DESIGN SOLUTIONS FOR THE "SUPER GRAY" HIGH CAPACITY SPRIGGER: A RECOMMENDATION REPORT FOR BERMUDA KING L.L.C.

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EXECUTIVE SUMMARY

The following section summarizes the recommendation report directed to Bermuda King L.L.C. of Kingfisher, Oklahoma. The proposal concerns the “Super Gray” high capacity prototype sprigged developed by Bermuda King L.L.C. The proposal reviews design imperfections of the current sprigger and suggests modifications directed toward improving the planting consistency of the high capacity sprigger.

The introduction to this report offers a brief foreword of the entire recommendation. It provides a short background concerning the development and intended function of the “Super Gray” sprigger. The introduction also explains the origin of the report which stems from a long-term cooperation between Bermuda King L.L.C. and Department of Biosystems and Agricultural Engineering senior design team at Oklahoma State University. The introduction also states the purpose of the report and provides the scope, or extent, of the report. The report serves the purpose of examining the cause of the problem and offering suggestions for improvement to Bermuda King. The report’s extent focuses entirely upon the feed mechanism of the “Super Gray” prototype.

The problem section begins by first defining the problem facing Bermuda King L.L.C. and the “Super Gray” sprigger. It provides a background of the problem including the cause of the problem based upon extensive testing by the Department of Biosystems and Agricultural Engineering senior design team. This section additionally provides a detailed description of the problem which originates in the feed mechanism of the

sprigger. The problem section further analyzes the problem by providing the significance that the problem poses to Bermuda King L.L.C.

The solutions section of the report initially reviews the design modifications proposed for the "Super Gray" prototype and evaluates the effectiveness of these modifications. Next, the solutions section provides a detailed description of the most plausible proposed solution. This includes providing and comparing design modifications to the sprigger's existing feed mechanism with the current design. This section also proposes and evaluates a series of additions to the prototype to create a funnel system for the throat area of the sprigger. Finally, the solutions section assesses the proposed solution feasibility based upon cost, time, and the effectiveness of the modifications. In fairness, part of this evaluation includes appraising the potential problems of the proposed solution.

The conclusion provides Bermuda King L.L.C. with our final recommendation for implementing the proposed solution. The conclusion summarizes the effectiveness of employing our solution and explains the method by which the design modifications produce more efficient planting rates. Additionally the conclusion analyzes additional safety factors provided by the proposed design modifications.

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INTRODUCTION

The following document provides a recommendation directed to Bermuda King L.L.C. The report suggests design improvements for future production of the company's high capacity spriggers. The proposal results from the design implementation and testing of a Bermuda King prototype named Super Gray.

Bermuda King L.L.C. developed the Super Gray prototype to specifically fill the needs of customers who plant large acreages, demand high planting rates, or for other reasons require a large box capacity. According to Brian Henderson, president of Bermuda King, Bermuda King L.L.C. manufactured the Super Gray prototype as an alternative to their rollback machine for increasing sprigger box capacity. This report discusses the results of our investigation as well as proposed design improvements. Expense, feasibility, and effectiveness governed the design criteria for all proposed improvements.

Bermuda King petitioned the Department of Biosystems and Agricultural Engineering at Oklahoma State University in an effort to trace and resolve some performance issues of the Super Gray prototype sprigger. Upon completion of initial testing, the Department of Biosystems and Agricultural Engineering senior mechanical design team determined there was much room for improvement with regards to the machine's planting uniformity. The prototype sprigger produced very erratic and inconsistent planting rates. It planted large clumps of sprigs in some areas while leaving other areas bare, and planting streaks across the width of the machine. In an effort to remedy the problem we conducted a series of tests and developed hypothesizes as to the cause of the problems. This report outlines the solutions we propose to improve machine performance.

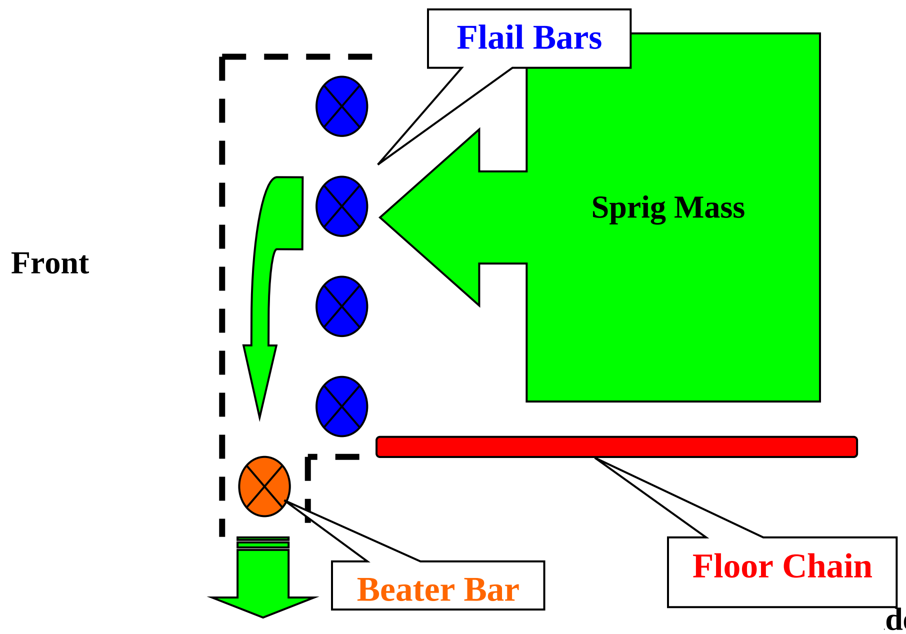
STATEMENT OF SUPER GRAY SPRIGGER LIMITATIONS

The Super Gray prototype has the tendency to plant inconsistent rates of Bermuda grass sprigs. Our report offers Bermuda King L.L.C. a description of the problem's sources. The following segment examines two possible causes of the observed problems. We hypothesize that the majority of Super Gray's problems stem from its inefficient feeding system. The feeding system governs the planting rate and uniformity of the sprigger. In the current design, the excessive lengths of the flail bar knives combined with their high rotational velocity allow the sprigger to consume large clumps of sprigs at once resulting in highly inconsistent planting rates. In addition, the substantially larger throat area of the Super Gray allows the profile of sprigs to vary as the sprigger bounces across the field. The combination of these two design features allows the actual planting rate to vary widely to both sides of the set rate.

DESCRIPTION OF THE SUPER GRAY SPRIGGER

Super Gray was fabricated in the late 1990s in an effort to develop a line of planters with increased carrying and planting capacity. The Super Gray was created to be an alternative to the current high-capacity planter, which uses an expensive and power intensive roll-back device. The Super Gray prototype did not see immediate success and the project was soon shelved.

Figure 1 illustrates the components of the feeding mechanism below. The feeder system is composed of a floor chain, four flail bars, and a beater bar. A large mass of sprigs contained in a feeder box is slowly fed forward by a floor chain. Four horizontal flail bars separate sprigs as the sprig mass moves forward. The four flail bars feed sprigs onto the beater bar, which then distributes the sprigs to the ground. The discharged sprigs are then pressed into the soil with rolling metal disks. Power is supplied by a tractor through a PTO shaft and into a right angle gear-box. There is no speed reduction in line to the flail bars or beater bar. A variable ring-cone gearbox with a 432:1 minimum reduction reduces the PTO shaft speed to the floor chain.



de View)

A DESCRIPTION OF SPRIGGING

The term sprigging involves a process of digging and planting grass sprigs. “Machine sprigging provides the most preferable and effective method of planting sprigs” [1]. The process involves harvesting sprigs by digging them from the ground. The sprigs are then placed into a machine. The machine plants the sprigs by distributing and pressing the sprigs into the ground. “The most important thing is to loosen up the soil and give it surface roughness.” This allows for better surface contact and anchorage of the sprigs into the soil. Scarifying the soil produces significantly better results as opposed to sprigs planted on hard ground [2].

EXPLORATION OFPROBLEMS ASSOCIATED WITH THE SUPER GRAY SPRIGGER

Initial Testing

We performed initial testing with the planter ‘as-delivered’ from the factory. The primary purposes of the initial test are listed below:

1. Gain an appreciation for the characteristics of Bermuda grass sprigs and the inherent problems associated with their handling.

2. Gain firsthand experience in the operation of Bermuda King harvesting and planting equipment.

3. Visually observe the planter in operation to gain insight into the problems and possible causes.

We tested the sprigger both in the field and at the lab to establish our benchmark.

Field Testing Setup

Figure 2 illustrates the field testing setup. Field tests took place at the Oklahoma State University Agronomy Farm Station. Sprigs were dug, loaded and replanted on site. Observations of the Super Gray’s planting consistency were compared to previous test results.

Field Testing Equipment:

- John Deere 7800 tractor
- Ford 7710 Tractor
- Super Gray High Capacity Sprigger
- Bermuda King Sprig Harvester

Figure 2: Field Testing

Lab Testing Setup

Figure 3, 4, and 5 illustrates the lab testing setup. A tarp placed below the sprigger discharge area captured the discharged sprigs. The tractor and sprigger remained stationary for all lab testing. A stopwatch timed test intervals. The sprigs discharged onto the tarp were placed onto a pallet and weighed on large metric scales.

Lab Testing Equipment and Materials:

- Ford 7710 tractor
- Super Gray High Capacity Sprigger
- Stopwatch
- Heavy-duty tarp
- Large weight scale (metric units)
- Small weight scale (English units)
- Bucket
- Pallet
- Tape measure
- Calculator

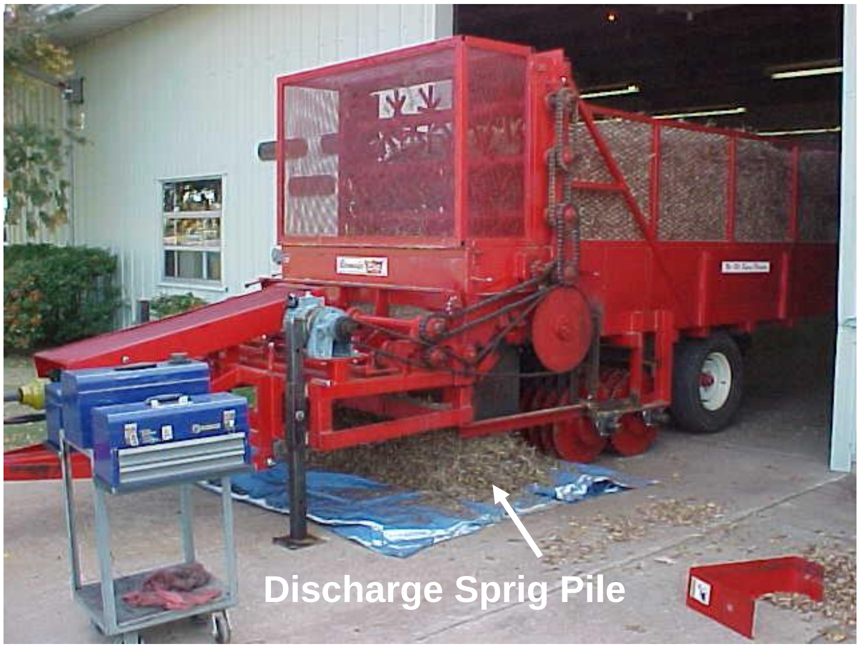


Figure 3: Lab Testing Setup (Left View)

Figure 4: Lab Testing Setup (Right View)

Figure 5: Weighing Sprig Test Samples

A bucket was filled to a level top with test sprigs and weighed. The bucket was then emptied and reweighed. The sprig weight was calculated by subtraction using the following equation:

$$Sprig\,Weight = (weight\,of\ sprigs\,and\,bucket) - (weight\,of\ bucket)$$

Volume was calculated from the dimensions of the bucket.
The density of the test sprigs was calculated by the following equation:

$$Density = \left(\frac{weight\,of\ sprigs}{volume\,of\ bucket}\right)$$

Planting rates were calculated based upon the weight of the sprigs discharged in a given amount of time. The volumes of sprigs for each test run were calculated by dividing that weight by the density of the sprigs. Planted volumes were then converted into an estimate of the planting rate for the machine in bushels per acre for a given ground speed.

Floor Chain Measurement and Planting Rate Capabilities

Before beginning initial lab testing, the theoretical planting rates for the sprigger needed to be calculated in order to evaluate the actual machine performance. To determine the range of the planter a series of test were conducted to determine the maximum chain speed available. A spreadsheet was then constructed to determine theoretical planting rates based on ring-cone settings at several user defined planting speeds. Table 1 shows the theoretical capacity of the planter before any modifications where made. The table indicates the highest planting rate attainable to be 327.9 bu/ac at 5 mph.

Table 1: Planting Rates

Gearbox Setting	Planting Rates (bu/ac)				
	5mph	6mph	7mph	8mph	9mph
1	32.8	27.3	23.4	20.5	18.2
2	65.6	54.6	46.8	41	36.4
3	98.4	82	70.3	61.5	54.6
4	131.2	109.3	93.7	82	72.9
5	163.9	136.6	117.1	102.5	91.1
6	196.7	163.9	140.5	123	109.3
7	229.5	191.3	163.9	143.5	127.5
8	262.3	218.6	187.4	163.9	145.7
9	295.1	245.9	210.8	184.4	163.9
10	327.9	273.2	234.2	204.9	182.2

Developing a Baseline

Quantification of variation in planting density was needed to so that performance of future modifications could be evaluated and measured against a baseline. To establish this baseline, the team loaded the planter with sprigs, placed a tarp beneath the beater bar on the ground, and engaged the planter for one minute. We collected and weighed the sprig output. Data from this test is reported in Table 2.

Table 2: Discharge Rates before Modification

Experiment	Time (min.)	Ringcone Setting	Discharge (kg)
1	1	10	51
2	1	10	100
3	1	10	67
4	1	5	40
5	1	5	45
6	1	5	34

After observing six test runs, the team felt modifications were needed to improve the metering of sprigs through the throat area. To address this problem the team removed the chains powering the second and fourth flail bars and tested the sprigger again (Figure 6). The non-powered flail bars had only a slight rotation during operation. The team conducted only two tests with this modification because sprigs jammed against flail bar #2 stalling the movement of the sprig pile. The results of these tests are listed below in Table 3.

