SENIOR CAPSTONE/
SENIOR DESIGN EXPERIENCE

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Grain Bin Floor Cleaning System

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Executive Summary

Cleaning grain bins can be a dangerous and time-consuming process. The hazards posed include unguarded augers, dust, mold, mildew, and the physical strain of manually cleaning a bin. The main goal of this project is to limit the time a farmer or hired worker is inside the bin during unloading. This will reduce or eliminate such hazards. Addressing these issues will also increase farm efficiency as it will free up workers for other chores. The return on investment of the project will likely be quick, based on the worker time saved, profit of the removed grain, and the value of increased safety of farm operations.

Research & Background

- [b]From 1964 to 2013, 167 incidents were identified involving entanglement in an energized auger inside an agricultural confined space
  - Nearly one-third (32.3%) of the incidents were fatal, and lower limb amputation was the most frequently reported injury type
- [c]In the first half of 2021, storage silos demonstrated the highest percentage of combustible dust incidents with six fires and six explosions reported
- [d]The dust, mold, and mildew inside bins can pose serious respiratory risks, such as chronic grain dust lung disease
- Current solutions consist of manual sweeping, or expensive paddle sweeps, bin vibrators, and grain vacuums

Solution Proposal & Selection

The team was composed of individuals with experience in farming, engineering, and safety. This background provided the motivation for the team to tackle this project. Three unique mechanisms for grain movement were evaluated. These included a blower system, a mechanical push/brush system, and a vacuum system. Ultimately, the team chose to develop a vacuum system due to its advantages in efficiency and dust management, as well as being adaptable to many applications and grain bin sizes.

Grain remaining behind a traditional sweep auger.

Characteristics & Limits

A set of several criteria and constraints were developed by the team based on the background research conducted on the problem.

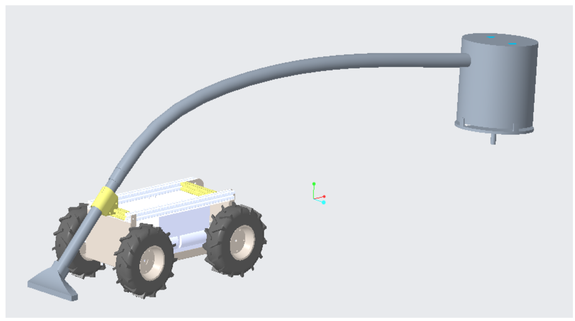
- Criteria:
  - Low in cost
  - Compact size
  - Useable in many bin sizes
  - Manageable weight
  - Minimize farmer time in bin
- Constraints:
  - Fit in a 2 ft. x 2 ft. bin opening
  - Move 2 inches of grain off a bin floor
  - Operate without intervention
  - Maintain OSHA compliance
- Codes followed:
  - ANSI/ASABE S624 (Grain Bin Access Safety)
  - OSHA 1910.272 (Grain Handling Facilities)
  - OSHA 1910.134 (Respiratory Protection)

Prototyping & Testing

Comprehensive research and testing was performed before determining a final design to prototype. After considering many ways to convey grain, the team decided that a vacuum system best met the criterion and constraints for the project. Once the design was determined, prototyping was needed. The prototype consists of a vacuum for conveying the grain, an airlock to maintain the vacuum while still moving grain, and a specially designed nozzle to aid in grain pickup in a bin. The prototype was sized to convey a grain flow rate of 1 bushel/minute of corn.

Left: horizontal airlock with motor attached.
Right: robotic system with mounted nozzle.

The key components of the system were designed in Creo Parametric and 3D printed using Bambu Labs printers. The printed components included the nozzle, nozzle mount, paddle, and airlock casing. Qualitative analysis of each airlock and nozzle iteration allowed the team to reach a final solution, as modeled below.



Creo PTC 3D CAD model.

Economic Analysis

The cost of materials for a full-scale system for a 42' diameter bin is estimated to be between $3,500 - $5,000, based on capacity and specific pricing. This estimation includes the vacuum and airlock combination, hose and hose reel, robotic platform, nozzle, and nozzle mount, as well as general hardware.

Airlock Sizing		
Number of Sectors	6.000	
Radius	4.500	in
Depth	5.000	in
Fill Percent	0.350	
Airlock Capacity	0.052	bu
Speed for 1 bu/min throughput	19.309	rpm

Item	Cost
Industrial, non-combustible vacuum/airlock system	$1,899.00
25 ft. 2.5-inch anti-static hose	$ 392.40
Hose reel	$ 210.00
Robotic platform	$2,000.00
12-inch wide nozzle	$ 32.50
Robotic nozzle mount	$ 4.80
Hardware	$ 124.99
Total	**$4,663.69**

Left: airlock sizing chart for prototype based on vacuum.
Right: estimated full-scale system cost for 42' bin

Cost Advantages:

- Labor
  - Cost for 42' diameter bin cleaning: ~$60/bin
- Safety
  - [a]Mean cost of worker's compensation injury corresponding to stepping in auger: $14,674
- Grain Value (current)
  - Corn: Approx. $1,075
  - Soybeans: Approx. $2,500

Project Impact & Sustainability

"History would show us farms are always looking to lower labor, and sometimes that comes with specialized equipment." - John Tyson, Extension

With the increasing difficulty of finding farm labor, and the hazards inherent in farming, solutions to maximize labor and safety are at the cutting edge of farming advances. Several industry professionals have indicated interest in the concept of the system. This includes a Kokomo Grain Elevator Superintendent out of Kokomo, IN, a southern Indiana corn and soybean farmer, and a west central Indiana corn, soybean, and wheat farmer.

References:

[a]Baidwan, Navneet Kaur, et al. "Cost, Severity and Prevalence of Agricultural-Related Injury Workers' Compensation Claims in Farming Operations from 14 U.S. States." *International Journal of Environmental Research and Public Health*, U.S. National Library of Medicine, 19 Apr. 2021, pmc.ncbi.nlm.nih.gov/articles/PMC8072536/.

[b]Chen, Y.-H., & Field, W. (2016). Summary of auger-related entanglement incidents occurring inside agricultural confined spaces. *Journal of Agricultural Safety and Health*, *22*(2), 91–106. https://doi.org/10.13031/jash.22.11118

[c]*Combustible Dust Incident Report for 2021 Released | Feed & Grain*. (n.d.). Retrieved November 24, 2024, from https://www.feedandgrain.com/safety/news/15386153/combustible-dust-incident-report-for-2021-released

[d]*1910.272—Grain Handling Facilities | Occupational Safety and Health Administration*. (n.d.). Retrieved November 24, 2024, from https://www.osha.gov/laws-regs/regulations/standardnumber/1910/1910.272

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