

Project Learning

Looking at conventional debalering machines they are basically the same. One rotating shaft with either teeth or hammers attached. Those designs all pose the same problem to our client. They induce shear forces onto the product stands and cause fines (smaller than $\frac{1}{8}$ "") to be produced. With this in mind a new way of debaling needed to be designed. From the beginning we desired to use premade components and implement them in new ways. That way if something were to fail it would be easy to procure the part and fix the machine. Conveyor chains with attachments, stump grinder teeth, sprockets, bearings, etc. Anything that can be bought will be.

The design that was decided on was what we believed closely emulated human hands pulling a bale apart. When hands pull apart a bale they move linearly not rotating like a shaft. Our design pulls teeth linearly through the face of the bale in an effort to reduce the amount of shear forces generated.

Why did the design not work?

While hammer mills created the desired steady out flow of material, the shearing action causes a great deal of material to be broken up into smaller particles, called fines. Fines become wasted product leading to poorer efficiency. Single shaft non hammer mill designs have a poor mass flow rate out as the material does not usually exit the machine until a full flake has been peeled off. This is because the material has a tendency to bunch up and fall out of the machine rather than creating a continuous flow.

What needed to be changed?

Design Goals

Client Goals

1. Mechanical device to pull apart and fluff agricultural materials
2. Produce less unusable particles, or fines, than a traditional hammer mill
3. Consistent outfeed of material; less than 15% change of mass flow rate
4. Easily transportable by a semi trailer
5. Prototype and Proof of concept to withstand 100 lb bales
6. Full scale device to withstand 2,000 lb bales
7. Conveyor like infeed system
8. Conveyor outfeed

Project Schedule

Week	Dates	Item	Start Date	End Date
Fall 2019				
1	Aug 26 - Aug 30	None		
2	Sep 2 - Sep 6	None		
3	Sep 9 - Sep 13	Team Assignment		
		Team Contract		
4	Sep 16 - Sep 20	None		
5	Sep 23 - Sep 27	Client Interview		
6	Sep 30 - Oct 4	PRD for Debaler	10/1/2019	10/3/2019
7	Oct 7 - Oct 11	Create Project Schedule	10/7/2019	10/8/2019
		Create Budget	10/7/2019	10/10/2019
		Basic Sketch of Initial Idea	10/7/2019	10/9/2019
		Submit Logbooks and Portfolio	10/10/2019	10/10/2019
		Touch base with client	10/12/2019	10/12/2010 9
8	Oct 14 - Oct 18	Snapshot	10/15/2019	10/15/2019
		Purchase hay bales	10/20/2019	10/20/2019
		Test force to pull apart bale	10/21/2019	10/21/2019
		Write Design validation plan	10/19/2019	11/5/2019
9	Oct 21 - Oct 25	Design Validation Plan	11/10/2019	11/10/2019
		Analysis on initial concept	10/25/2019	10/25/2019
		Begin modeling of debaler	11/5/2019	
		Spec out motor/hydro pumps		
		Write project value proposal	11/12/2019	11/12/2019
10	Oct 28 - Nov 1	Project Value Proposal		
		Begin modeling of infeed	11/10/2019	
		Begin modeling of hopper and outfeed	11/5/2019	

		Write Wikipage	11/2/2019	
11	Nov 4 - Nov 8	Draft Wikipage	11/2/2019	11/2/2019
		Construct simple proof of concept model	11/7/20109	
12	Nov 11 - Nov 15	Logbook/portfolio review		
		Complete proof of concept model	11/13/2019	11/13/2019
13	Nov 18 - Nov 22	Concept Design Review with client		
		Team Member Citizenship		
14	Nov 25 - Nov 29	Thanksgiving Break		
15	Dec 2 - Dec 6	Prep for Snapshot #2		
16	Dec 9 - Dec 13	Snapshot #2		
		Logbook/portfolio review		
		Wikipage update		

Spring 2020			
1	Jan 20 - Jan 24		
2	Jan 27 - Jan 31	Register for Design Expo	
3	Feb 3 - Feb7	Complete drawing packet for scale model	
		Start work on scale of project to full-size	
4	Feb 10 - Feb 14	Purchase material	
5	Feb 17 - Feb 21	Engineering Release Review	
		Logbook Review	
6	Feb 24 - Feb 28	Begin construction/fabrication	
7	Mar 2 - Mar 6	Prep Material for Snapshot 3	
8	Mar 9 - Mar 13	Snapshot #3	
		Team member citizenship form	
9	Mar 16 - Mar 20		
10	Mar 23 - Mar 27		
11	Mar 30 - Apr 3		
12	Apr 6 - Apr 10		
13	Apr 13 - Apr 17	Logbook Review	
14	Apr 20 - Apr 24		
15	Apr 27 - May 1	Expo	
		Technical Presentation	
		Booth Display/poster	
16	May 4 - May 8		