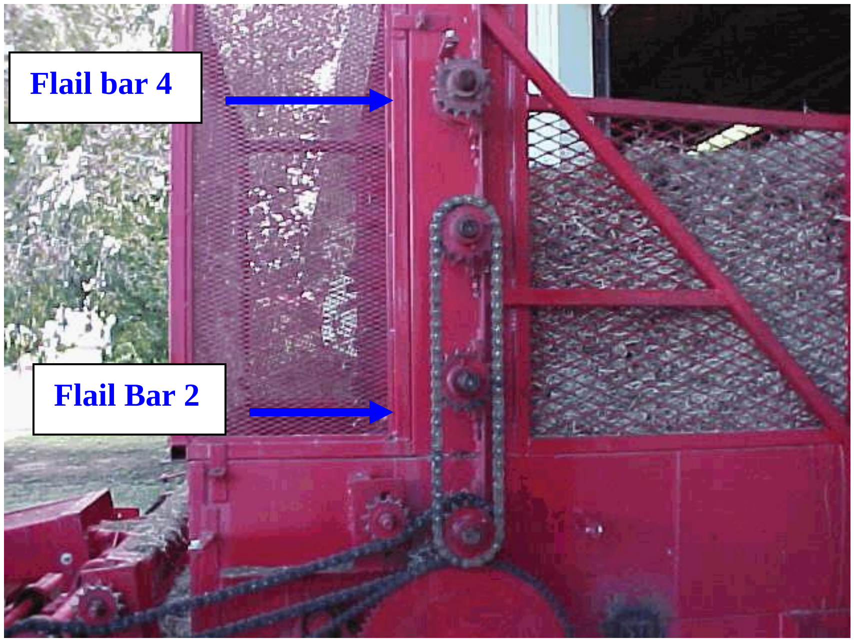


Figure 6: Chains Removed from Flail Bars 2 and 4

Table 3: Discharge Rates after Test Modification

Experiment	Time (min.)	Ring-cone Setting	Discharge (kg)
1	1	10	28
2	1	10	16

The team then concluded that flail #2 needed to rotate during operation to keep the sprigs from building up behind it. A hydraulic motor was mounted to power the second flail bar by use of a chain and sprockets. Oil flow control valve was connected in series with hydraulic lines running from the test tractor to the motor to control motor speed. (Figure 7).

The team first performed a series of tests to determine the optimal rotational speed and direction for improving metering characteristics. Counter rotation at 20 rpm produced the best results; the group preformed a set of three tests with these settings. These results are posted in Table 5.

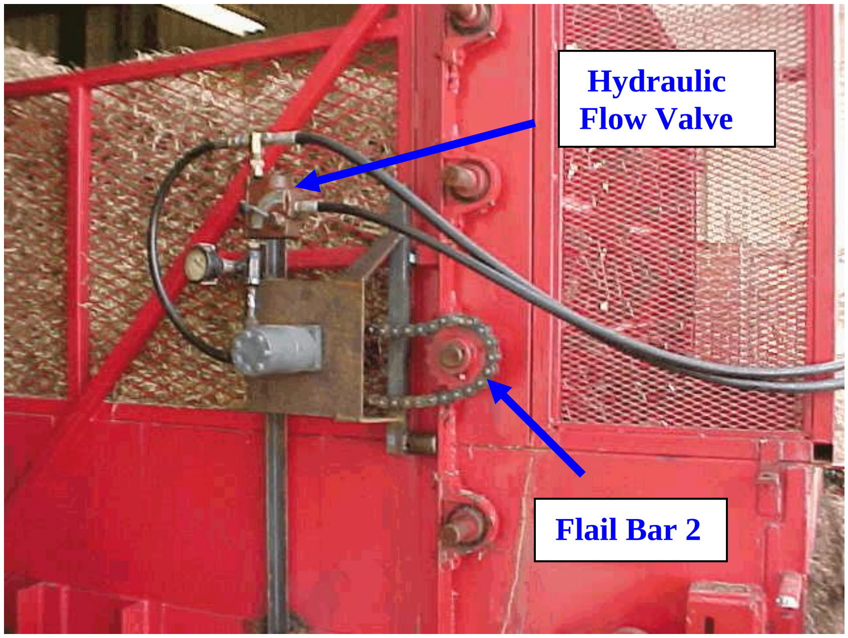


Figure 7: Hydraulic Motor Mounting

Table 4: Discharge Rates with Hydraulic Motor

Experiment	Time (min.)	Ringcone Setting	Discharge (kg)
1	1	10	17
2	1	10	11
3	1	10	15

Results of the Initial Field Testing

The group observed two major problems during the initial operation of the machine. The machine produced very inconsistent planting rates both across the width of the sprigger and along the length of a pass (See Figure 8). The top rear portion of the mass of sprigs also rolled back during operation (See Figure 9). In Figure 9, the horizontal line represents the desired sprig depth, and the diagonal dotted line illustrates the effects of the sprigs sloughing off of the back of the pile. Because planting rate is directly proportional to profile height, any variation in profile height produces variation in planting rate.

Figure 8: Inconsistent Sprig Application

Figure 9: Sloughing of Sprig Mass

(Note the difference between the two dotted lines)

The feed rate of the high capacity sprigger becoming non-uniform during operation leading to inconsistent planting rates is the largest problem associated with the machine. This problem originates in the design of the vertical flail bar system designed to remove sprigs from the pile and supply them to the beater bar for distribution. The excessive length of the knives causes large quantities of sprigs to be ejected in spurts resulting in highly inconsistent planting rates. This erratic planting presents unsatisfactory planting results to those who use the equipment for commercial purposes.

DEFINITION OF THE PROTOTYPE PROBLEM

Initial testing revealed the origin of much of the variation in planting rates to be the fact that the flail bars engaging at varying horizontal depths of sprigs over the course of normal operation. In addition, due to the large metering throat area, the floor chain must move extremely slow to achieve the desired planting rates. In comparison to the standard Bermuda King sprigger, the Super Gray throat area is more than four times as large. As a result, the floor chain must move at ¼ the speed to achieve the same planting rate. The end result of this is that the flail bars are capable of removing significantly higher rates of sprigs from their rotational area than the floor chain can deliver for most planting rates.

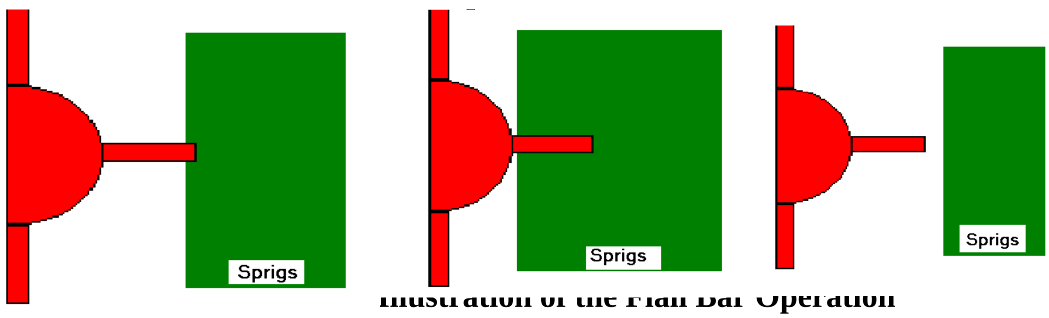


Illustration of the Flail Bar Operation

Figure 10 illustrates the three operation modes of the flail bar. During normal operation, only the tip of the flail bar engages and removes sprigs from the pile as seen in the left image. However, as illustrated in the middle image, during initial start up or in rough terrain, the sprig pile shifts forward until stopped by the drum of the flail bar; this results momentarily in significantly higher planting rates. The image on the right illustrates the exact opposite situation. Here the sprig pile rests beyond the rotational area of the flail bars. Thus the flail bars continue to run empty until the floor chain moves the pile forward allowing them to engage again. This situation results in initially high planting rate as the flail bars remove sprigs outside their intended rotational area; however, the planting rate falls off over an extended period of time until the floor chain catches up.

Bermuda King also observed a design criterion that contributed to planting inconsistency. The height of sprigs in the box decreases as the machine empties causing the effective metering throat area to decrease as well. A reduction in throat area while operating at a constant floor chain speed results in decreased planting rates. Sprig settling also contributes to the change in the height of the sprig profile during operation but does not contribute to planting rate variation

As the sprigs settle, the bulk density of the sprigs in the box increases which allows for an equal planting rate with a smaller throat area. However, some of the variation in sprig height results from sprigs falling off the back of the pile as the sprig mass moves forward which reduces planting rates. The testing concluded the sprigger only effectively planted 85% of the sprigs in the box.

SOLUTIONS TO THE PROTOTYPE SPRIGGER

This section of the report offers three potential solutions for Bermuda King's prototype sprigger design and analyzes each potential solution.

DESIGN CRITERIA

An acceptable solution must meet certain design criteria and also fit within Bermuda King's manufacturing capabilities. The solutions' ability to decrease the sprigger's variability in planting rate is the first criteria that will be considered. Second, the ease with which Bermuda King can implement and produce the solution will be evaluated. This includes the cost and time requirements of each solution.

Dimensional restrictions limit design characteristics of the prototype based on ease of transportation, usability, and ability of loading with a front end loader. Also, the dimensions of the redesigned prototype should not exceed Bermuda King's capabilities to manufacture it. The finished prototype must provide easily understood and operable instruments and controls. In addition, the controls must occupy both convenient and safe locations. To provide safety, the prototype will require warning labels and safety shields in the proper places where possible injury could occur.

SOLUTION 1: PROTOTYPE SPRIGGER REDESIGN

The following section offers a description and analysis of the first potential solution: completely redesigning the current prototype.

Description of Solution 1

This solution includes extensive research to develop an alternative method of handling and planting Bermuda grass sprigs. It is evident that the current methods used on the Super Gray do not produce a consistent planting rate and through further research a new method could be developed.

This design solution would place the main priority on redesign of the feeding mechanism that separates the sprigs from the mass.

This comprehensive solution offers the most extensive plan for correcting the planting efficiency of the prototype sprigger. This plan of action demands a completely new and innovative design to allow the machine to handle and plant a large volume of sprigs. This solution implies that Bermuda King would discard the traditional methods used on Super Gray to feed the sprigs so that a new, more effective method can be developed. The new feeding mechanism is the main concern, and all surrounding components will need to conform to the new feeding mechanism.

Feasibility of Solution 1

Due to economic and time constraints, researching and designing an entirely new sprigger may not be in the best interests of Bermuda King at this time. Designing a new machine would result in excessive expenses and would also require valuable time setting up the manufacturing processes for an entirely new machine. We do not feel that this is the best solution at this time.

SOLUTION 2: FLAIL BAR REDESIGN AND SPEED REDUCTION

This solution requires two processes: redesigning three flail bars and reducing their speed.

Description of Solution 2

The proposal incorporates removal of the top flail bar and redesigning the remaining three flail bars. The three horizontal flail bars supply sprigs to the bottom beater drum. The beater drum's diameter will increase from three and a half inches to five and a half inches while the shaft's length and diameter will remain the same. Removable shafts will be used in place of the current method of welding the shafts to the flail bar which will allow much easier instillation and removal of the flail bars. A 3/8 inch bolt is used to connect the flail bar to the shaft through a collar welded to the side of the drum. The length of the knives will also decrease from 7 to 4.5 inches. Figures 3 & 4 on the next page show these modifications.

Current Flail Bar Design:

- 1.5 in. x 11 in. shaft
- 8 in. right side shaft extension
- 11 in. left side shaft extension
- 3.5 in. diameter drum
- 3 in. spacing between knives
- 45 degree angle between knives
- 3/8 in. x 1.25 in. x 7 in. knives
- 3/8 in. x 3/16 in. x 6 in. keyway

New Flail Bar Design:

- 1.5 in. x 11 in. shaft
- 8 in. right side shaft extension
- 11 in. left side shaft extension
- 5.5 in. diameter drum
- 3 in. spacing between knives
- 22.5 degree angle between knives
- 3/8 in. x 1.25 in. x 4.5 in. knives
- 3/8 in. x 3/16 in. x 6 in. keyway
- 2.5 in. collars
- 3/8 in. x bolts
- 3/8 in. nuts

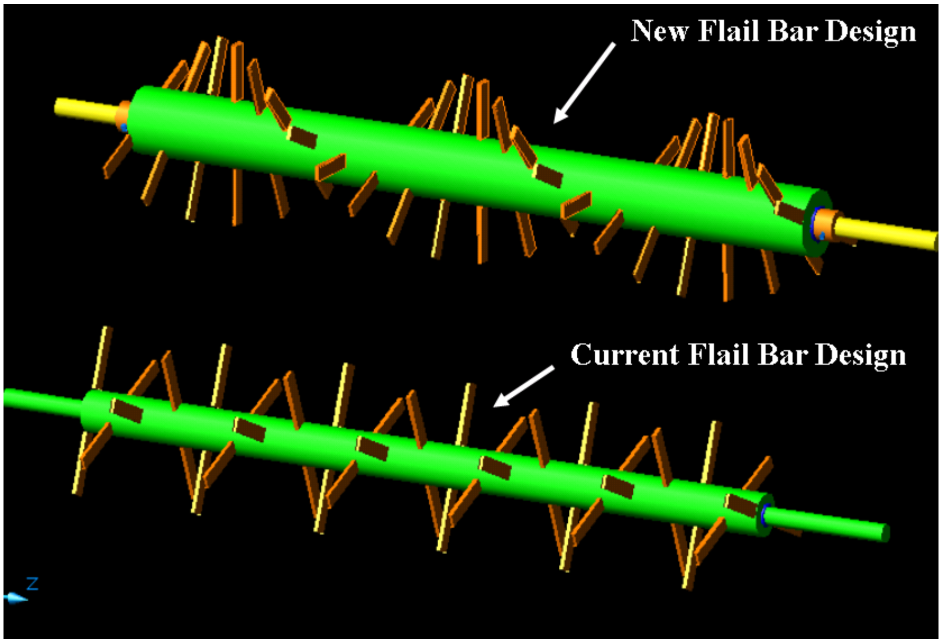


Figure 3: Comparison of flail bar designs.

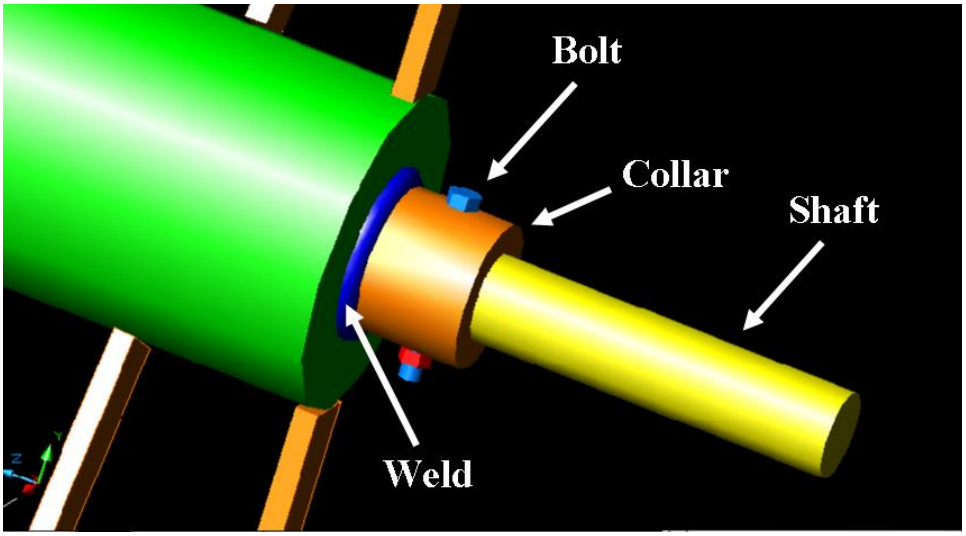


Figure 4: 3-D AutoCAD Drawing of Flail Bar Ends

Reducing Flail Bar Speed

The three vertical flail bars speed was reduced to half of original by replacing the current sixteen tooth drive sprocket with a thirty-two tooth drive sprocket. The flail bar was reduced to curtail the problem of the bars removing sprigs at an excessive rate. The three new flail bars feed the single beater bar of equal size. The capacity of the redesigned flail bars operating at ½ original speed more closely match the capacity of the beater bar.

