer race is a vane assembly. The vane assembly makes up the actuator for rotation. A single vane is projected radially outward from an inner ring attached to the boom. A ring attached to the feller head fits around the vane with a groove on the inner surface to allow radial movement of the vane. 180 degrees from the vane around the ring are two ports. Ports open into a block fitting into the groove and open on opposite sides of the block allowing hydraulic pressure to be applied to either side of the vane. Axial rotation of the feller head is made up of the bearing assembly and the vane assembly. To prevent movement of the feller head, a disk type brake applies a normal force on each side of a disk attached to the ring with the groove of the vane assembly. Frictional forces from the brake assembly attached to the boom prevent any axial movement of the feller head. Hydraulic pressure releases the brake and spring force actuates the brake when pressure is released.

Relevance

To infringe on a patent, the new idea must be described by the claims in the existing patent. Infringement on the patent may occur if the rotational component of the Vassar design implements hydraulic rotation. Patent US 6435235 claim 1 describes a bearing with the inner or outer race attached to either a mounting or head structure with the vane assembly described above (Hicks, 2002). Claims 2 through 10 describe the vane assembly as coplanar with the bearing, the vane and groove directions with respect to the axis of rotation, and the mounting of the bearing and vane assemblies. Claims 11 through 13 explain the brake assembly and hydraulic circuit to operate the rotation. Claims 14 through 20 appear to repeat the previous claims with the exception that a tree harvester stated in each claim. Although compact in design and resistant to any obstructions coming in contact with the system the patent referrers to a forestry shear. This patent appears to apply specifically to larger forestry type shears, so a similar concept could be conceivable for the Vassar project if it found to be an economically feasible solution.

Patent Number 6,408,906

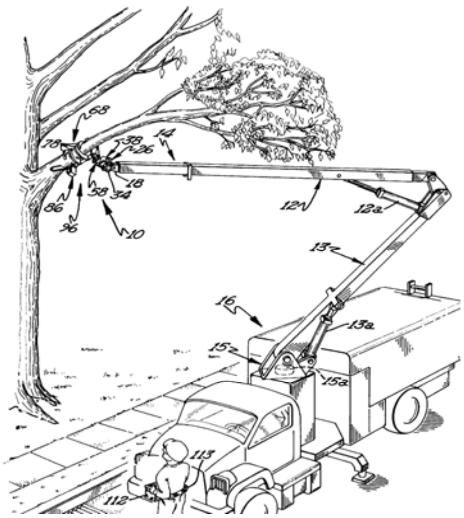

Figure 4. Image of patent number 6,408,906

The US Patent 6,408,906 describes a attachment for a fiberglass boom to trim trees around utility lines (Moon, 2002). The claims describe a rotation apparatus for a gripping and cutting assembly mounted to the end of a tubular boom. This rotation apparatus is rotated by mounting the gripping and cutting assembly directly to a hydraulic motor. One end of the motor is mounted to the boom and the rotating end of the motor is mounted to the cutting or gripping assembly.

Relevance

Claims 9 through 13 describe the rotation component (Moon, 2002). The claims refer to the gripping and cutting assembly being mounted on a tubular boom via the rotation assembly. The new Vassar tree shear may infringe on the patent only if using hydraulic or electrical power to provide for rotation. There are two major differences between the cutting systems the rotation components are applied to. The first is the claims refer to the system being mounted on a tubular boom. A tubular boom could describe a boom different than the skid steer boom that the Vassar tree shear is used on. The second difference is the claims specify a gripping and cutting assembly. After reviewing the claims on the rotation components of the implement, the patent poses no concern for the new Vassar tree shear design. It has been confirmed that the new Vassar shear design will not include gripping assemblies. US Patent 6408906 poses concern for the new Vassar design only if electrical or hydraulic actuation if found to be the preferable mode of rotation.

