Department of Biosystems and Agricultural Engineering
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Biosystems Design Projects

Ergonomic Sampling Tool to Obtain Bulk Feed Samples Safely

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Background

State-level feed regulations are overseen by the American Feed Industry Association (AFIA)[1]. Ensuring feed quality and safety through proper sampling techniques is essential. The Animal Feed Safety Program, managed by the Michigan Department of Agriculture and Rural Development (MDARD), oversees feed facilities to ensure standards are met with guidance from the Association of American Feed Control Officials (AAFCO)[2]. The current sampling method that needs replacing is shown in Figure 1:

Figure 1: Current sampling tool

The shift towards bulk feed distribution has added safety risks to feed inspectors. The current sampling method, as per the AAFCO standard, calls for inspectors to get close to the flowing grain, posing additional risks such as climbing onto trucks or reaching over from ladders. To lessen these risks, MDARD is exploring safer sampling methods from the ground, prioritizing safety and ergonomic considerations to protect inspectors. Figure 2 shows an image of a typical loading station for feed trucks.

Figure 2: Typical feed truck loading station with a catwalk

This leads to the problem statement: Optimize the sampling prototype to improve ergonomics and safety for feed inspectors while ensuring correct representative samples

Objectives

- Determine sample cup weight and material to withstand roughly 8,000 lb/min of feed
- Acquire representative samples with less than 10% relative error between the new system and the current system
- Test the prototype with the three different types of feed shown in Figure 3

Figure 3: Three different types of bulk feed: combination, grain, and pellet

Constraints

- Hold 5 lb. of feed
- Perform sampling at various heights up to 13.5 ft
- Fit within all MDARD vehicles
- Meet Occupational Safety and Health Administration (OSHA) standards
- Hold pellet, fine grain and combination feed individually
- Effective in all types of weather
- Inner compartment must be able to be properly sanitized
- Can be used from the ground and catwalks

Design Alternatives

Four design alternatives were conceptualized and considered. The first three are shown in Figures 4 to 6.

- Design 1: Optimized Pole

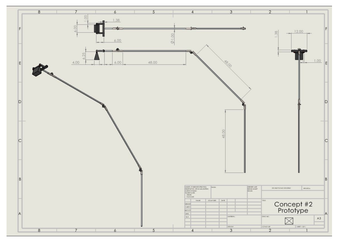

Figure 4: SolidWorks model of the optimized pole

- Design 2: Rigid 90° Elbow

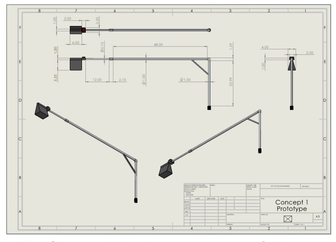

Figure 5: SolidWorks model of the rigid 90° elbow

- Design 3: Vacuum Nozzle

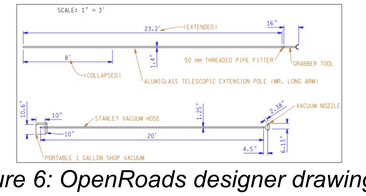

Figure 6: OpenRoads designer drawing of the vacuum design

- Design 4: Ratchet Straps
  - Consists of two ratchet straps meeting over the truck to hang a sampling cup below the hopper
  - This design was deemed nonviable, and the team's focus shifted to the other designs.

Selected Design

Designs were rated and compared using a decision matrix, shown in Table 1. Design #2, the rigid 90° elbow pole, scored the highest overall. This design was chosen since it provided the maximum overall rating of ergonomics, maneuverability, durability, and sampling time while also ensuring the standard sampling cup size was still used.

Table 1: Decision Matrix

	Factor	Ergonomics	Maneuverability	Durability	Cost	Sampling Time	
	Weight (%)	30	25	25	10	10	Total
Alternative	Optimized Pole	3	7	10	8	5	6.45
	Rigid 90° Elbow	7	10	7	1	7	7.15
	Vacuum	10	5	5	5	7	6.7
	Truck Straps	5	3	3	10	3	4.3

Key features of this design include:

- An aluminum tube with four different segments
- Back up camera and monitor powered with portable battery pack
- Handle for more ergonomic hold
- Standardized MDARD sampling cup
- Removable horizontal pole for sampling from the catwalk
- Foam pad for resting the horizontal rod against the side of the truck

The fully constructed prototype can be easily switched for sampling from the ground or from a catwalk. The prototype can be seen prepared for sampling from the ground in Figure 7.