Testing

After these modifications were made to Super Gray, field testing was conducted to determine their effectiveness. Streaking was almost eliminated, as was the volume of sprigs planted at initial startup. Variations were still present, but they were not as noticeable because they were on a smaller scale.

Feasibility of Solution 2

Although redesigning the flail bars fits well within Bermuda King's financial and time limitations (Appendix B), the solution does not adequately solve the problem. The redesigned flail bars provide a significant increase in planting efficiency but still fail to achieve the desired consistency. While a step in the right direction, this solution alone does not solve the problem.

Many clumps of grass sprigs were still thrown at the front of the cage by the flail bars. These sprigs were falling in front of the beater bar and being planted in bunches. There were also a sizeable amount of sprigs hanging up on the front of the floor chain. These clumps of sprigs also decreased the uniformity of the planting rate.

SOLUTION 3: METERING THE SPRIGGER PLANTING RATE

Description of Solution 3

Solution 3 attempts to control the path of the sprigs as they are separated by the flail bars until they are planted. A front plug strip and a funnel are used to concentrate the grass sprigs onto a spreader bar, which is placed directly below the funnel opening. Further definition of the throat area is also used to increase uniformity.

Front Plug Strip

An angled piece of sheet metal was placed above the beater bar to ensure that sprigs that were thrown against the front of the cage still made contact with the beater bar. The sheet metal fills the gap between the beater bar knives and the front of the feeder area. The front plug strip is made of sixteen-gage, low-carbon steel and is welded to the inside of the feeder area.

Dimensions:

- 72 in. Wide
- 3.5 in. Base Length
- 5 in. Angled Length
- 45 degree Bend

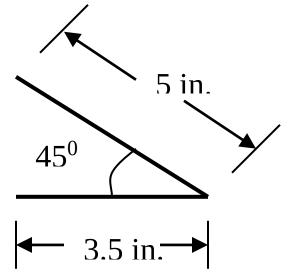


Figure 5: Front Plug Strip Dimensions

Funnel System

A funnel system was fabricated below the beater bar to further work the sprigs before they are planted. It collects all of the sprigs that fall from the beater bar and also gather the clumps of sprigs that hang up on the floor chain. It concentrated the sprigs onto a spreader bar that is installed directly below the funnel opening (Figure 6).

A chain and sprocket assembly supplies the power to the lower beater drum. The 60-series standard roller chain connects a sixteen-tooth sprocket on the beater bar shaft with a sprocket of equivalent size attached to the spreader bar.

Figure 6: Spreader Bar Drive System

Front Baffle

To further define the throat area, the front baffle was modified and moved. The baffle was lengthened so that it covered a portion of the top flail bar. It forms a 45-degree angle with the top of the cage and makes contact at the top.

The baffle defines the desired throat area and acts as a temporary storage device for the sprigs. During operation, the sprigs slide up the baffle until the sprig mass reduces to a height shorter than the defined throat area. At this point, the sprigs then slide down the baffle to maintain a consistent sprig profile. Figures 7 and 8 illustrate the front baffle and throat area.

Dimensions:

- 72 in. wide
- 3 in. top bend height
- 12 in. angled length
- 45 degree bend

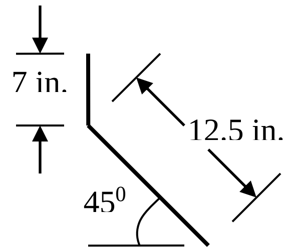


Figure 7: Front Baffle Dimensions

Testing

Field testing was done after these modifications were made. The front plug strip was very effective in controlling the springs that were thrown against the front of the cage. It funneled the sprigs onto the beater bar as planned.

The funnel below the beater bar concentrated the sprigs onto the spreader bar and greatly increased the uniformity of the sprigs that were planted. It focused the sprigs on the spreader bar so that they were worked one more time.

The improved front baffle also played a large part in presenting a consistent profile of sprigs to the flail bars. Excess sprigs rode up the baffle until the lack of sprigs in the throat area allowed the sprigs to fall back down.

These modifications produced the most consistent planting rates that we saw throughout the entire project. Appendix D Table 9 provides lab testing results for Solution 3, which were almost perfect.

Feasibility of Solution 3

The combination of the second and third solutions that produced the best results is still easy and cheap to manufacture. Compared to the time involved in fabricating an entire machine, the additional time required for these modifications are negligible. The cost is also very inexpensive and are included in Appendix A.

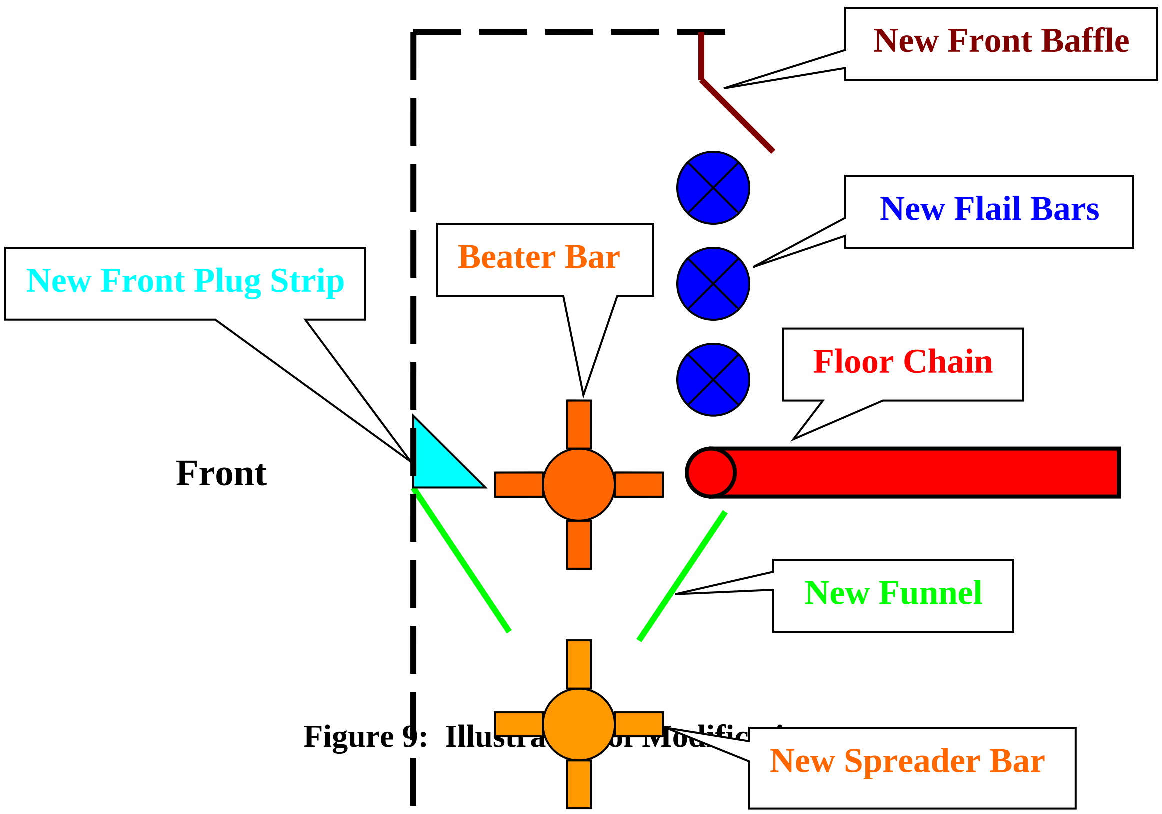


Figure 9: Illustra... of Modific...

CONCLUSION

Based upon Bermuda King's budget and time constraints, the third solution offers the greatest improvement for the least investment. This solution refines the sprig handling process from the initial sprig profile that is offered to the flail bars until the last time the sprigs are worked and planted. It is the recommendation of the group that Bermuda King reviews this research and testing to develop a plan that best fits their needs. From decreasing the variability of the planting rate to improving the accessibility of the sprigger's components, these solutions provide substantial improvements over previous prototypes.

BEFORE

Figure 14: Lack of Consistency in Sprig Application

AFTER

Figure 15: Consistency in Sprig Application

APPENDIX A: COSTS

Table 5: Current Flail Bars Costs

Current Flail Bar Design			
Material	Quantity	Cost/Quantity	Cost
3/8in. x 1 1/4in. x 7in. Knives	108 ft.	$0.36/ft.	$38.88
3 ½ in. sch. 40 Drum	22 ft.	$2.40/ft.	$52.80
1 ½ in. Shaft	29 ft.	$1.95/ft.	$55.90
5/8 in. Round End Plate	8	$3.60/piece	$28.80
Total			**$176.38**

Material Prices courtesy of Allen Glasser, shop foreman of Bermuda King.

Table 6: New Flail Bars Costs

New Flail Bar Design			
Material	Quantity	Cost/Quantity	Cost
3/8in. x 1 1/4in. x 7in. Knives	52 ft.	$0.36/ft.	$18.72
5 ½ in. sch. 40 Drum	16.5 ft.	$4.15/ft.	$68.48
1 ½ in. Shaft	21.5 ft.	$1.95/ft.	$41.93
5/8 in. End Plate	6	$4.73/piece	$28.38
2 ½ in. Collars	6	$4.30/piece	$25.80
3/8in. x 3 in. Bolts	6	$12.73/50	$1.53
3/8in. Nylon Locking Nuts	6	$6.50/100	$0.39
Total			**$185.23**

Material Prices courtesy of Allen Glasser, shop foreman of Bermuda King, and Wayne Kiner, OSU Biosystems and Agriculture Engineering Lab manager.

Table 7: Additional Material Costs

Material	**Quantity**	**Cost/Quantity**	**Cost**
4 ft. x 8 ft. 16 gage sheet metal	1	$40.00/sheet	$40.00
1 in. angle iron	17 ft.	$0.25/ft.	$4.25
1.5 in. square tubing	12 ft.	$0.35/ft.	$4.20
Total			**$48.45**