Patent Number 5,503,201

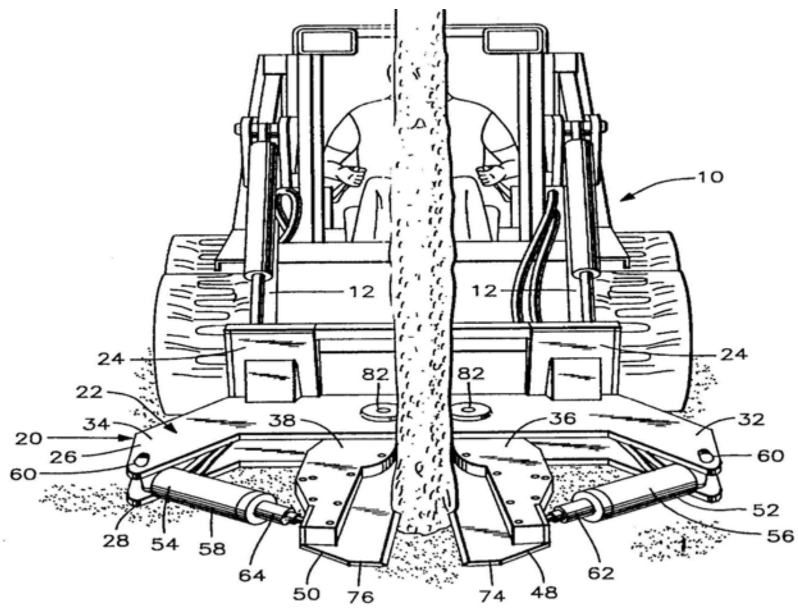

Figure 5. Image of patent number 5,503,201

Dean R. Strickland and Kenneth C. Fobian, of Caney and Havanna Kansas respectively, invented the tree shear of patent number 5,503,201 in 1996. Their tree shear is the basic type that has been copied by many companies. It consists of a one-piece frame with a fluid cylinder pivotally supported on each end of the frame. Connected to the end of the cylinders by ball and socket joint are two pincer-type blades that are also pivotally supported at the frame. The tree shear was designed to be mounted onto a front-end loader with lift arms. Strickland and Fobian also decided to design their hydraulic cylinders with a downward angle of 3.8594° while facing outward. According the patent, the main purpose of the tree shear is to provide a tree shear that is capable of being mounted onto different types of front loader vehicles and used to make a clean ground level cut through a tree trunk.

Relevance

Patent number 5,503,201 is important to Clam Lake Engineering because it is the basic tree shear model and it appeared on almost all of the patent searches for a tree shear. Strickland and Fobian's tree shear is similar to Vassar's tree shear and CLE's new concepts in general. The one-piece frame from Strickland and Fobian is significant because of Vassar's wish to also have a one-piece frame. Where Strickland and Fobian's design begins to differ from our concepts and Vassar's wishes is in the fact that Strickland and Fobian's tree shear does not have the blades directly flush with the ground. The design also does not have any rotation capability. Even though this design is somewhat similar to The Vassar Company's design, the similarities appear purely cosmetic, and not mechanically similar. There should not be any infringement issues from this patent (Solie, 2006).

Patent Number: 4,913,203

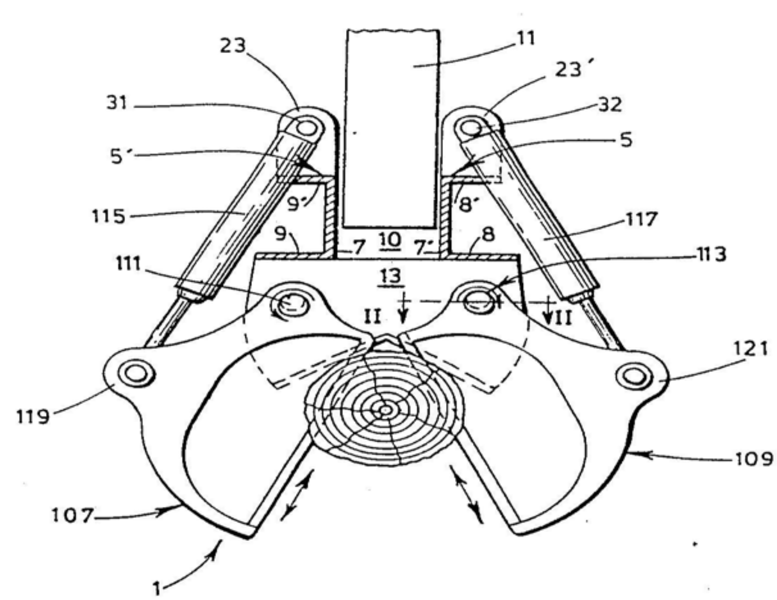

Figure 6. Image of patent number 4,913,203

Michael Lessard, of Lac St. Jean Canada, invented the tree harvester of patent number 4,913,203. Lessard designed his tree harvester to solve the problem he believed tree shears to have. Lessard's tree harvester consists of the basic components such as the frame, cutting blades, and hydraulics cylinders. Lessard also incorporated a grapple to hold the tree trunk, an elongated boom on the frame of the harvester, and an oscillatory motion of the blades. According to Lessard, tree shears caused a crushing damage beyond the shear plane leaving the lower end of the tree damaged. The oscillatory motion that mimics a saw motion is supposed to alleviate that additional damage to the lower end of a tree. Lessard's design also pivots up and down by the axis below the frame.

Relevance

Patent number 4,913,203 is relevant to Clam Lake Engineering in the sense that it represents a few aspects that are undesirable. First, Lessard's design incorporates an oscillatory motion via a motor on a shaft which causes the blades to cut in a saw motion. Vassar indicated they would like to keep the shear cuts used by their tree shears. Secondly, Lessard's design also incorporates a rotational movement about a pivot point by hydraulic means. For design and by the wishes of Vassar, CLE will be incorporating a rotational movement but it will be manual. Lastly, Lessard designed his tree harvester with an elongated boom attached to it. This resulted in a different style of frame for the tree harvester instead of the "C" shape frame that it widely used among tree shear makers. CLE will be keeping the classic "C" shape frame for the design for Vassar.