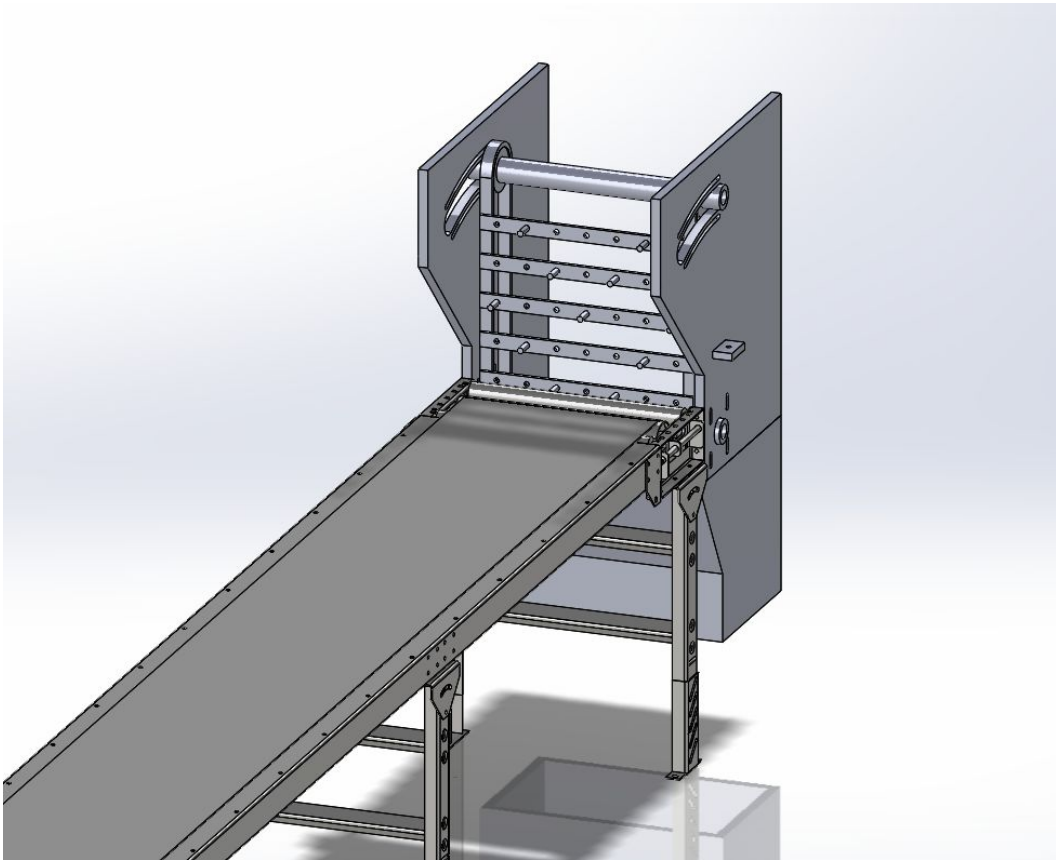
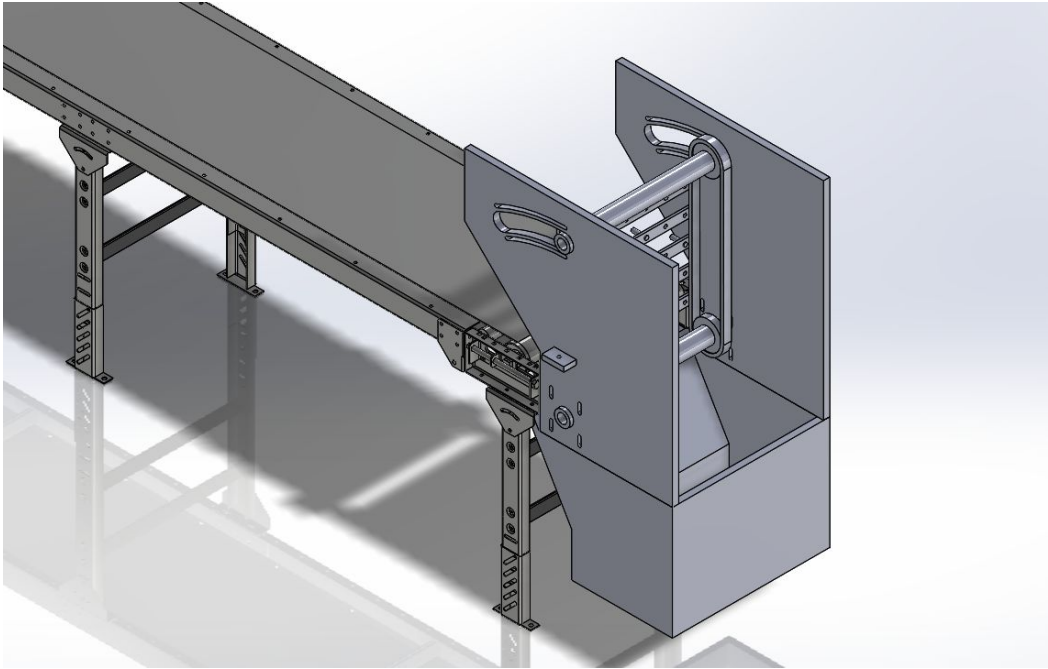
Specs and Constraints