APPENDIX B: AUTOCAD DRAWINGS

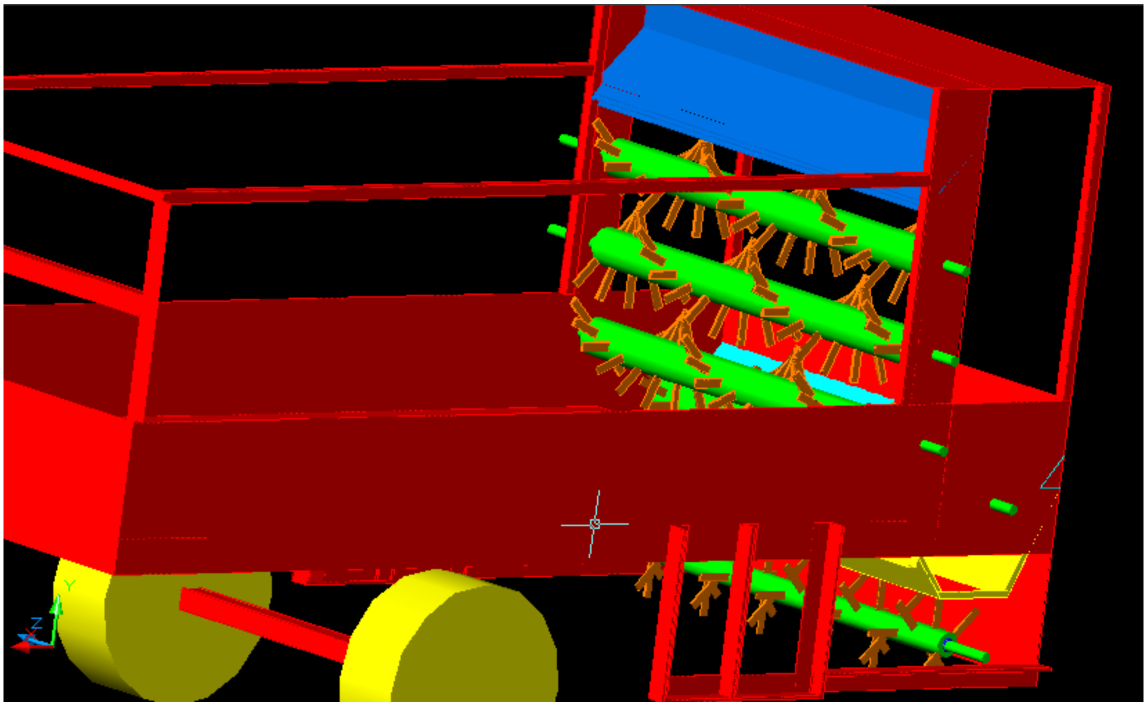


Figure 18: 3-D AutoCAD Drawing of "Super Gray" with Modifications

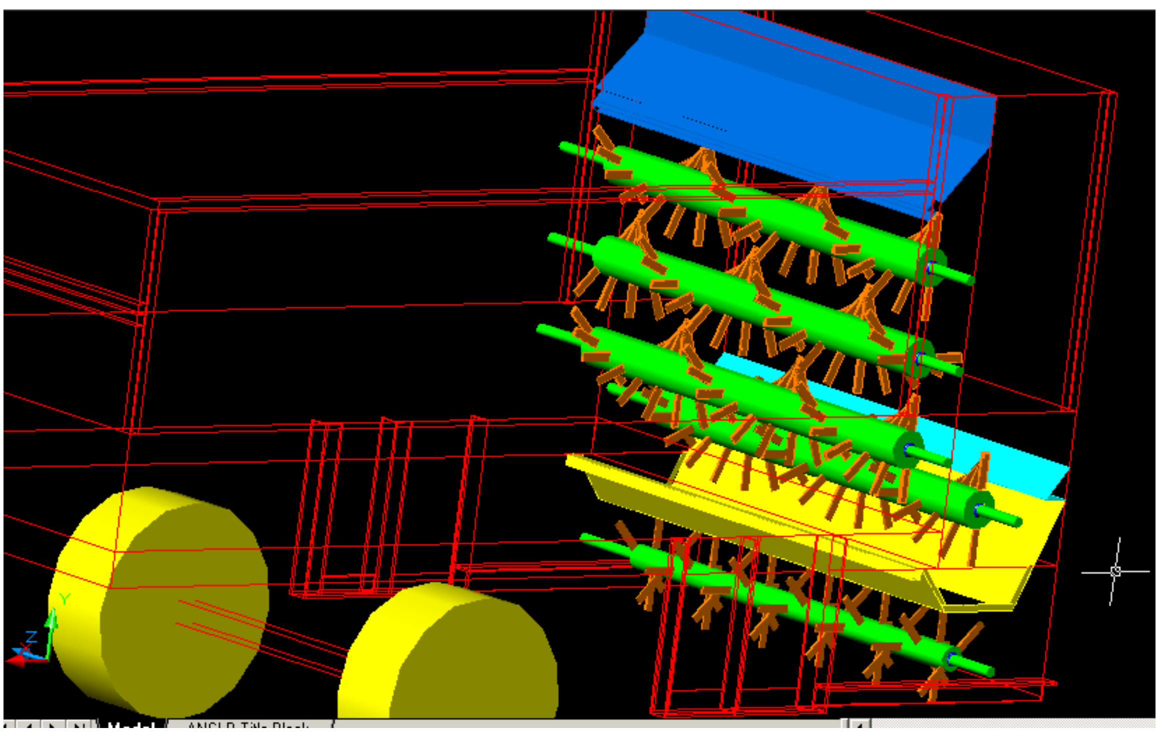
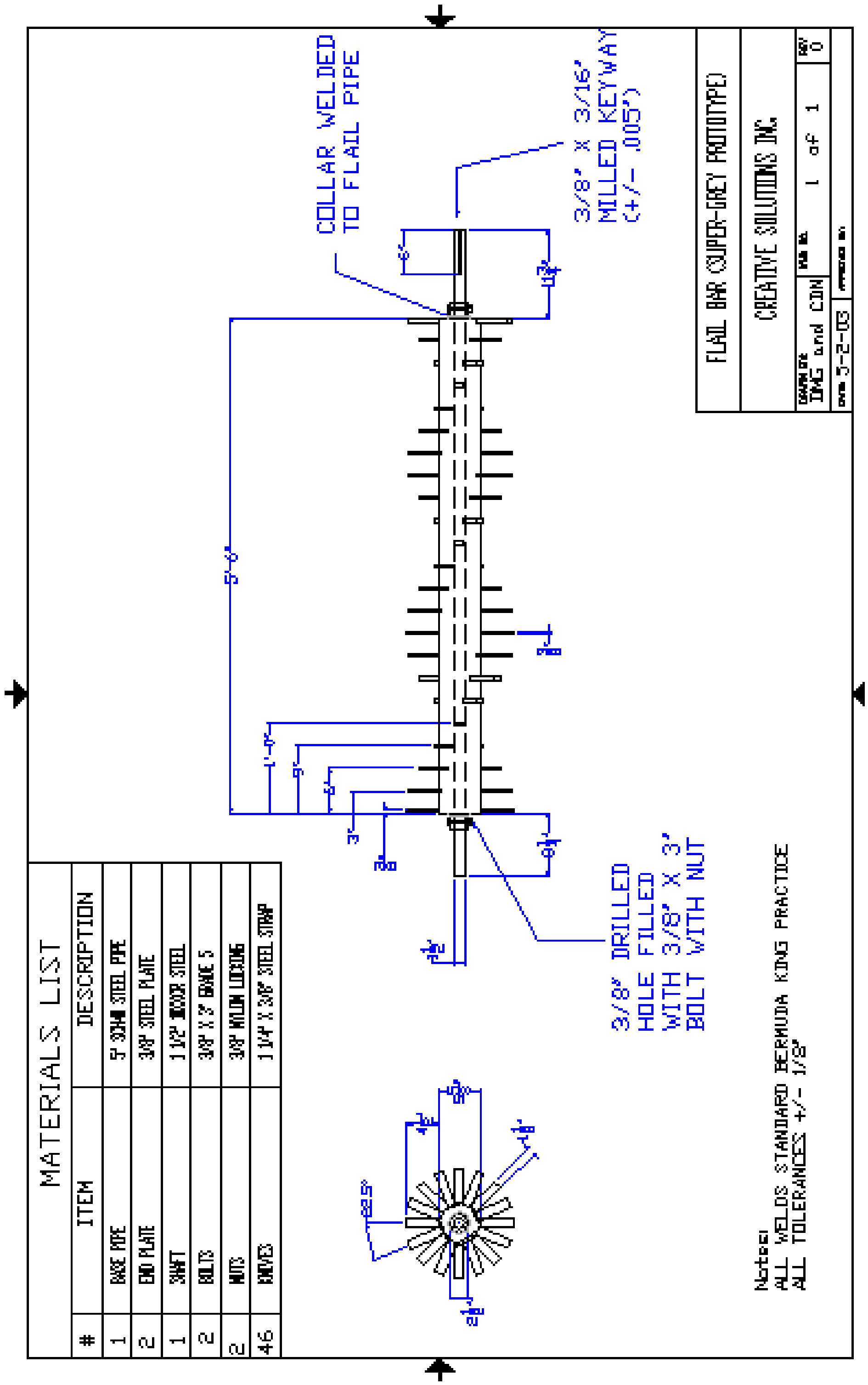


Figure 19: 3-D AutoCAD Drawing of "Super Gray" Modifications

APPENDIX C: FLAIL BAR AUTOCAD DRAWING



APPENDIX D: SOLUTION 3 LAB TESTING RESULTS

Table 8: Testing Results before Modification

Gearbox Setting	Bushels Collected	Rate Planted (bu/ac) @ 10mph	Calc. Planting Rate @ 10mph	% Error
5	12.4	103	82	25.1
5	14.0	115	82	40.8
5	10.6	87	82	6.4
10	15.9	131	164	20.2
10	31.1	257	164	56.4
10	20.8	172	164	4.8
			Average Error	25.62

Table 9: Testing Results after Modification

Gearbox Setting	Bushels Collected	Rate Planted (bu/ac) @ 10mph	Calculated Planting Rate @10mph	% Error
3	16.8	138.5*	112	23.6
3	16.8	138.5*	112	23.6
3	16.8	138.5*	112	23.6
3	17.1	141.4	112	26.3
6	26.8	220.9*	222	-0.5
6	26.4	218.0	222	-1.8
6	26.8	220.9*	222	-0.5
			Average Error	13.47

*Note the improvement in consistency between tests for each gearbox setting.

REFERENCES

[1] "World Feeder Planting Instructions," Mechanical Sprigger
http://www.worldfeeder.com/GrowersInfo.html

[2] http://www.turfgrass.com

2002-2003
Bermuda King L.L.C.
Senior Design Project

Presented by CSI:

Mickey Friedrich

Darren George

Cash Maitlen

Matt Steinert

BERMUDA GRASS HARVESTERS AND PLANTERS

CSI

Project Sponsor

- Bermuda King L.L.C.
  - Owners: Brent and Brian Henderson
  - An industry leader in the development of sprig harvesting and planting equipment
  - Operating in the Kingfisher area for over 35yrs.
  - Visit their website at www.bermudaking.com

All About Sprigs

- Alternative method of establishing grass
  - An individual stem or piece of stem of grass without any adhering soil
  - Sprigs are dug from existing stand of grass
- Advantages
  - Much cheaper than sod
  - Faster and more uniform stand than seeding

Tools of the Trade

Digger

Sprigger

The Digging Process

- Sprig Harvester (Digger)
  - Digs sprigs and separates them from soil
  - Returns sufficient quantity of sprigs to harvest area for re-establishment
  - Directs cleaned sprigs into truck or trailer for collection

Tools of the Trade

DiggerSprigger

The Sprigging Process

- Sprig Planter (Sprigger)
  - Separates sprigs from pile
  - Meters sprigs at desired rate for planting
  - Incorporates or presses sprigs into soil to facilitate rooting

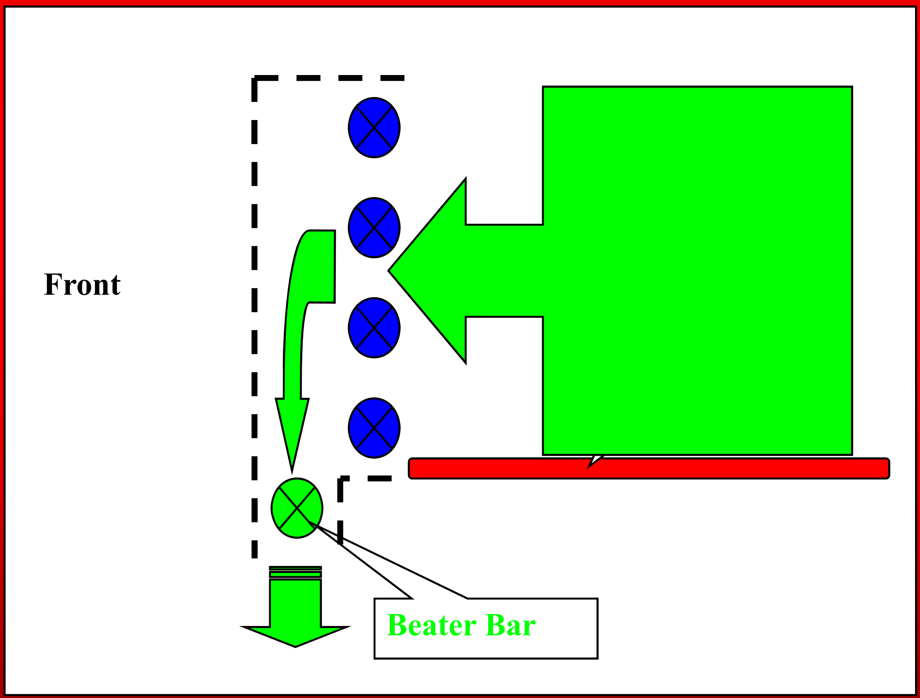
Design Project

Bermuda King Super-Gray Prototype

Basis for Prototype Creation

- Decrease fill time
  - Increase box capacity
- Alternative to roll-back device
  - Expensive and power intensive
- Originally developed in late 90's
  - Operated only once before being shelved

Super Gray Design



Perceived Problem

- Non-uniform planting rate
  - Rate varied during operation
- Variation of sprig height in box
  - Height of sprigs in box decreases as box empties
  - Believed to be cause of non-uniformity

Project Presented by Bermuda King

- Develop an adaptation to current prototype design enabling a consistent profile of sprigs to be delivered to the flail bars
- Open to any alternative designs for increasing box capacity

Goal of Fall Testing

- Define and quantify problems associated with machine

Off to the Field!

Initial Testing

- Goals:
  - Gain an appreciation for the characteristics of Bermuda grass sprigs and the inherent problems associated with their handling
  - Gain firsthand experience in the operation of Bermuda King harvesting and planting equipment
  - Operate machine “As Delivered” to observe possible problems

Our Analysis of Initial Testing

- Planting rate was highly variable
  - Significantly higher planting rates are produced in the first 5 seconds of operation following loading
  - Extremely erratic planting rates during planting of final 10% of sprigs
  - Erratic planting rates when traversing rough terrain or traveling uphill
  - Streaking
  - Over application at most settings

Challenge: Variation

Flail bars engage varying horizontal depths of sprigs causing "sprig piles"


Streaking

Plan of Attack

- Develop baseline variation
- Develop mini-solutions
- Create a package

Developing a Baseline

Gearbox Calibration

Developed calibration between gearbox settings and theoretical planting rates

Gear Box Setting	Planting Rate (bu/acre)		
Speed (mph)	5 mph	7 mph	9 mph
1	32.8	23.4	18.2
3	98.4	70.3	54.6
5	163.9	117.1	91.1
7	229.5	163.9	127.5
9	295.1	210.8	163.9
10	327.9	324.2	182.2

Gear Box Setting	Chain Speed (ft/min)
1	0.104
3	0.311
5	0.518
7	0.725
9	0.932
10	1.035

Stationary Test Procedure

- Calibrated sprig density for our set of test sprigs   5.66 lbs/ft^3
- Machine operated stationary for 1 minute @ 540 PTO rpm while sprigs were collected and then weighed
- Test conducted over wide range of gearbox settings

Summary of Results

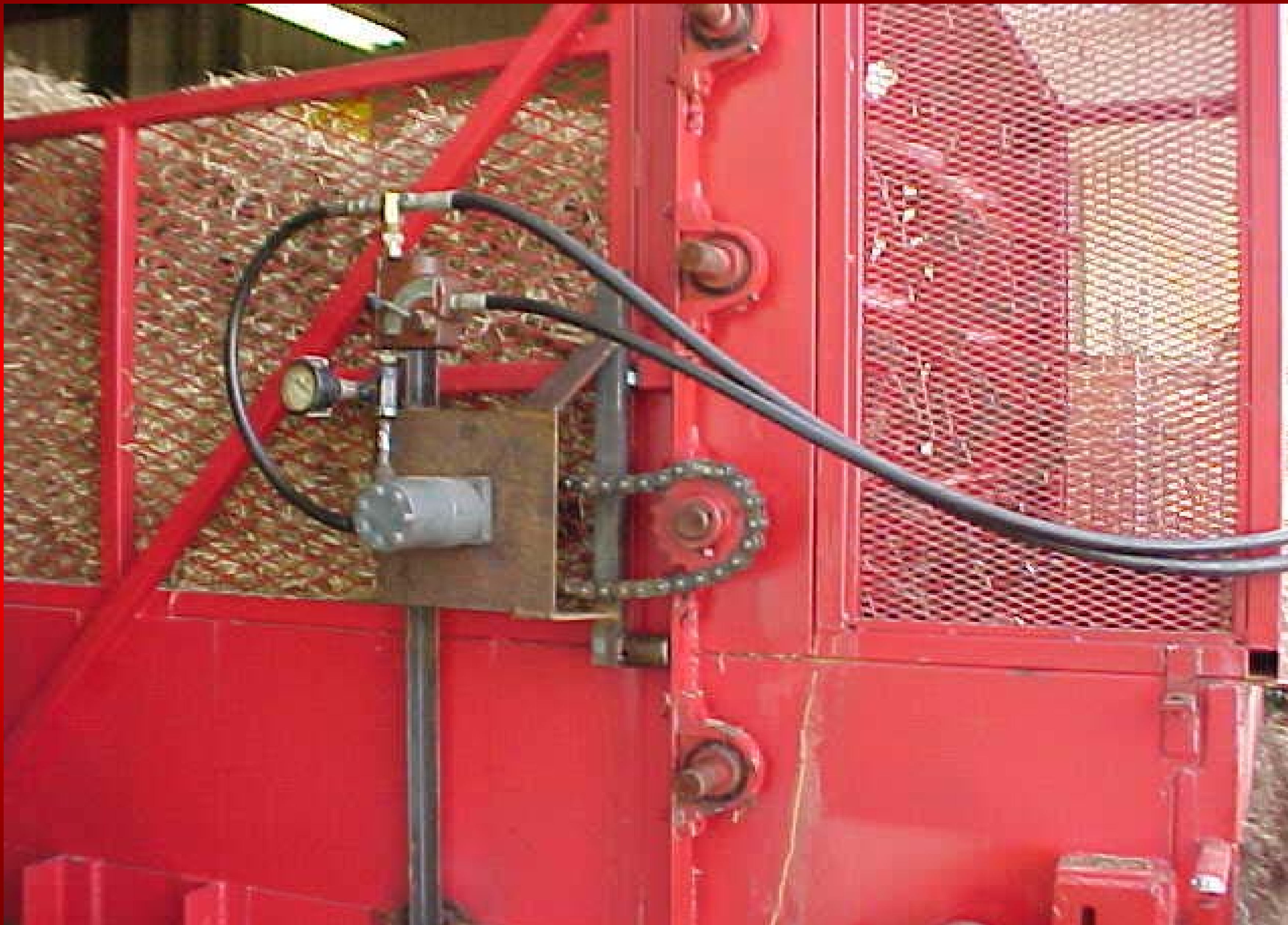
Gearbox Setting	Rate Planted (bu/ac) @ 10mph	Calc. Planting Rate (bu/ac) @ 10mph	Error
10	131	164	-20.22%
10	257	164	56.43%
10	172	164	4.80%
5	103	82	25.14%
5	115	82	40.78%
5	87	82	6.37%
		Average Error	18.88%