Patent Number 5,553,993

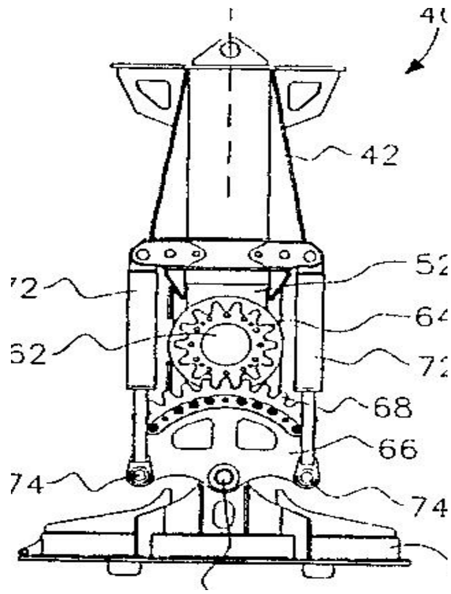

Figure 7. Image of patent number 5,553,993

US Patent 5,553,993 describes Sylvain Gilbert and Michel Taillon's (1996) design for a rotation mechanism for forestry tree shears. The mechanism consists of a rack and pinion arrangement actuated by two hydraulic cylinders. The patent contains seven claims. Claim 1 defines the rack and pinion arrangement. Claims 3 and 4 define the actuation using hydraulic cylinders. Claims 4 through 7 pertain to the tree felling apparatus itself.

Relevance

This design bears a striking resemblance to one of the early designs for rotation of the Vassar tree shear. However, it is clear from the claims in this patent that the patented design is for a "logging vehicle" (Gilbert and Taillon, 1996). While the Vassar tree shear is designed to cut down trees, it is not intended for use in the logging industry and is therefore not part of a logging vehicle. The geometry of CLE's initial design is also vastly different from that of the patented product. Even if the preliminary design incorporates the rack and pinion design, CLE does not feel that US Patent 5,553,993 will pose a problem.

Patent Number 5,318,081

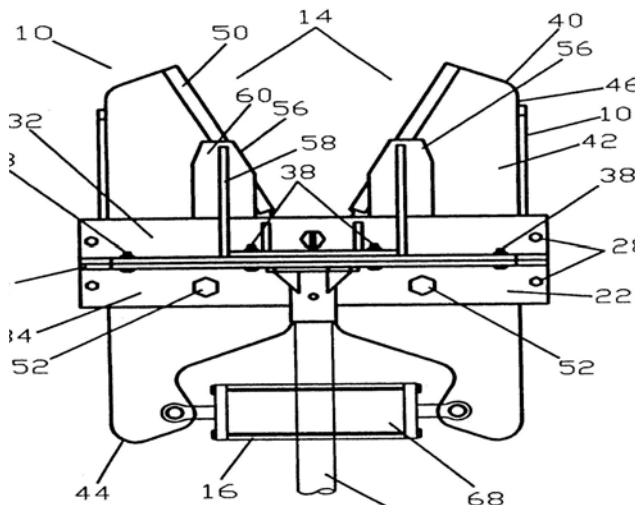

Figure 8. Image of patent number 5,318,081

US Patent 5,318,081 deals with John Parkhurst's (1994) design for a rotatable hydraulic tree trimmer. This design implements a horizontally mounted hydraulic cylinder for actuation of the shearing blades. The shearing mechanism is placed at the end of a long boom. There is a hydraulic cylinder placed at the base of the boom such that it provides a simple means of rotating the shear. The patent contains 13 claims. Claims 1 through 5 describe the actual tree trimmer. Claims 6, 7, 12, and 13 define the rotating mechanism. The remainders of the claims deal with mounting the device to a vehicle.

Relevance

Vassar Equipment expressed a desire to have horizontally mounted hydraulic cylinders on their shear to maximize cutting force. They also showed great interest in a simple rotational mechanism for their shear. This patent goes to great lengths defining and constraining the geometry of the shear. The general shape of Vassar Equipment's tree shears to date has been vastly different from that of the patented shear, so no patent infringement issues should arise from using horizontal cylinders. The rotation mechanism set forth in this patent is specifically for use on a long boom. Vassar Equipment has shown no interest in placing their shear at the end of a long boom as described in this patent. A similar rotating mechanism mounted to a frame rather than a boom should not pose any threat of legal action (Solie, 2006).

Manufacturer Review

Once CLE had a general idea for the goals of the tree shear design, CLE began to search the internet for existing designs. Few companies were found that produced tree shears that resembled basic concepts that CLE is hoping to attain. All of these companies were different enough that there should not be any design or patent infringement.

The manufacturer search began by visiting the Google.com website and searching for hydraulic tree shears. This, along with searching product listings on Ebay.com, gave a wide assortment of companies to choose from that offered skid-steer mounted tree shears. In addition to these methods, leads on locally made tree shears were followed. These proved to be manufactured by the same companies that were found on the internet.

Dymax

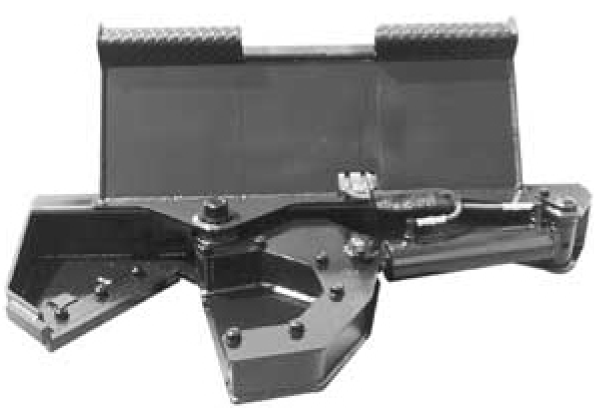

Figure 9. Dymax tree shear (www.dymaxattachments.com, 2006)

Dymax (2006) was the first company that had a website with a hydraulically operated tree shear. The website address was www.treeshear.com, and it offered different models of rotating and non-rotating shears. However, after review of these models CLE noticed inherent design differences, such as a shorter, smaller base. The tree shears that Dymax builds also have cylinders that have an almost parallel alignment with the blades, whereas CLE is looking to design the new Vassar tree shear with nearly perpendicular hydraulic cylinders. After consulting with the company via phone, it was determined there would be no patent infringement on their design.