1. Reduction of fines pieces under $\frac{1}{8}$ " diameter, compared to fines produced by a hammer mill (possible removal of fines altogether)
2. Mass flow rate of output feed must not vary more than +/- 15%
3. Must be able to accommodate multiple types of biomass, such as corn stover, straw, and other baled crops
4. Full scale prototype must be able to accommodate a 4' x 4' bale (1 ton)

Analysis of Alternatives

In terms of safety the design will have guards over the feed system, chain assembly, bale debaling interface and any point of entry into the machine. The cost can be lower if inferior parts are to be used. If the teeth are replaced with just hardened bolts just for an example. Durability is tied directly with cost. Less expensive means less durable. The goal is to implement it into any conveyor system. If the system can handle a bale this debaler should work. After setting are set, this machine won't have to be messed with.

Engineering Modeling



Experimental Design

Design Validation Research

Requirement	Test	Test Subject	Target Date	Result	Recommendation
Minimal generation of fines during debaling of material	Fluff bale material apart and measure fines already contained in bale before processing	1 straw bale and 1 grass bale	10/21/19	Tested 10/21/19 -1 flake of straw contains approximately 2 oz of fines, 1 flake of grass contains approximately 4 oz	
Force required to draw claws through material	Draw a pitchfork through the bale material in different orientations and measure the force required to do so	1 straw bale and 1 grass bale	10/21/19	Tested 10/21/19 - Force to draw pitchfork through bale at a depth of 2" ranges from 5-15lbs	Draw claws through bale perpendicular to the orientation of the material, as this was observed to require much less force and causes better dispersion of material
Consistent feed of bales into debaling mechanism	Test whether a claw feed, conveyor feed, or gravity feed best suit the goal of the project	1 bale, as well as conveyor, claw, gravity feed mechanisms	11/18/19		

Data Analysis

Raw data collected from initial testing is shown below. The first two tables show data collected from drawing the pitch fork through bales perpendicular to the strands of grass and straw respectively.

Grass	Test 1	Test 2	Test 3	Test 4
Time (sec)	Weight (lbs)	Weight (lbs)	Weight (lbs)	Weight (lbs)
0	0	0	0	0
1	1.875	1.75	1.5	0.625
2	3.6875	3.75	3.625	2.875
3	6.25	8.875	5.5	7.75
4	8.75	11.25	6.625	10.625
5	6.625	11.75	7.875	11.75
6	3.25	11.875	8.5	11.5
7		9.125	8.125	8.875
8		8.25	7.5	7.5
9		7.625	6.25	
10			3.75	

Straw	Test 1	Test 2	Test 3	Test 4
Time (sec)	Weight (lbs)	Weight (lbs)	Weight (lbs)	Weight (lbs)
0	0	0	0	0
1	1.875	1.25	1	1.375
2	5.5625	5.75	2.25	2.5
3		12.5	4.25	4.875
4		15.25	5.5	4.375
5		14.625	5.75	3.625
6		14.75	6.375	
7		16.5		
8		21.875		
9		18.5		
10		10.375		

Raw data from tests where the pitchfork was pulled parallel to the strands of the bale is shown below.

Straw Par	Test 1	Test 2	Test 3
Time (sec)	Weight (lbs)	Weight (lbs)	Weight (lbs)
0	0	0	0
1	0.75	0.625	1.125
2	1.875	2	2.875
3	4.5	3.5	5.25
4	6.25	4	6.5
5	9.125	4.5	7.5
6	9	5.625	8
7		6.75	8.75
8			9
9			9.5
10			

Appendices

Basic dimensions and compositions of the bales used in testing are represented in the tables shown below

Straw			Units
Volume	19"X13"X6"	1482	inches^3
Bulk	1.875 lbs		
Fines	0.25 lbs		
Fines by Volume	0.0001686909582	0.02%	
Fines by Mass	.1333	13.3%	

Grass			Units
Volume	19"X13"X3"	741	Inches^3
Bulk	2.75 Lbs		
Fines	0.25 lbs		
Fines by Volume	0.0003373819163	0.03%	
Fines by Mass	.0909	9.09%	