Test Observations

- During this and all previous tests, top flail bar engaged very few sprigs
- Floor chain does not slip under sprig pile
- Large metering throat and extremely slow moving floor chain make consistent metering difficult

Modifications

- Disconnected top flail bar to reduce throat area
- Converted middle flail bar to hydraulic drive so that we could vary its speed and direction



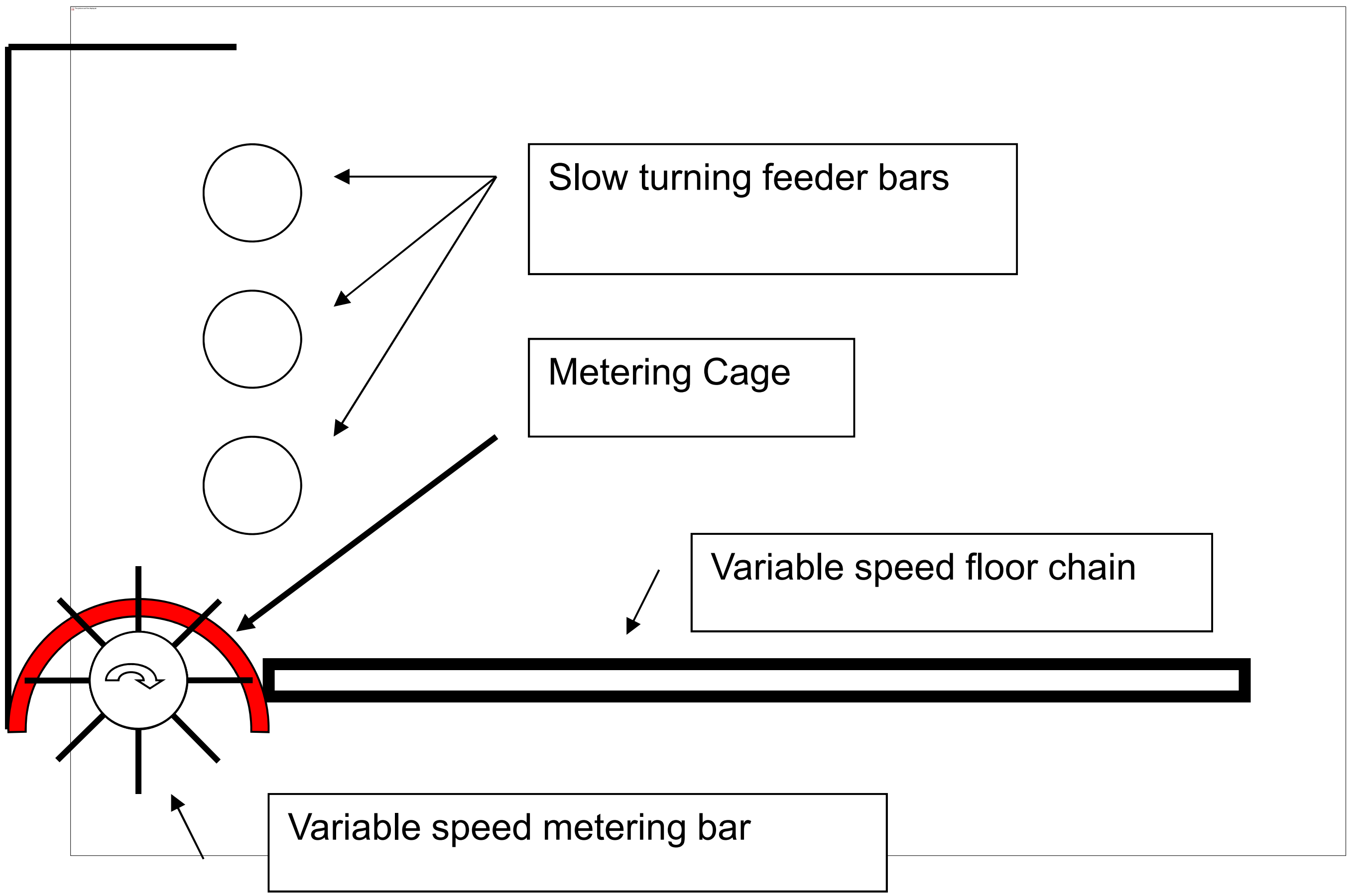
Performance of Modifications

- Removal of top flail bar
  - Successful in reducing throat area, no negative impact on performance
- Hydraulic drive of second bar
  - Improved metering consistency when rotated slowly and used as a “metering bar” to supply sprigs to bottom bar
- Possibility of rotating all vertical flail bars slower to be used as metering bars

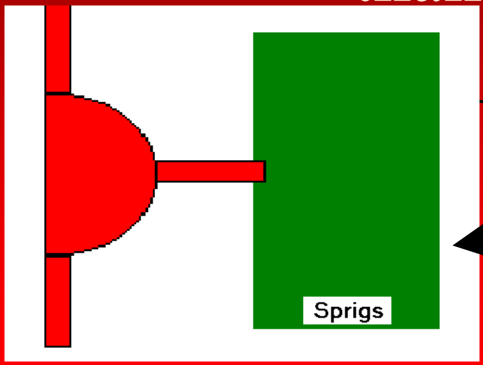
Alternative Solutions

- Metering Cage
  - Turn flail bars slowly and use caged beater bar to meter sprigs
- Lift and Feed Design
  - Ramp floor chain at front and used “flipper” drum to define throat area
- Cleated Floor Chain
  - Used to drag sprigs through small frontal opening

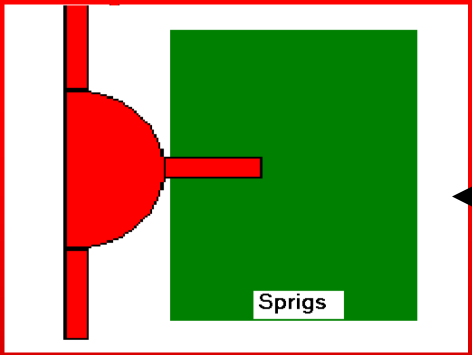
Alternative Solution (Metering Cage)



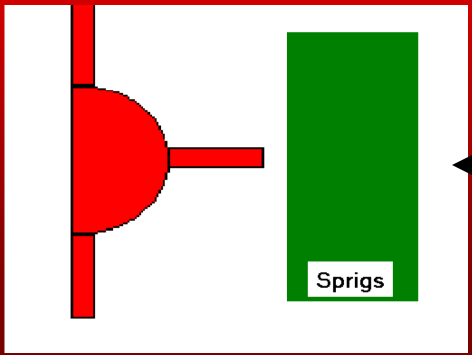
Flail bars remove sprigs at significantly higher rates than the floor chain can deliver sprigs



- Normal Operation
  - Only tip of flail bar engages sprigs



- Initial Start-up or Bouncing
  - Spring pile moves forward until stopped by drum, causing flail bars to engage a much larger volume of sprigs
  - Causes sprig piles



- Sprigs not inside flail bar travel area are removed by bars
  - Reduced planting rate, no sprigs available to bar

Proposed Solutions

- We feel that the inconsistent metering characteristics of current flail bar system are the largest source of planting rate error and the most critical problem.

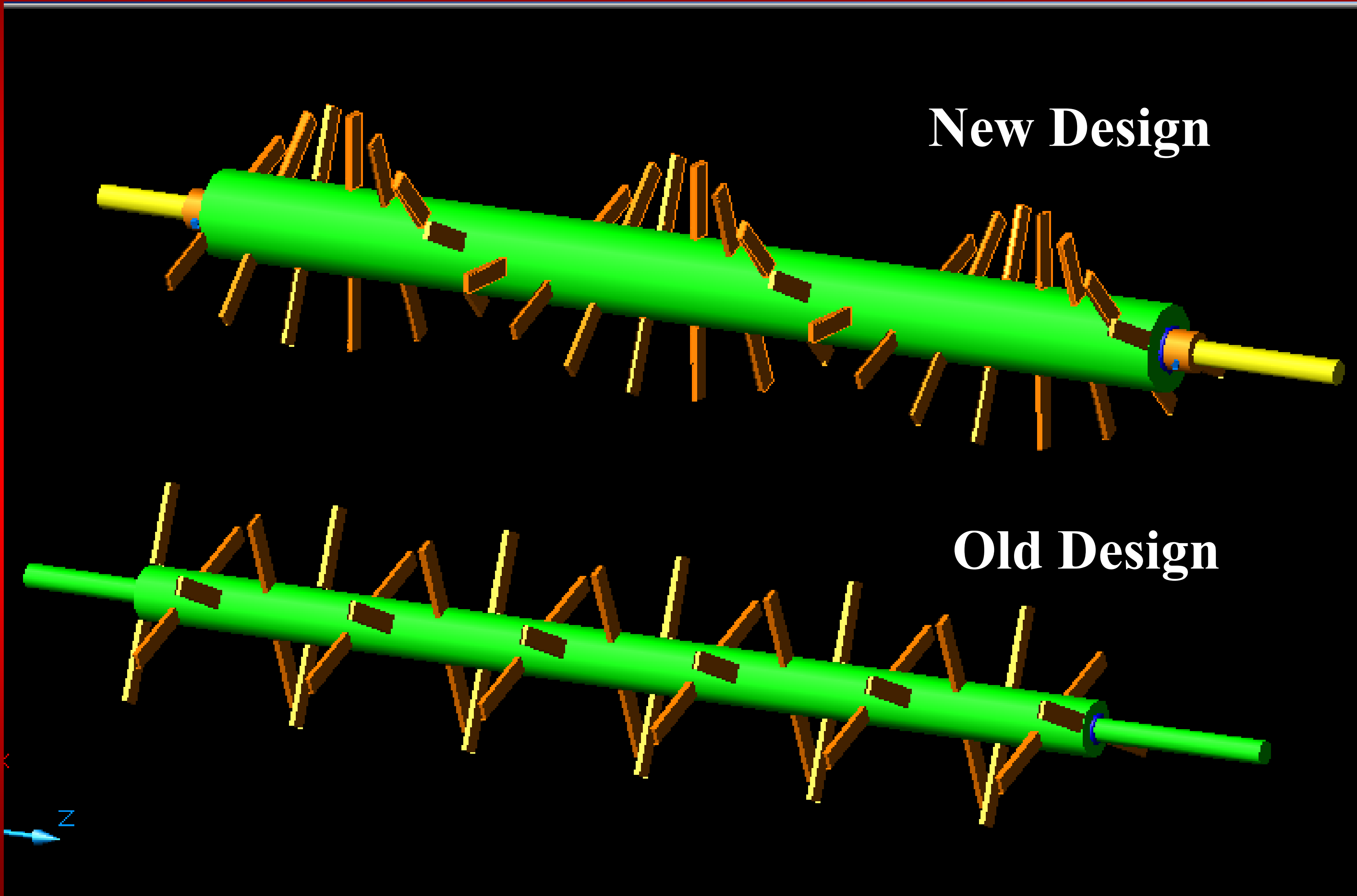
- Proposed Solution
  1. Removal of top flail bar to reduce and better define the throat area
  2. Increase flail bar drum diameter while decreasing individual flail bars lengths

Strategy for Modifications

- First, implement series of modifications individually and evaluate the effects on machine performance
- Finally, evaluate performance of modifications collectively

Flail Bar Modifications

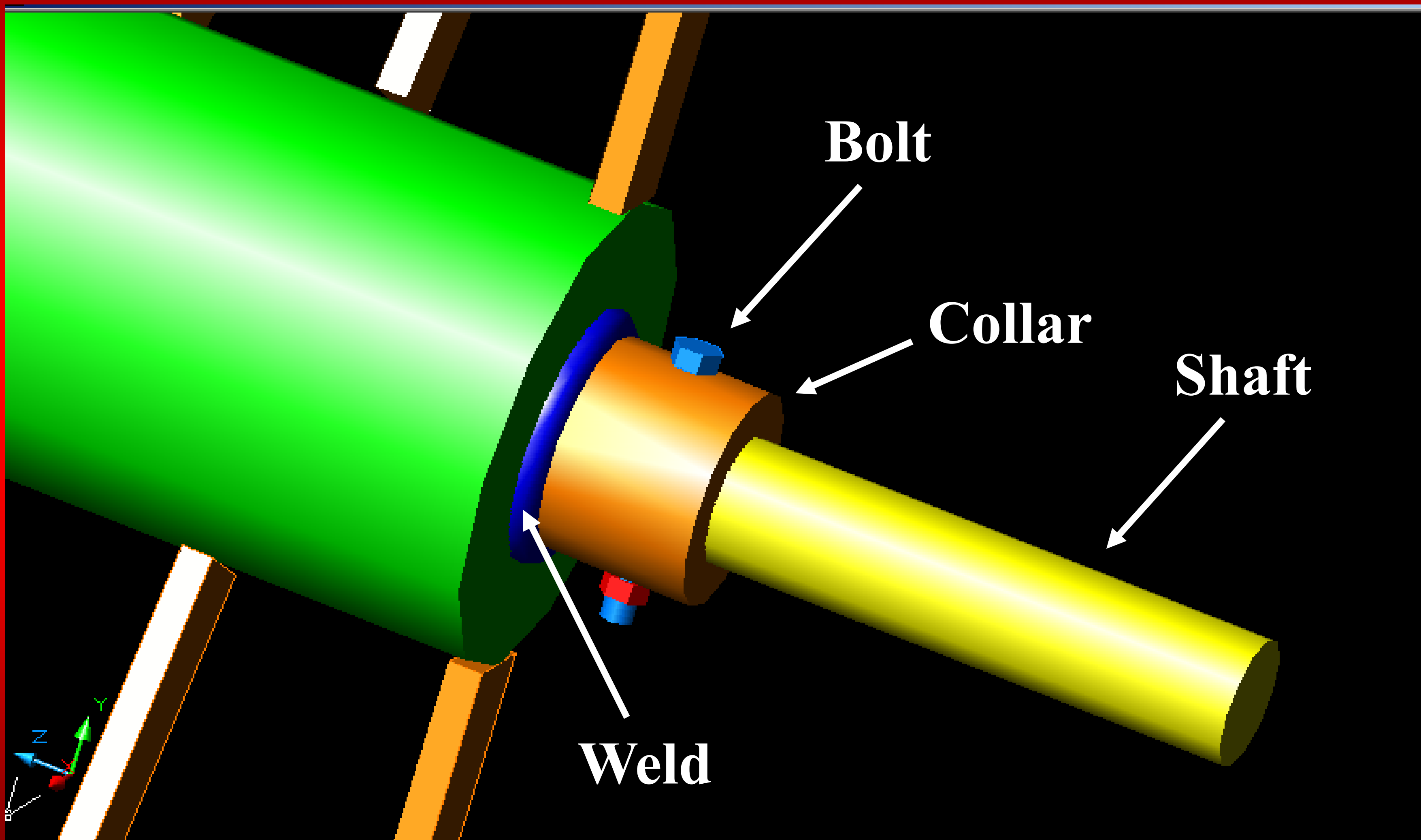
- Believed many of the metering problems could be corrected by modifying flail bars
- Contacted Bermuda King about manufacturing new flail bars
  - Larger drum diameter
  - Place knives in slow spiral pattern around drum