Grace Manufacturing

Figure 10. Grace Manufacturing (www.treeterminator.com, 2006)

Grace Manufacturing (2006) offered a tree shear that resembled the one Dymax constructed. As before, the frame was much smaller and not as curved as CLE will propose to the Vassar Equipment Company, so it was also determined this company does not pose a patent infringement threat.

Skid Steer Solutions

Figure 11.Skid Steer Solutions tree shear (www.skidsteersolutions.com, 2006)

Lastly, CLE found a hydraulic tree shear with Skid Steer Solutions (2006). This design was vastly different from the ideal proposed design because it used a single moving blade and a stationary anvil/grip. However, the shear Skid Steer Solutions built was relevant because it used hydraulic rotation. The company was very unhelpful as far as giving any patent numbers for their design. After patent searching and reviewing their website,

CLE was unable to find any patents they hold on this design or any patent infringement that would result if a rotating design is chosen that uses a hydraulic cylinder and steel track.

Customer Requirements

As a legitimate engineering firm, Clam Lake Engineering must meet the needs of their customers. Customers include both The Vassar Company and their clients as well. As a progressive engineering company that views the big picture, Clam Lake aims to design with The Vassar Company and their customers in mind.

The Vassar Company requires a newly designed tree shear with the capabilities to rotate and a frame requiring less effort to produce. Both requirements allow the Vassar tree shear to remain competitive in the market. To be competitive, the new features must be offered to the customers at an attractive price. Clam Lake Engineering looked at several possibilities with rotation and has determined keeping the mechanism for rotation simple would be the best approach. Minimizing the number of parts on the frame allows Vassar to produce their shears more efficiently. This would in turn allow to Vassar to offer their product at a better price or increase their profit margins. Many of Vassar's competitors offer rotation as a feature on their tree shears. To remain competitive in the tree shear market Vassar must keep their shear design up to date with their competitor's designs, but not so much as to infringe or copy other designs. Clam Lake intends to make the new features of the tree shear innovative and original.

Some other requirements include the weight of the machine remain under the 1100 lb limit on the SS-4 shear, the brush guard portion of the machine intact during redesign, and the capability to hold up under the maximum 3000 psi hydraulic pressure using the current 4 in cylinder in the SS-4 shear. Vassar preferred the 1100 lb weight limit assuming many of their costumers own equipment that cannot handle loads above the 1100 lb limit. Vassar is satisfied with their current brush guard design and the design of the rear portion of the frame due to the versatility of the mounting surfaces. As advertised, the current Vassar shear operates at pressures up to 3000 psi. The new shear should be designed with this in mind. The new shear must also be cost effective, maintainable, practical in operation, and appealing to the customer. Meeting the above requirements should satisfy both Vassar and their customers.

Engineering Specifications

Based on requirements from The Vassar Company and CLE's engineering experience, the following specifications must be met by the new tree shear. For clarity, the specifications have been broken into three sections: Dimensions, Forces, and Special Considerations. The Dimensions section deals with the physical shape of the tree shear and how its dimensions impact its functionality. The Forces section deals with the stresses imposed on the shear during the tree cutting process as well as the stresses on the rotational joint due to the weight of the implement. Special Considerations covers such things as angle of rotation and user-friendliness.

Dimensions

The new tree shear should be large enough to cut down a ten inch tree but small enough to be mounted to a 30-40 horsepower skid-steer loader. The width of the frame should be such that the horizontally mounted rams have room to contract enough to allow a ten inch tree to fit between the blades. This will mean widening the frame slightly due to the change in ram angle. The length of the implement should be minimized in order to shorten the moment arm acting on the loader. If the new shear becomes too long, the center of gravity could move out far enough to tip over a small skid-steer loader. However, the shear must be long enough to place a ten inch tree between the blades and allow for a rotation mechanism to be placed between the blade frame and the mounting frame. The height of the mounting frame must remain the same as the original design, as per The Vassar Company's instructions not to change the mounting hardware. The height of the blade frame should be minimized in order to save weight while remaining robust enough to meet The Vassar Company's high standards.

Forces

The primary forces acting on the tree shear are the shearing forces imparted on the tree by the hydraulic rams and the impact forces imparted on the frame when an operator runs into a tree. The maximum ram forces have been estimated by multiplying the maximum rated hydraulic pressure of 3000 psi by the bore area of the four-inch rams. This resulted in a maximum force of approximately 40,000 pounds per hydraulic cylinder. The frame and welds must be designed to withstand this loading. The frame must also be robust enough to withstand the impact of a 6,000 pound loader with an 1,100 pound tree shear mounted to it hitting a tree at an estimated speed of five miles per hour (Kimmel, 2006). The resulting impulse is approximately 44,000 lb*ft/s. The impact time is assumed to be on the order of one tenth of a second (www.wikipedia.com, 2006). This leads to a force of 14,000 pounds being absorbed by the frame during impact.

