Objective:
The Indiana Grain Buyers and Warehousing Licensing Agency (IGBWLA) audits the inventory of grain locations throughout the state. The agency would like a technology to measure grain height without bin climbing by personnel. A feasible solution should greatly increase the safety of grain bin auditors, decrease the labor costs of auditing, and increase the auditors’ efficiency.

Constraints
• No permanent installation required
• No climbing required
• Accurate within 1 ft of actual height
• Cost Effective

Possible Solutions
• Sonographic Sensing: Measuring a sound profile of the bin wall to determine grain fill
  • A telescoping pole could be used to tap the bin sidewall
  • Unwieldy
  • Height limitations
  • A remote controlled bin climber could be fitted with a tapping device which would create a sound recording
  • Safety hazard
  • Time constraint for construction
• Thermal Imaging:
  • Capture thermal images of the grain wall to detect differences in bin sidewall temperature
  • Cost effective
  • User Friendly

Preliminary Research
In order to verify that thermal imaging is a valid and reliable solution, the team:
• Investigated how grain and air effect bin wall temperature profile using small scale tests (Figures 1-3)
• Modeled full size bin based on lab test results using a FEA transient thermal analysis in ANSYS
• Captured thermal images of partially filled grain bins in variety of conditions (Figures 4-6)
• Analyzed grain bulk vs. headspace temperature data (collected 2002, by Dr. Klein Ileleji) to predict optimal inventory inspection times (Figures 8-9)

Thermal Imaging Solution Results
• Grain and air change temperature at different rates leading to a temperature difference between air headspace & grain bulk inside of a bin
• Thermal images reflect the temperature gradient along the outside of the bin wall
• Use of an infrared camera has been proven as a viable possibility for determining the height of grain in a bin

Financial Assessment
• Traditional labor costs: $42,500/yr
• Thermal imaging labor costs: $31,750/yr
• Total saving: $10,750/yr
• Thermal imaging camera: $5000-$10000
• Payback time: 1 year

Outcomes & Impact
Thermal imaging was verified as a viable solution, capable of accurately delineating grain height in metal bins. With further development, a thermal imaging solution will:
• Reduce risk of falling/entrapment for auditors
• Decrease labor costs
• Increase auditor efficiency

Grain volume sample calculation:
\[ V = \text{height} \times \pi \times \left( \frac{\text{diameter}}{2} \right)^2 \pm 0.14 \times \pi \times \left( \frac{\text{diameter}}{2} \right)^2 \times \pm \text{for angle of repose: (+) filling } (-) \text{ emptying} \]

Figure 1 & 2: Small scale grain bin temperature test using IR sensor and thermocouple
Figure 3: Small scale test results show temperature difference exists on bin wall
Figure 4: Grain Bin, Montmorency, IN
Figure 5: Throckmorton Farms
Figure 6: Throckmorton Farms
Figure 7: Fluke TiR1 thermal imager
Figure 8: Temperature differences of grain and headspace on an average day in June 2002
Figure 9: Optimal times of day with the greatest grain and air temperature differences

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