New Design
Old Design
Z

New Flail Bars

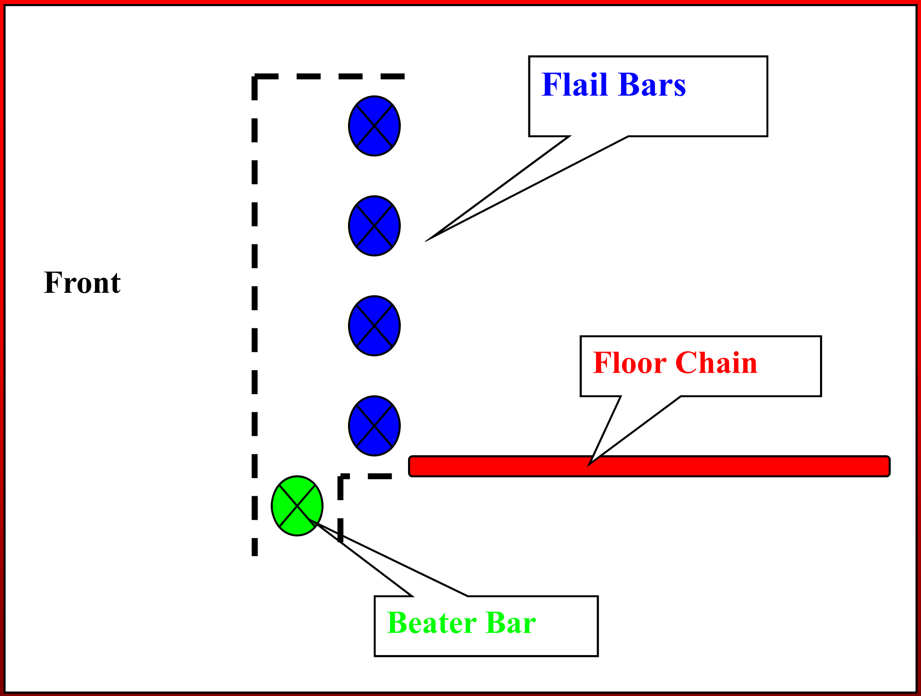
Further Flail Bar Modifications

- Flail bar mounting system was modified to allow for flail bar removal without machine disassembly
  - Short collars welded to either end of drum
  - Shaft slides through drum and is pinned


Bolt
Collar
Shaft
Weld

Flail Bar Modifications

- While installing new flail bars it was decided to reduce their operating speed by ½
- Why????
  - Flail bars remove sprigs at excessive rate
  - Three flail bars feed single beater bar of equal size
  - Capacity of flail bars and beater bar more equally matched



Front Baffle

- Installed front baffle to close gap left by removal of top flail bar

Testing Round 1

Round 1 Scorecard

- Volume of sprigs planted at initial startup was significantly reduced
- "Streaking" of sprigs was eliminated
- Variation still present, but on a smaller scale
- Magnitude of variation also reduced

Testing Round 1

Remaining Problems

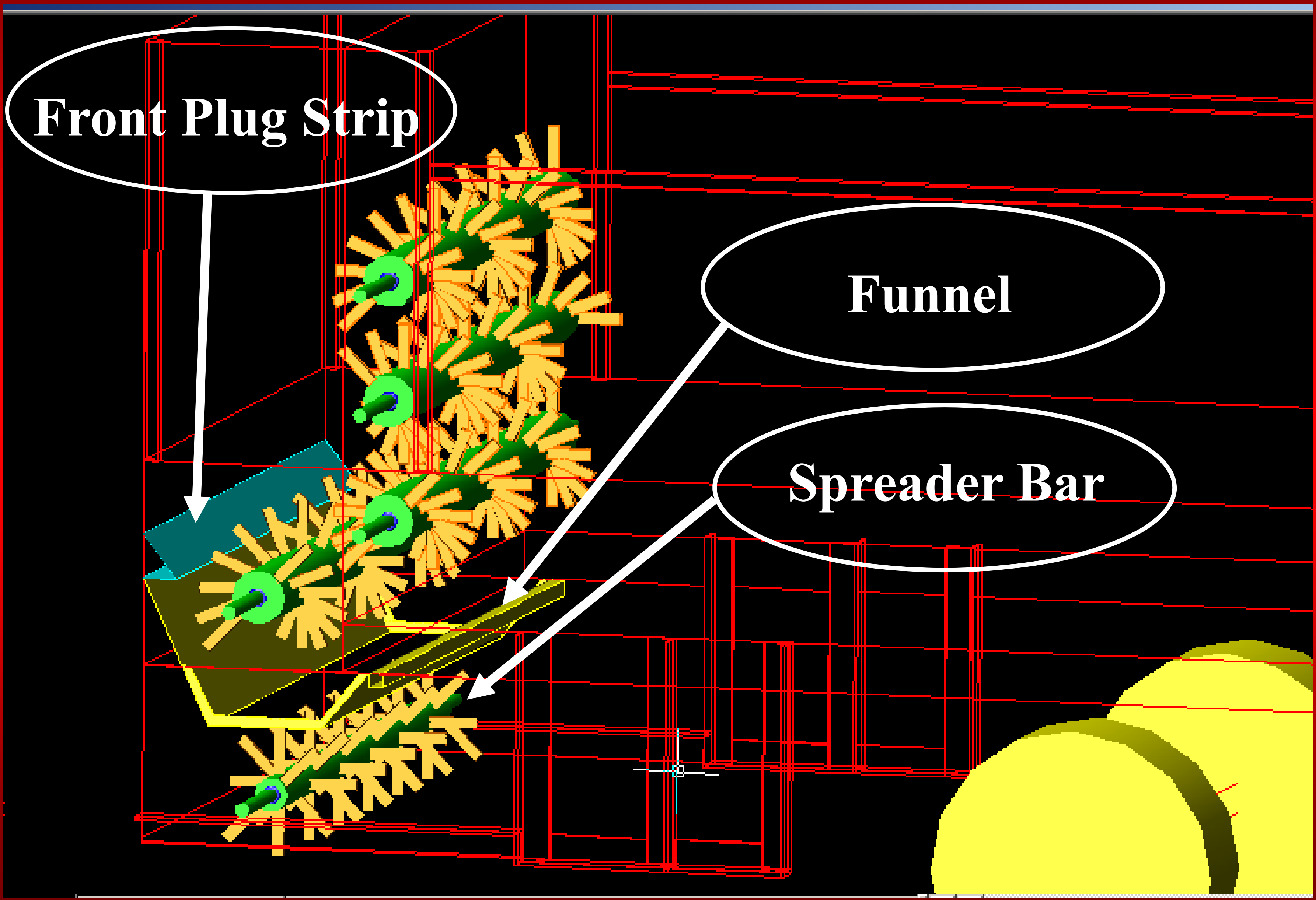
- Clusters of sprigs are flung against front cage and fall past beater bar without contacting it
  - Produces patchy spread of sprigs
- Large bunches of sprigs hang up on front of floor chain
  - Piles of sprigs planted

Sprig Clusters

Hanging from Floor Chain

Round 2

- Fabricated plug strip in front of beater bar to close gap between it and front of cage
- Fabricated funnel to concentrate sprigs on a lower spreader bar
  - Eliminate hung-up sprigs from floor chain
  - Catch sprigs flung to front of cage
- Spreader bar installed below funnel
  - Increase uniformity by working sprigs one last time


Front Plug Strip
Funnel
Spreader Bar

Front Plug Strip

Funnel and Spreader Bar

Round 2 Scorecard

- Plug Strip
  - Directs material flung at front cage back to beater bar
  - Accumulates extra sprigs supplied by flail bar allowing them to be distributed over a larger area
- Funnel and Spreader Bar
  - Catches material riding over edge of floor chain and directs it to spreader bar
  - Spreader bar then spreads any remaining bunches

Remaining Problems

- Throat area still not well defined
  - Box sides not tall enough to hold volume of sprigs sufficient to keep throat full.
  - Throat area must be approx. 1 ft shorter than box sides
- Baffle located too far from top flail bar
  - Sprigs fall off top of pile and into flail bars

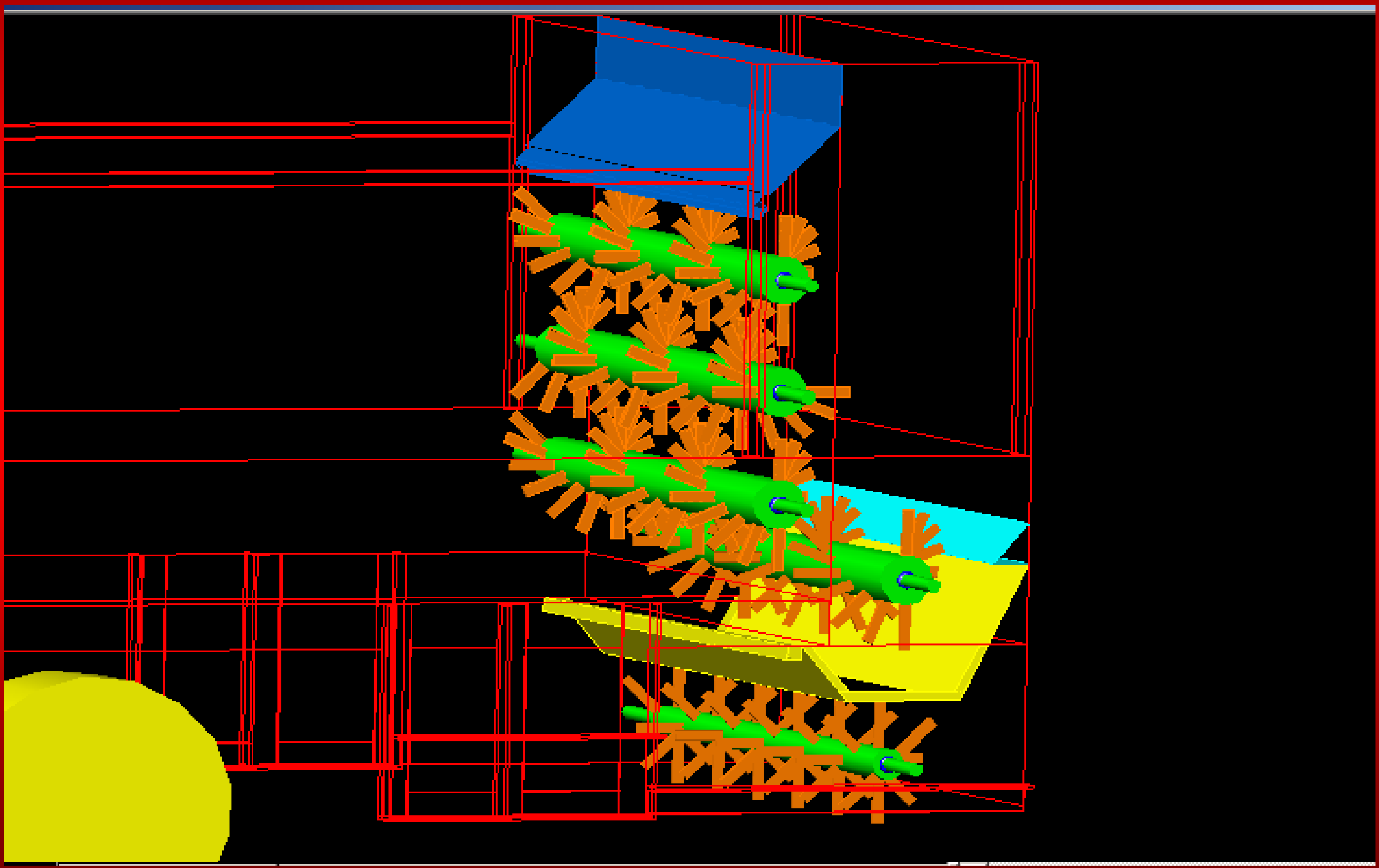
Final Modification

- Further definition of throat area
  - Shorted throat area by moving baffle plate down
  - Bottom of baffle closer; even with midline of top flail bar
  - Should increase uniformity by keeping throat area constant

Throat Area

Distinct Throat Area

The Final System



Final Field Testing

More Field Testing

Round 3 Scorecard

- Most uniform planting we saw in project
- Additional sprigs ride up baffle and later fall down to fill any gaps in sprig cross section
- Still need numbers to support field observations

Lab Testing

- Goals
  - Test modifications to sprigger for improvement over fall results
  - Look for uniformity and consistency

Final Round

Lab Testing Results

Gearbox Setting	Rate Planted (bu/Ac) @ 10mph	% error
3	138.5	23.6
3	138.5	23.6
3	138.5	23.6
3	141.4	26.3
6	220.9	-0.5
6	218.0	-1.8
6	220.9	-0.5

Night & Day

Before

After

Results/Conclusions

- This sprigger is an alternative to rollback for customers needing extremely high planting rates
- Sprigger needs places in system to absorb shock loads of sprigs

Recommendations to Bermuda King

- Use larger diameter flail bars w/shortened knives rotating at lowers speeds
- Install shoots and plates to force sprigs through beater and spreader bars
- Add spreader bar
- Build box sides 1ft taller than throat area

Thank You's

- Bermuda King
  - Brian Henderson
  - Allen Gray
- BAE Lab
  - Wayne Kiner
  - Robert Harrington
  - Robert Harshman
- OSU Applications Engineers
  - Clay Buford
- OSU Foundation Seed
- OSU Agronomy Research Station

Sprigger…………..a WMD?????

Questions…………????????

2002-2003

Bermuda King *L.L.C.*

Senior Design Project

Fall Report

<u>*Submitted by*</u>
Cash Maitlen
Darren George
Mickey Friedrich
Matthew Steinert

11 December 2002
BAE 4012
Dr. Paul Weckler

Introduction

Bermuda King L.L.C.; of Kingfisher, Oklahoma, is an industry leader in the development of Bermuda grass harvesting and planting equipment. The company's chief products include various configurations of grass sprig planters and harvesters. Started in the late 1950's by Willard Duffy, Bermuda King is currently owned by Brent and Brian Henderson. The company has recently expressed a desire to improve their current planter designs in order to stay competitive in the market place. The need to improve and update these products has led to an association with the department of Biosystems and Agricultural Engineering (BAE) at Oklahoma State University (OSU). In particular, students in the BAE senior design class have worked directly with Bermuda King and Clay Buford P.E., an application engineer employed by the OSU extension service. This partnership has yielded positive results in the past and is expected to continue into the future.

Within the 2002-2003 senior design class, a group of four BAE students have created a team named Creative Solutions Incorporated (CSI). Bermuda King has sought the inspiration and dedication of CSI to resolve problems with their high capacity prototype design.