Other Considerations

Other considerations for this design are weight, angle of rotation, and user-friendliness. The Vassar Company has asked that the total weight of the shear be no more than 1,100 pounds. This ensures that the load capacity of the loaders is not exceeded. The members of CLE agree that the optimum angle of rotation is ninety degrees each way from horizontal. This will allow the new shear to trim limbs on either side of a tree utilizing the flush-cut capability of the shear. The shear will also be lockable in other intermediate positions for limbs that are neither horizontal nor vertical. If the new design is not user friendly, it will not be able to compete with other shears on the market. This applies especially to the manual rotation feature. The rotation mechanism must be simple enough that the average user will not need to consult a user’s manual to operate it. The mechanism must also be easy enough to use that an average user can rotate the shear alone. Placing an actuating lever near the edge of the frame and placing the axis of rotation as close to the center of gravity as possible should make the new shear as user friendly as possible.

Task List

The following list contains tasks which must be completed in order to fulfill the requirements of this project.

- Generate ideas
- Model designs
- Rate designs
- Produce drawings
- Deliver drawings
- Analyze designs
    - Rotation
    - Frame
    - Blades
- Present ideas and get approval
- Purchase materials
- Assemble prototype
- Prototype testing
- Produce presentations and reports

Schedule

See Appendix A: Gantt Charts.

Feasibility and Design Criteria

Feasibility analysis will consist of three major components: cost, user-friendliness, and strength. These three criteria must be handled if this is to be a successful project. If a tree shear is not strong, user-friendly, and low cost it will not sell.

Cost

Cost is a major concern for any project. The cost parameters for this project are materials, manufacturing processes, and whether or not parts can be manufactured in-house. Titanium is an excellent material, but its prohibitively high cost would take it out of consideration for this project. Some manufacturing processes cost more than others. If a part can be slightly modified such that it can be cut on a flame table rather than machined, that would make the modified part more desirable. There are some manufacturing processes that simply cannot be performer at Vassar's Perkins facility. Any parts that require CNC machining, for example, would need to be manufactured by a third party.

User-Friendliness

User-friendliness is just as important as cost. If a customer has a bad experience with a Vassar product, that person would be less likely to come back in the future. The new tree shear must be easy to use. The rotation mechanism, for example, should be operable by one person without the aid of an owner's manual. Every feature should be analyzed and a determination of its level of user comfort should be mad. Parts that are determined to be "unfriendly" must be redesigned to make the tree shear easier to use.

Strength

Simply being inexpensive and easy to use is not enough. A tree shear must be strong. Operators of tree shears are notoriously hard on equipment. It is common practice to hit trees at relatively high speeds to decrease the time between trees. With this in mind, a highly conservative factor of safety will be applied to the entire tree shear. Much like the user-friendliness issue, if a customer breaks a tree shear on the first day they are not likely to come back and buy another.

Preliminary Design Concepts

After considering the requirements the new tree shear must fulfill, Clam Lake formulated new designs. The main issue facing Vassar is the problem of rotation. Many of Clam Lake's ideas were formulated after interviewing H. Clay Buford, P.E.. Mr. Buford is an OSU applications engineer who serves small manufacturers in Oklahoma. Clam Lake's solution to the problems of rotation, flush cutting, and improve frame design are discussed below.

Rotation

Initially, both hand-moved and hydraulically actuated rotation systems were considered. One option was a rack and pinion arrangement with a hydraulic cylinder to move a straight rack horizontally over a pinion mounted to the frontal section. Through further discussion of the problem with Larry Kimmel, it was determined that a hand moved system was preferred; therefore, the hydraulic system was put on hold while the team determined more efficient hand-moved designs. Another proposed new idea involved using two pipes with bearings between them. The proposed idea was to utilize severed round stock as the bearings or commercially produced bearings if available. The idea of one large gear powered by an electric or hydraulic motor turning a small gear was also considered. Clam Lake then had an idea of drawn over mandrel (DOM) tubing placed within another tube of slightly larger size and using a flange and pin design to hold the cutting portion of the shear at the desired angle, as shown below in Figure 13.

Flush Cutting

Ideas for flush cutting had to also incorporate frame design. After modeling the system in Pro-E, CLE began to explore different options that would lower the blades. Threaded blade carriers were the first options focused on. Also, making the carriers thicker would possibly lower the blades as well. Another option that CLE thought about was to angle the blades downward. This would enable the blades to visibly be touching the ground when the unit was on a level floor.

Improved Frame Design

The highest priority in the frame design that CLE considered was to ensure that the hydraulic cylinders were as close to a 90º angle as possible. Therefore the first brainstorming session resulted in both a rectangular and two C-shaped design. The team further developed the C-shape, and added another plate that enabled the cylinders to be placed within the two plates. The three C-shape frame ideas are pictured below in Figures 12, 13, and 14.