Figure 7: Fully constructed prototype

Switching to catwalk sampling is as simple as removing the cup and attaching it to one of the vertical segments. The tool can be seen prepared for catwalk sampling in Figure 8.

Figure 8: Catwalk sampling customization

Testing

Testing was conducted to find the change in force felt while feed drops. A luggage scale was fixed to the pole to measure this force. Feed was dropped five times. The results are shown in Table 2:

Table 2: Testing results

Trial	Initial Weight (lbs.)	Final Weight (lbs.)
1	2.2	4.4
2	1.8	3.6
3	2.7	4.5
4	2.2	3.7
5	1.8	3.5
Average	2.14	3.94

- Force increased nearly 85% on average
- A handle was added to improve control over the tool
- Testing did not consider the foam pad that rests on the side of trucks

On-site testing was conducted at the Purina site in Lansing. Four samples were collected using the tool. This is shown in Figure 9.

Figure 9: Prototype collecting sample

- 5 seconds to fill cup
- 25 seconds total to retrieve sample

Following testing, optimization is needed.

- Increase inner diameters of the poles to reduce weight
- Implement leveling mechanism

Ergonomics

Ergonomic calculations are important for this design, especially for safeguarding users' safety, comfort, and efficiency while using this tool. These calculations rely on recommended ranges sourced from the Occupational Safety and Health Administration (OSHA) standards and the textbook 'Human Factors in Engineering and Design'[3].

Table 3: Key ergonomic values for the selected design, including loading force, total bending moment, and the moment at hand.

Parameter	Recommended Range	Calculated Output
Force	45 to 110 N	49.59 N
Total Bending Moment	55 to 99 Nm	64.61 Nm
Moment at Hand	30 to 50 Nm	31.92 Nm

Continuously refining the design based on user feedback, such as adding two lower handles, can address any possible discomfort and boost efficiency. Additionally, conducting biomechanical analysis and ongoing monitoring ensure optimization for worker safety.

Economics

In constructing the prototype, a bill of materials was generated to track the purchased parts. This is shown in Table 4.

Table 4: Prototype bill of materials

Item	Quatity	Description	Part #	Cost
Alro Steel				
1	1	Aluminum Rod	Part #: 20211200	$186.24
Amazon				
2	1	Foam Pad	ASIN : B01A86Z870	$19.95
3	1	Phone Mount	ASIN : B077L9742K	$18.95
4	1	Back Up Camera	ASIN: B07Q85L22L	$119.99
5	1	Battery Pack	ASIN: B07JGG163B	$69.99
Home Depot				
6	1	6' Aluminum Rod	Model # 50-A100ID/6	$28.14
Grainger				
8	1	90° Aluminum Pipe Elbow	Item: 54WK23	$15.63
McMaster-Carr				
9	1	Aluminum sheet	Item: 88895K106	$29.11
			Total	$488.00

A total construction cost of $488.00 was accrued. With 7 feed inspectors currently employed, this comes out to $3,416.00 to get this tool to all inspectors. This cost only includes materials and not manufacturing labor. Optimization and further testing is necessary before this tool can be fully implemented by the sampling department.

As this tool would be a one-time expense for each inspector, this cost would be justifiable. The prototype uses universal connections to simplify replacing parts if they were to be damaged. This tool would serve as a long-term solution to the issues brought with the switch over to bulk feed distribution.

MDARD hopes to further test the tool after this project. With further testing, the tool will be optimized to meet MDARD's needs.

Select References

1. American Feed Industry Association. (2023). History of feed regulations. https://www.afia.org/issues/feed-food-safety/history-of-feed-regulations/
2. Association of American Feed Control Officials. (2020). Feed Inspector's Manual: 8th ed. Association of American Feed Control Officials Inspection and Sampling Committee .https://www.aafco.org/document/feed-inspectors-manual-8th-ed/
3. McCormick, E. J., & Sanders, M. S. (1987). Human Factors in Engineering and Design (6th ed.). McGraw-Hill.

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