In the late 1990's a prototype machine, called the Super Gray (Figure 1), was fabricated in an effort to develop a line of planters with increased box carrying capacity. It was hoped that the Super Gray would be an alternative to the current high capacity planter which makes use of an expensive and power intensive roll-back device. The Super Gray prototype did not see immediate success and due to limited resources of the company, the machine was shelved.

Prototype Machine

Fig. 1 The "Super Gray" Prototype built by Bermuda King.

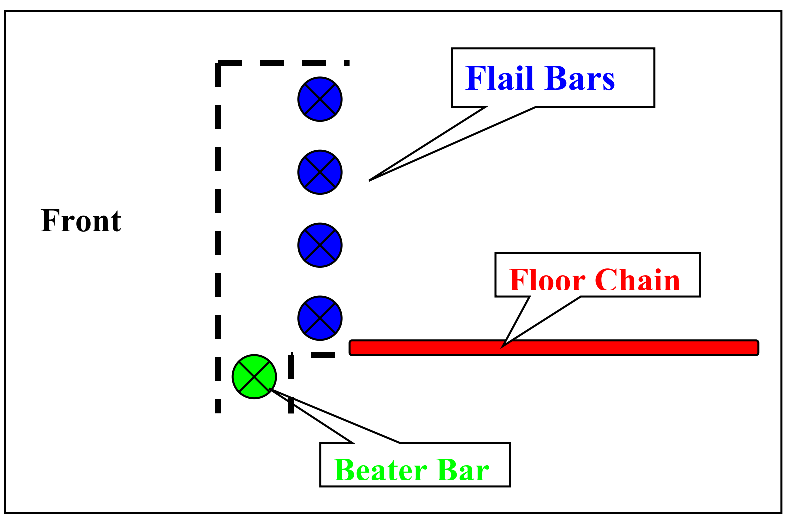


Fig. 2 Simplified Model of Prototype Feeding Configuration (side view)

The prototype configuration, as illustrated in Figure 2, is composed of a floor chain which slowly feeds the sprig mass into four vertically aligned flail bars. The flail bars then attempt to control the feeding rate of sprigs onto the beater bar which in turn distributes the sprigs to the ground. The sprigs are then pressed into the soil with vertical disks. Power is supplied by a tractor through a PTO shaft and into a right angle gear-box. There is no speed reduction in line to the flail bars or beater bar. Speed reduction to the floor chain is accomplished through a variable ring-cone gearbox with a 432:1 minimum reduction and sprockets.

Statement of Work

Following discussions with Brian Henderson of Bermuda King and Clay Buford of the OSU extension service, the following items are to be considered in regard to CSI's involvement with the Super Gray project.

1) The planter's inability to supply a consistent profile of sprigs to the flail bars.
2) The uncontrollable variability in planting density.
3) A desire to plant between 30 and 1000 bu./ac. at speeds up to 10mph.
4) Bermuda King must be able to manufacture the design solutions in house.

The path CSI will take to complete the project will be to analyze the problems in question and develop concepts which will improve the planters performance in these areas, then after selection of the most promising concepts by Bermuda King, design and fabrication of the components will be completed by CSI. Bermuda King is to supply CSI with the Super Gray prototype for testing and modification, in addition to financial support needed for parts, material, and supplies.

CSI will make all test data, drawings, and any other information pertaining to the project available to Bermuda King. Also, the prototype planter with modifications will be returned to Bermuda King.

An oral presentation of CSI's design solution concepts will be presented to Bermuda King in January 2003. After discussion and approval by Bermuda King the project will continue through the end of the 2003 spring semester. A full report and final presentation will be delivered in May of 2003.

Detailed drawings of all design components and modifications will be created. An operator's manual will also be written for proper operation and understanding of the solution. The operator's manual will be easy to understand and will contain any necessary drawings.

A finalized prototype will be constructed and presented to Bermuda King in May of 2003. The modified prototype's performance should be a marked improvement over the initial design.

Design Criteria

Many design factors are associated with the solution. The design solution should be compatible with current Bermuda King sprigger designs. A reasonable design budget to solve the problem needs to be established and proposed to Bermuda King. The design budget needs to include a realistic cost estimate of materials, services, and labor involved with the design work and modifications which is not provided by CSI or any other uncompensated source.

Dimensional restrictions are limited to the ability of the solution to be safely transported, used, and to be loaded by a front end loader. The dimensions of the solution should not exceed the capabilities of Bermuda King to manufacture the solution. All instruments and controls of the solution should be easily understood and operated. All controls should be placed in a convenient and safe location. Warning labels and safety shields need to be placed where possible injury could occur.

Testing

The project brought to use is one that is not clearly defined. It is known that planting rates are highly variable with this machine but the exact cause of the variability remains a mystery. Therefore, it was decided that the first course of action in developing a solution would be to perform extensive testing on the machine to define problems and formulate solutions.

Initial Testing

Initial testing was done with the planter “as-delivered”. The primary purposes of the initial test are listed below.

1. Gain an appreciation for the characteristics of Bermuda grass sprigs and the inherent problems associated with their handling.
2. Gain firsthand experience in the operation of Bermuda King harvesting and planting equipment.
3. Visually observe the planter in operation to gain insight into the problems and possible causes.

Two main problems were observed during the initial operation of the machine. The planting rate is very inconsistent both across the width of the sprigger and along the length of a pass, and the top rear portion of the mass of sprigs roll back as the box is emptied. These two problems are closely related, since the planting rate cannot be expected to remain constant when the profile of sprigs offered to the flail bars is not consistent. But providing a consistent profile to the flail bars would not adequately solve the problem of variation in planting rate. There is a need for further design analysis and refinement of the flail bars and in the overall metering of the sprigs. The problems described can be easily seen in Figure 3 and 4.

Fig. 3 Note the difference between the two dotted lines. The horizontal line is the desired sprig depth, while the diagonal dotted line illustrates the effects of the sprigs sloughing off of the back of the pile.

Fig. 4 In the right picture the lack of consistency in the application of the sprigs is easily seen by the streaking and clumping.

Floor Chain Measurement and Planting Rate Capabilities

Bermuda King suggested a range of planting rates of 30 – 1000 bushel per acre be considered. To determine the range of the "as-delivered" planter a series of test were conducted to determine the maximum chain speed available. A spreadsheet was constructed to determine theoretical planting rates based on ring-cone settings and floor chain speeds. Table 1 indicates the capability of the planter "as-delivered". The table indicates the highest planting rate to attained is 327.9 bu/ac while traveling at 5 mph.

Gearbox Setting	Planting Rates (bu/ac)				
	5mph	6mph	7mph	8mph	9mph
1	32.8	27.3	23.4	20.5	18.2
2	65.6	54.6	46.8	41.0	36.4
3	98.4	82.0	70.3	61.5	54.6
4	131.2	109.3	93.7	82.0	72.9
5	163.9	136.6	117.1	102.5	91.1
6	196.7	163.9	140.5	123.0	109.3
7	229.5	191.3	163.9	143.5	127.5
8	262.3	218.6	187.4	163.9	145.7
9	295.1	245.9	210.8	184.4	163.9
10	327.9	273.2	234.2	204.9	182.2

Table 1

Developing a Baseline

To quantify the variation in planting density and to determine if future modifications improved that variation, a baseline needed to be developed. To accomplish this the planter was loaded with sprigs, a tarp was placed beneath the beater bar on the ground, the planter was engaged for one minute and the sprig output was collected and weighed (See Figure 5). Data from this test is shown below in Table 2.

Fig. 5 Second Test Setup

Experiment	Time (min.)	Ringcone Setting	Discharge (kg)
1	1	10	51
2	1	10	100
3	1	10	67
4	1	5	40
5	1	5	45
6	1	5	34

Table 2 Discharge Rates before Modification

After observing six test runs it was determined that some modification was needed to help meter the flow of sprigs through the throat area. The chains powering the second and fourth flail bars were removed to observe results (See Figure 6). The non-powered flail bars were observed only to have slight rotation during operation. Only two tests were conducted to analyze the results of the modification because sprigs were noticed to jam against flail bar 2. The results are listed below in Table 3.

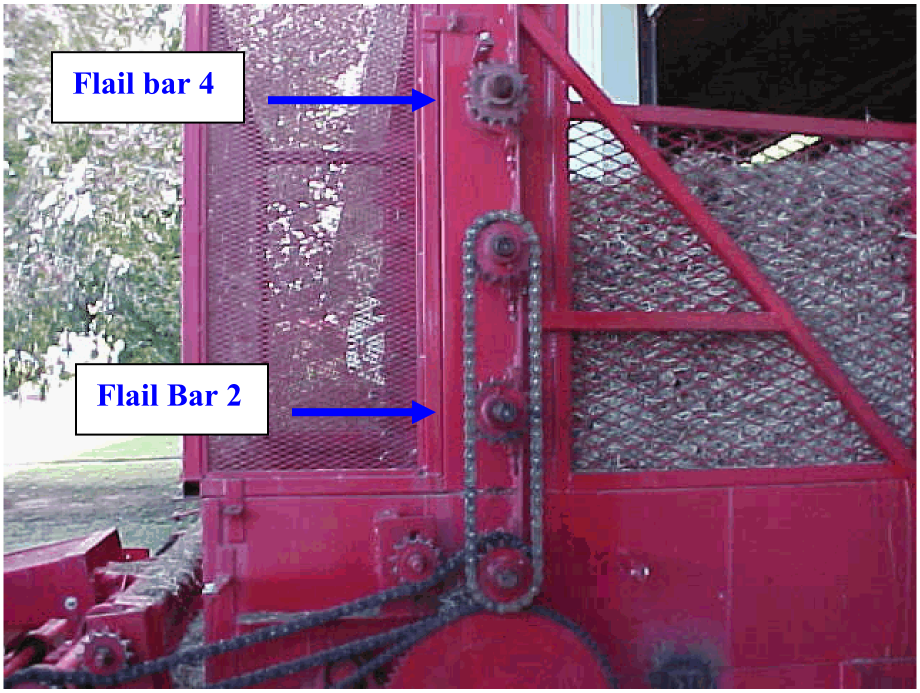


Fig. 6 Chains Removed from Flail Bars 2 and 4

Experiment	Time (min.)	Ring-cone Setting	Discharge (kg)
1	1	10	28
2	1	10	16

Table 3.

It was then decided that flail bar 2 needed to be rotated during operation to keep the sprigs from jamming against it. A hydraulic motor was mounted to power the second flail bar by use of a chain and sprockets (Figure 7). An oil flow control valve was connected in series with hydraulic lines running from the test tractor to the motor.

A series of tests was first performed to observe which direction of rotation and the rotation rate which would produce the best discharge characteristics. Counter rotation at 20 rpm was found to produce the best results, and a set of three tests were performed for these settings. These results are posted in Table 4.

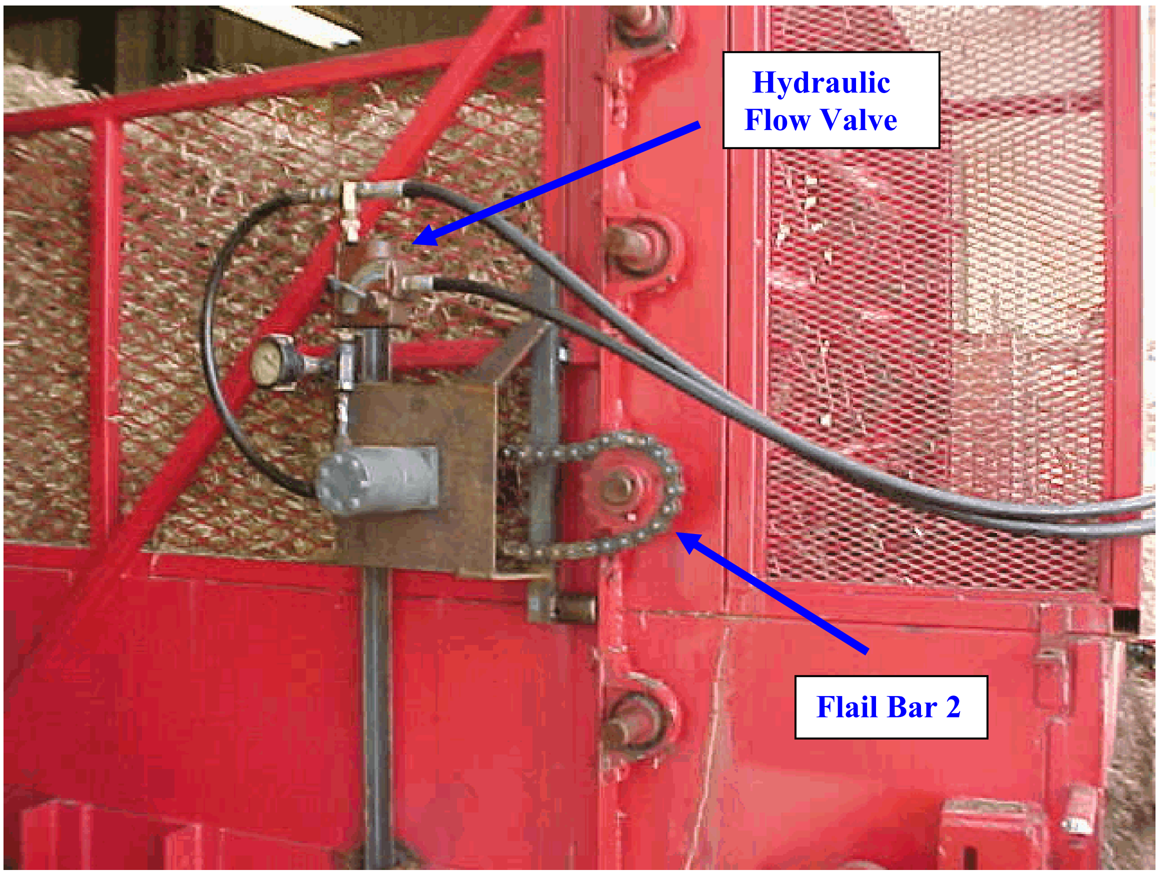


Fig. 7 Hydraulic Motor Mounting

Experiment	Time (min.)	Ringcone Setting	Discharge (kg)
1	1	10	17
2	1	10	11
3	1	10	15

Table 3 Discharge Rates with Hydraulic Motor

While this modification did not improve our ability to achieve the target rate, it did decrease the rate variation, thus allowing us to plant a more uniform rate. Therefore, we believe this shows promise as a possible solution.

Definition of Problems

After extensive testing we believe the root cause of all variation in planting rate to be the fact that the flail bars engage varying horizontal depths of sprigs throughout operation. As a result of the large metering throat area the floor chain must move extremely slow to achieve desired planting rates in the bottom half of the range. In comparison to the standard Bermuda King sprigger, the Super Gray throat area is more than 4 time as large, and as a result the floor chain must move at ¼ the speed to achieve the same planting rate. This creates the actual "problem": the flail bars are capable of removing significantly higher rates of sprigs from their rotational area than the floor chain can deliver for most planting rates.