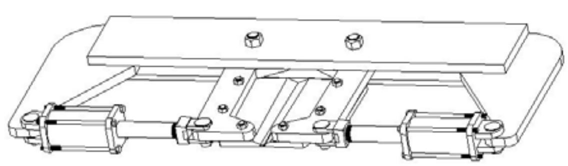

Figure 12. Initial Double Plate C-Shape Frame

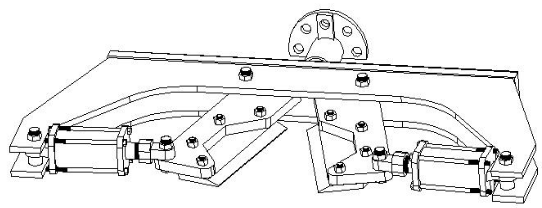

Figure 13. Double Plate Frame Design with Flange

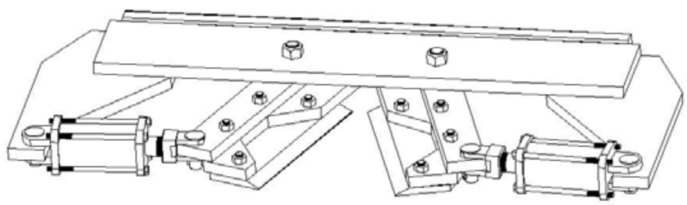

Figure 14. Single Plate C-Frame Alternate Design

Evaluation of Possible Designs

Clam Lake Engineering utilized ProE to formulate new designs. Designs were formed to the specifications above. Although some dimensions possibly require modification and material may be added to the design Clam Lake and Vasser choose to follow. ProE drawings of the previous Vasser Shear proved to be useful as a foundation for new models.

Rotation

Rotation for the new design of the Vassar shear proved to be a challenge for Clam Lake. Rotation mechanisms such as bearings, drive rollers, and shaft-collar type setups were considered. Bearings of the size needed to support the shear are costly. Drive rollers are costly as well, and a single drive roller can only support a small portion of the force produced by the moment arm of the shear weight. After initial research, a shaft and collar type setup could not be found, but when visiting with Mr. Buford DOM tubing was mentioned. DOM tubing comes in many combinations of inside and outside diameters. Due to its versatile dimensions and relatively low price, DOM tubing has become a front-runner in the rotational design concepts.

Frame

The shear frame shown in Figure 13 depicts a three piece frame with the blades on the same plane as the bottom frame plate. An issue arising with this design is the cylinder type. The current Vassar shear utilizes rod-clevis cylinders manufactured by Midway Manufacturing, Inc. Clam Lake Engineering is left with two choices to follow up on the design: search for a cylinder that is compatible with the design or modify the design to use the current rod-clevis cylinder. Single eye cylinders with both a single eye cylinder cap and single eye rod clevis are not manufactured by Midway.

The shear frame shown in Figure 14 in the previous section is a four piece frame with a single eye clevis on the rod end of the cylinder. Issues with the frame include the bolt size on the blade carrier connection to the frame and the stresses on the top plate of the frame. The current shear possesses two plates: one supporting the bottom of the pivot bolt on the blade carrier and the other supporting the top. The concept shown supports only the top of the pivot bolt. Also adding to the stresses is the cylinder alignment with the blade. The rod connection to the blade carrier is offset with the blade, creating torsion on the end of the side plates of the frame. The torsion is transferred to the top plate thus increasing the bending stresses in the top plate.

Determination of Suitable Designs

After analyzing the possible designs two frame designs, one mode of rotation, and one modification for flush-cutting have been chosen. One frame design utilizes two parallel C-shaped plates with the blades and hydraulic cylinders between then, as seen in Figure 13. The other frame design is comprised of a thick top plate with two other plates welded to the sides. The blades on this design are supported by cantilevered pins while the rams attach to the side pieces, as seen in Figure 14. The only strong, cost efficient, user friendly mode of rotation thus far is a tube in tube assembly with a flange and post arrangement to lock in key angles, as seen in Figure 13. The first flush-cut modification was simply to shorten the blades and make them hang below the bottom frame plate of the frame in Figure 12. The other flush cut modification was to simply remove the bottom plate and reinforce the cantilevered pin of the frame in Figure 14.

Projected Budget

Table 1. Projected Material Costs

Item	Unit Price	Qty	Cost
4" Hydraulic Cylinder	$150	2	$300
3 Spool Hydr. Control Valve	$125	1	$125
1" Thick Plate 4'x8'	$832	1	$832
1-1/4" Thick Plate 4'x8'	$1,216	1	$1,216
3"x .5" Strap 20'	$102	4	$408
3"x3"x3/16" Square Tubing 20'	$51	6	$306
Machine Selector Valve, 1/2in.	$90	1	$90
8" Thick Wall Tubing	$100	1	$100
6" Thick Wall Tubing	$100	1	$100
A36 Steel (1'x1')	$220	2	$440
Misc Small Parts	$200	1	$200
		Total	**$4,117**

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Appendix A

Gantt Charts

Clam Lake

Engineering

Vassar Tree Shear Project

Clam Lake
Engineering

CL
Am
La
Ke

- Clint Cosgrove
- Matt Lemmons
- Lance Klement
- Kevin Taylor

Vassar Equipment

- Family Owned
- Located in Perkins
- Vast Array of Products

Tree Shears

- Simple
- Effective
- Safe

Current Design

- Vassar currently offers 7, 10, 12, & 16″ tree shears
- Main focus is on 10″ (SS-4)
- Main frame is ½″ steel plate
- No rotation
- Blades not flush with the ground

History of Customer Service

- Rigorous testing at demonstrations
- Shears withstand much abuse by customers
- Vassar believes in their product, 2/3 cost reimbursement for trade-in upgrades
- Very few failures

Customer Requirements

Frame Rotation

- Manual Rotation

Flush Cutting

- Blades sitting on floor
- Customer appeal

Customer Requirements

New Features

Simplified Frame

- Less parts

- Reshaping frame to align cylinders with blades

Customer Requirements

Limitations

- 10 inch tree shear weight under 1100 lbs.
- Brush guard remain intact
- Withstand 3000 psi hydraulic pressure

Engineering Specifications

Dimensions

- Allow a 10 in tree to fit between blades

- Length of implement must be minimized

- Height of the frame remains the same

Engineering Specifications

Forces

- shearing forces on the tree from hydraulic rams and impact forces

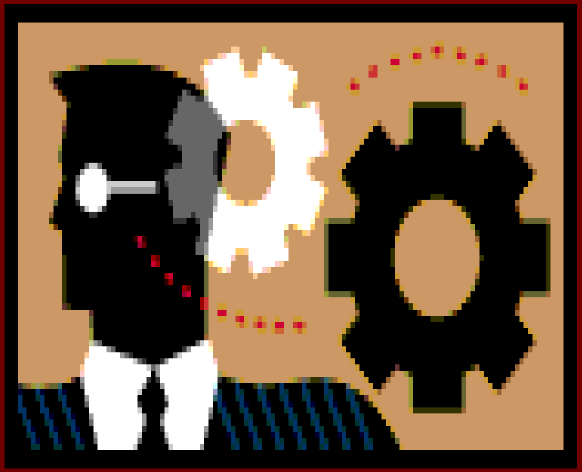
- 40,000 lbs. from rams

- impact loading of 14,000 lbs.

Engineering Specifications

Other Considerations

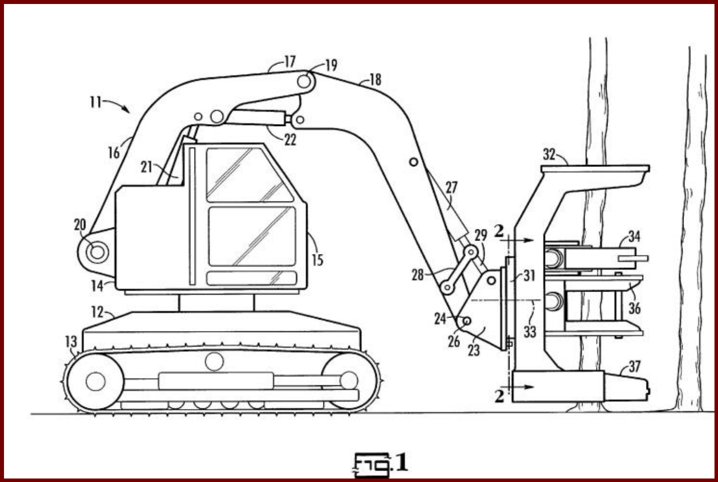
- Weight
- Angle of rotation
- User-friendly?



Patent Searches

Most patents cover industrial logging implements

- Attention is on gripping the tree



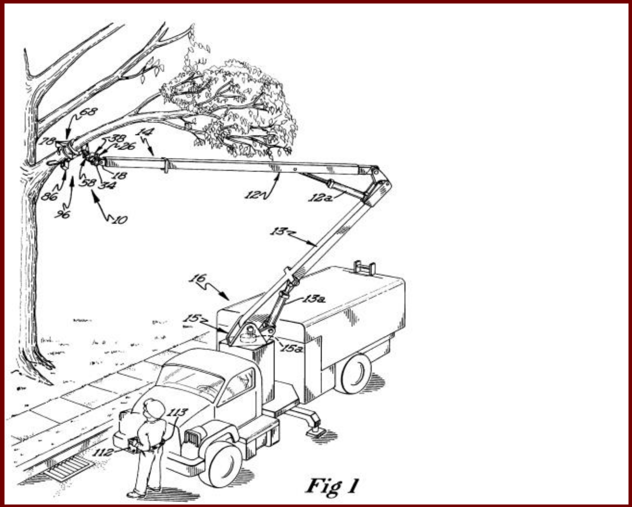
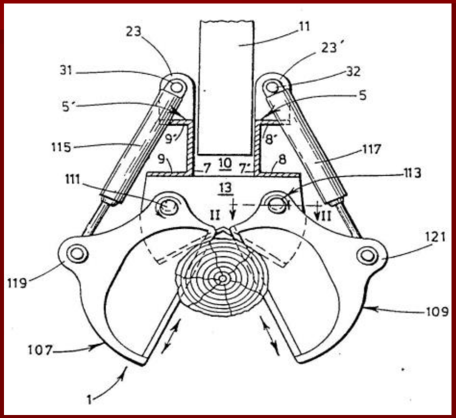


Fig 1

Others covered boom-mounted shears

- These designs were more like “loppers”

Patent Searches

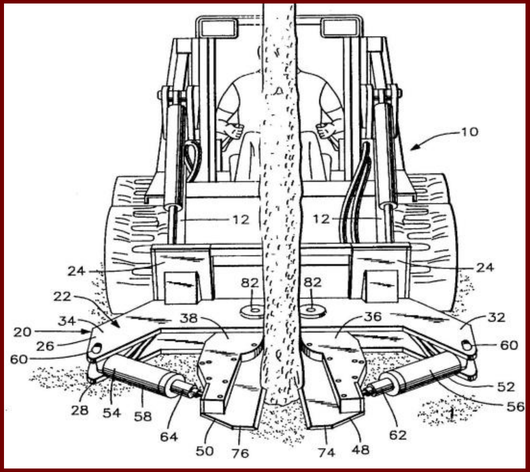


Design uses oscillatory movement

- Cylinder placement and frame shape are much different

Contains a C-shaped frame

- Patent is for blade angle, also does not sit flush with ground



The Competition

Dymax Inc.