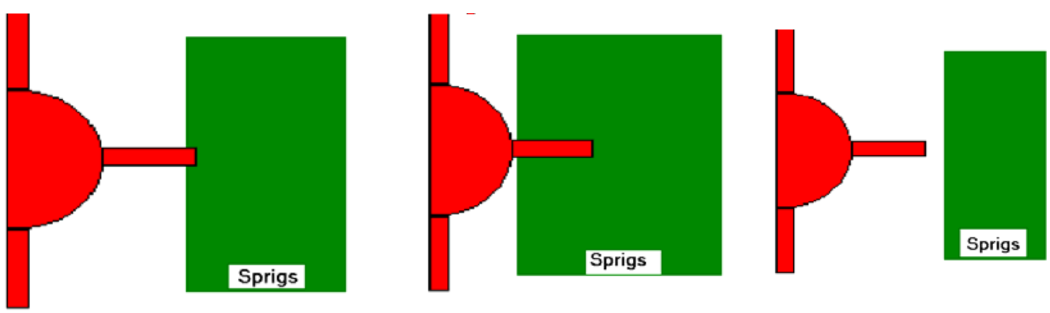


Fig. 8 Illustration of Flail Bar Operation

The three operation modes of the flail bar are illustrated in (Figure 8). During normal operation only the tip of the flail bar engages and removes and sprigs from the pile as seen in the left image. However, as illustrated in the middle image during initial start up or in rough terrain, the sprig pile shifts forward until stopped by the drum of the flail bar which causes significantly higher rates to be momentary planted. The image on the right is the exact opposite of the previous situation. Here the flail bars have previously separated sprigs from the pile which were not in their rotational area, therefore the flail bars continue to run empty until the floor chain moves the pile forward and engage them again. During this situation an initially higher rate is planted as the flail bars remove sprigs outside their rotational area; however planting rate is reduced over an extended period of time until the floor chain catches up.

The second problem contributing to rate inconsistency is one which was initially observed by Bermuda King. The height of sprigs in the box decreases as the machine empties causing the effective metering throat area to decrease as well. A smaller throat area and constant floor chain speed result in decreased planting rates. This is partially offset by the fact that some of the change is height is a result of the sprigs settling. As they settle the bulk density of the sprigs in the box increases and thus an equal planting rate can be achieved with a smaller throat area. However, some of the change in sprig height is a result of sprigs falling off the back of the pile as the sprig mass moves forward. This is a contributing factor to the reduced planting rates we observed as the final 10% of sprigs in the box were planted.

Solutions Approach

Two completely different approaches to developing solutions are possible. One method is to develop a totally new concept from scratch. The other approach is to develop a series of small modifications and adjustments intended to improve the performance of the prototype machine. Due to the scope of this class and the time required to adequately design and fabricate a complete machine, we are concentrating our efforts on maximizing the current prototype design. Our goal is to develop a series of "mini-solutions" which can then be packaged to provide optimal improvement in planter performance.

Proposal #1

The first proposed design modification is to incorporate a set of multiple mini-solutions. First, we suggest decreasing the flail bar length while increasing the flail bar drum diameter to correct the problems entailed with current flail bar design and its' engagement of varying amounts of sprigs. We also believe performance could be improved if the speed of the flail bars were reduced. A moving tailgate could also be incorporated into this design to further increase planting accuracy.

Proposal #2

The second proposal is also simply a set of modification to the current machine design. It would consist of utilizing three vertical flail bars to supply sprigs to the bottom beater drum. A slotted cage would be placed over the beater drum and sprig metering would be controlled by the speed of the beater drum.

Proposal #3

The third and final proposal is to retract previous statements and investigate a revolutionary new sprigger design not based on the current prototype. This would change the nature of the project into more of an investigation of possible concepts rather than the creation of a fully operational prototype. In the end the decision about which course of action we choose to pursue will be the discretion of Bermuda King and its' owners. Currently, we plan to meet with Bermuda King and their management just after the first of the year to discuss the future and direction of this project.

2002-2003
Bermuda King L.L.C.
Senior Design Project

Presented by CSI:

Mickey Friedrich
Darren George
Cash Maitlen
Matt Steinert

Project Sponsor

- Project is sponsored by Bermuda King L.L.C. Owners Brent and Brian Henderson
- Bermuda King is an industry leader in the development of sprig harvesting and planting equipment.
- Operating in the Kingfisher area for over 35yrs.
- Visit their website at www.bermudaking.com

Initial Proposed Design Project

- Develop Sod to Sprigs Planter
- Patent search   www.uspto.gov
  - Revealed Similar Patented Devices
- It was the decision of Bermuda King not to continue this project due to possible future legal implications.

Revised Design Project

Bermuda King Super-Gray Prototype

Basis for Prototype Creation

- Decrease fill time.
  - Increase box capacity
- Alternative to roll-back device
  - expensive and power intensive.
- Originally developed late 90’s it was
  - operated only once before being shelved.

Perceived Problem

- Non-uniformity of planting rate.
  - Rate varied as box emptied
- Variation of sprig height in box.
  - Height of sprigs in box decreases as box empties.
  - Believed to be cause of non-uniformity

Project Presented by Bermuda King

- Develop an adaptation to current prototype design enabling a consistent profile of sprigs to be delivered to the flair bars.
  - They initially felt that this could be achieved by the installation of a moving end gate to prevent sprigs from falling off the back of the pile.
- Open to any alternative designs for increasing box capacity.

Initial Testing

- Goal was for the group to:
  - Gain an appreciation for the characteristics of bermuda grass sprigs and the inherent problems associated with their handling.
  - Gain firsthand experience in the operation of Bermuda King harvesting and planting equipment.
  - Operate machine “As Delivered” to observe possible problems.

Learning the Ropes!

Our Analysis of Initial Testing

- Planting rate was highly variable.
  - Significantly higher planting rates are produced in the first 5 seconds of operation following loading.
  - Extremely erratic planting rates during planting of final 10% of sprigs.
  - Erratic planting rates when traversing rough terrain or traveling uphill.
  - Lowest rate setting on machine still produces what appeared to be a relatively high planting rate.
- Height of sprigs does decrease as box empties.

Challenge #1 (Desired Planting Rate)

- Machine is not capable of obtaining desired planting range of 30-1000 bu/ac at 10 mph.
- Planting rates are difficult to set accurately.
  - A 10 bu/ac rate change corresponds to ½ unit change in gearbox setting.

Gearbox Calibration

Developed calibration between gearbox settings and theoretical planting rates.

Gearbox Setting	Planting Rates (bu/ac)				
Speed (mph)	3	4	5	6	7
1	54.6	41.0	32.8	27.3	23.4
2	109.3	82.0	65.6	54.6	46.8
3	163.9	123.0	98.4	82.0	70.3
4	218.6	163.9	131.2	109.3	93.7
5	273.2	204.9	163.9	136.6	117.1
6	327.9	245.9	196.7	163.9	140.5
7	382.5	286.9	229.5	191.3	163.9
8	437.2	327.9	262.3	218.6	187.4
9	491.8	368.9	295.1	245.9	210.8
10	546.5	409.9	327.9	273.2	234.2

Gearbox Setting	Chain Speed (ft/min)
1	0.104
2	0.207
3	0.311
4	0.414
5	0.518
6	0.621
7	0.725
8	0.828
9	0.932
10	1.035

Challenge #2 (Variation)

Flail bars engage varying horizontal depths of sprigs causing "sprig piles" to be planted.

Plan of Attack

- Develop baseline variation.
- Develop mini-solutions.
- Create a package.

Developing a Baseline

Test Procedure

- Calibrated sprig density for our set of test sprigs. 5.66 lbs/ft^3

- Machine operated stationary for 1 minute @ 540 pto rpm while sprigs were collected and then weighed.

- Test conducted over wide range of gearbox settings.

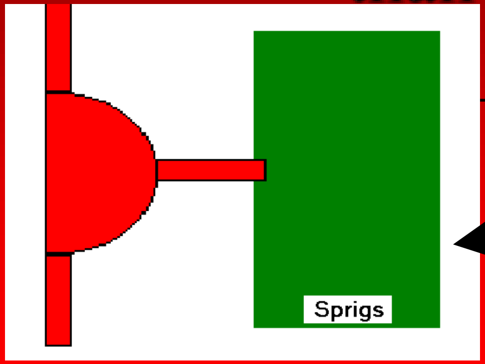
Summary of Results

Gearbox Setting	Rate Planted (bu/ac) @ 10mph	Calc. Planting Rate (bu/ac) @ 10mph	Error
10	131	164	-20.22%
10	257	164	56.43%
10	172	164	4.80%
5	103	82	25.14%
5	115	82	40.78%
5	87	82	6.37%
		Average Error	18.88%

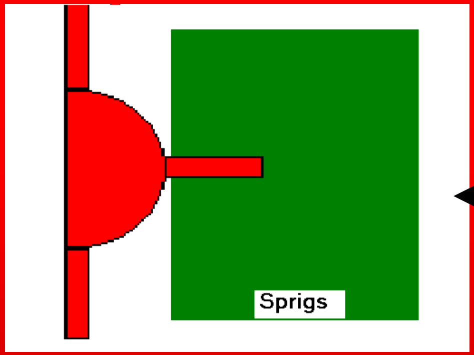
Test Observations

- During this and all previous test top flail bar engaged very few sprigs.
- Floor chain does not slip at the back of the sprig pile.
  - Change in box height is due to settling of sprigs.
- Large metering throat and extremely slow moving floor chain making consistent metering difficult.

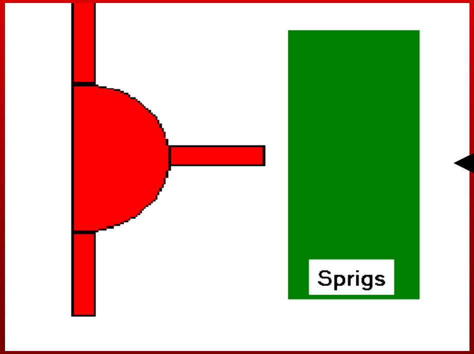
Flail bars remove sprigs at significantly higher rates than the floor chain can deliver sprigs.



- Normal Operation
  - Only tip of flail bar engages sprigs



- Initial Start-up or Bouncing
  - Sprig pile moves forward until stopped by drum causing flail bars to engage a much larger volume of sprigs
  - Causes sprig piles to be planted.



- Sprigs not inside flail bar travel area are removed by bars.
  - Reduced Planting rate, no sprigs available to bar.

Modifications

- Disconnected top flail bar to reduce throat area.
- Converted middle flail bar to hydraulic drive so that we could vary it's speed and direction.
- Eventual complete removal of top flail bar.

Performance of Modifications

- Removal of top flail bar
  - Successful in reducing throat area, no negative impact on performance.
- Hydraulic drive of second bar
  - Improved metering consistency when rotated slowly and used as a “metering bar” to supply sprigs to bottom bar.
- Possibility of rotating all vertical flail bars slower to be used as metering bars.

Proposed Solutions

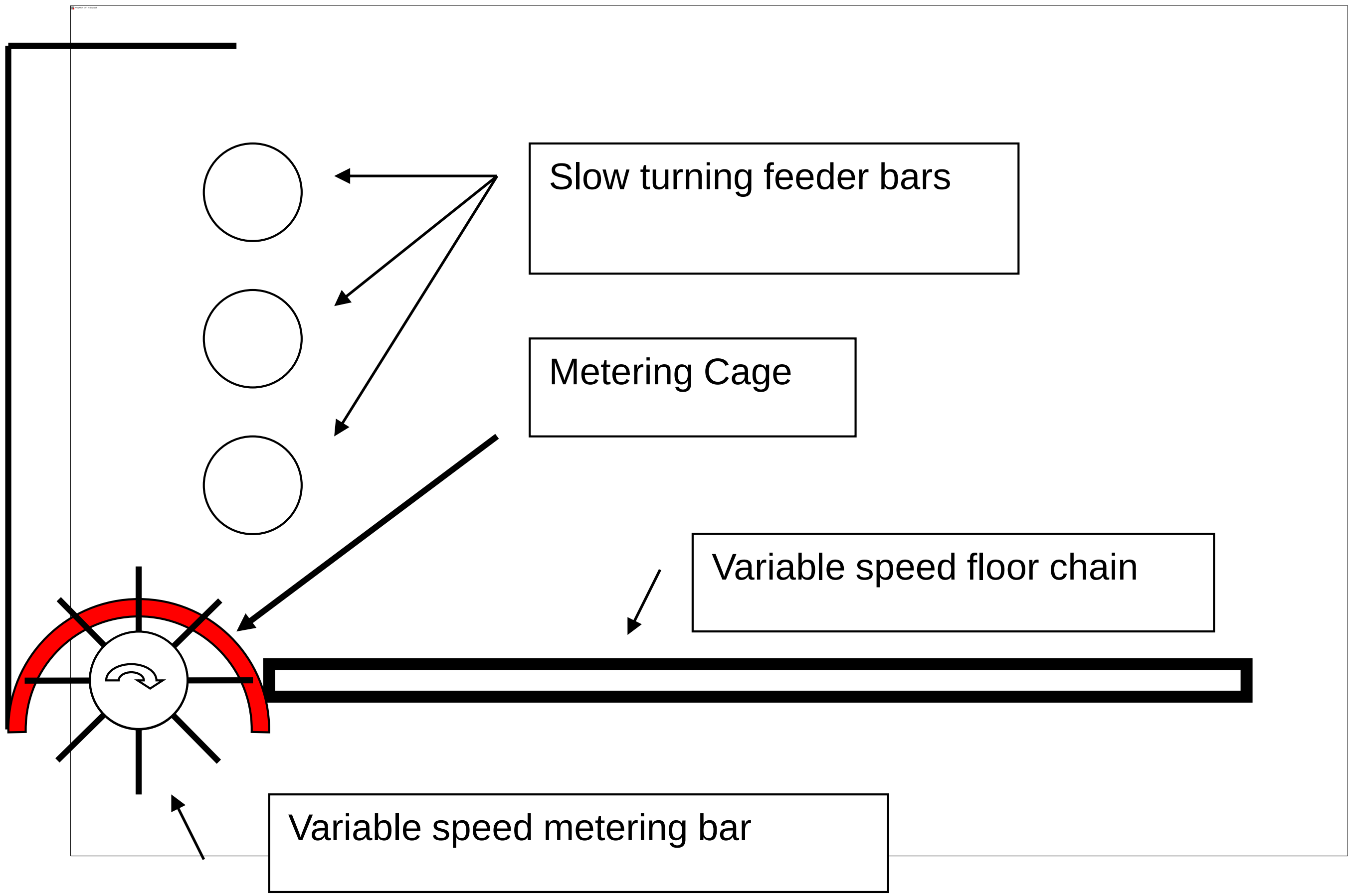
- We feel that the inconsistent metering characteristics of current flail bar system are the largest source of planting rate error and the most critical problem.

- Proposed Solution
  1. Removal of Top Flail bar to reduce throat area.
  2. Increase Flail bar drum diameter while decreasing individual flail bars lengths.

Alternative Solutions

- Metering Cage
  - Turn flail bars slow and use caged beater bar to meter sprigs
- Lift and Feed Design
  - Ramp floor chain at front and used “flipper” drum to define throat area.
- Cleated Floor Chain
  - Used to drag sprigs through small frontal opening.

Alternative Solution (Metering Cage)



Sprigging……………..A spectator Sport!

Questions……….????????