- Only uses one shear blade
- May make non-uniform cuts
- Mount is not the same

Skid Steer Solutions

- Only uses one shear blade
- Rotational, but with hydraulics
- No known patents

The Competition

Grace Manufacturing

- Frame is not curved
- Hydraulic cylinders close to 45º
- No rotation
- No patents pending

Cost

- Materials
- Manufacturing
- In House/ Send Out

User Friendliness

- Regular Use
- Maintenance

Strength

- Cutting
- Impact
- Fatigue

Considerations for Rotation

- Requirements
  - Low Rotational Speed
  - Must Support the Shear Weight
  - Low Cost
  - Easily Manufactured

Considerations For Rotation

- Hydraulic/Electric Rotation
  - Rotation with a hydraulic cylinder
    - Rotation with a rack and pinion
    - Rotation with an lever arm
  - Rotation with a hydraulic/electric motor

*All require more than one hydraulic circuit

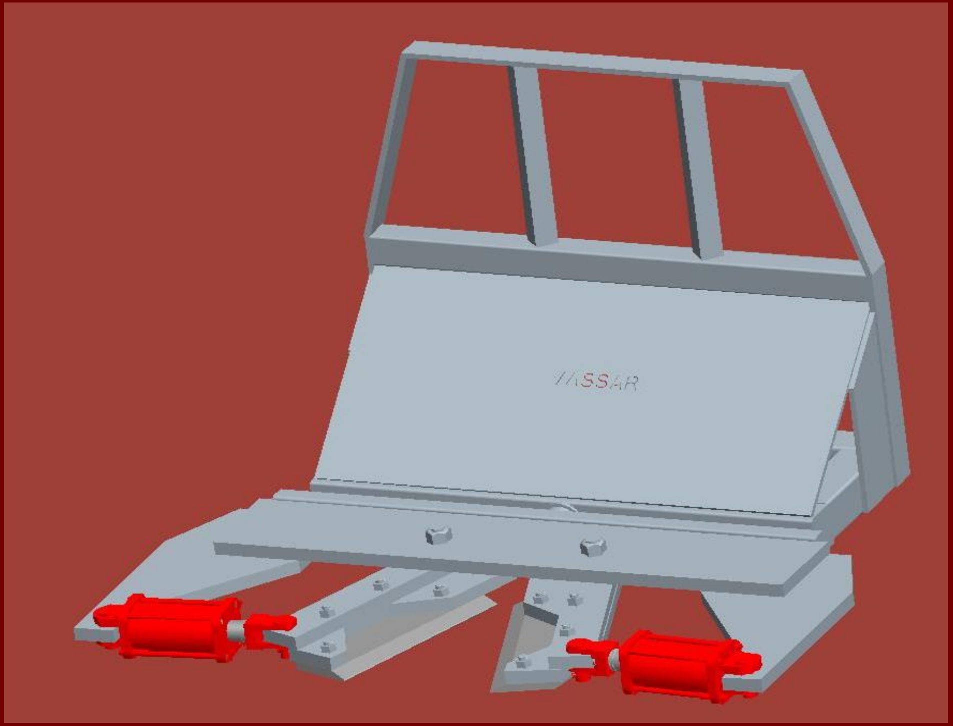
- Rotation by hand

Possible Designs-Rotation Mechanism

- Bearings
  - Expensive
  - Require Low Tolerances
- Drive Rollers
  - Low
- DOM Tubing
  - Almost Unlimited Amount of Sizes
  - Appropriate Wall Thickness
  - Cost Effective

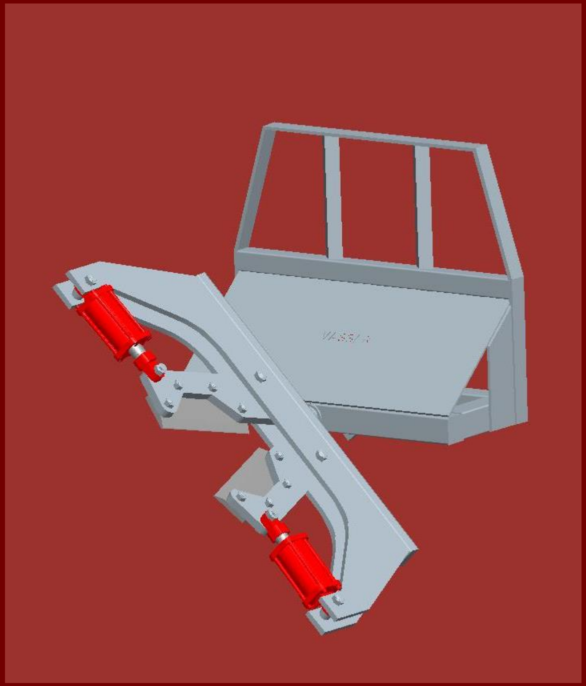
Possible Designs-Frame

- Four Piece Frame
  - Less Parts
  - Max Cylinder Force
  - Manual Rotation



Possible Designs-Frame

- Three Piece Frame
  - Less Parts
  - Maximum Cylinder Force
  - Flush Cut



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