

NC-213 Progress Report for 2025

Title

Integration of Cable-free Grain-Sensor Networks with Computational Fluid Dynamics to Predict Stored Bulk Ingredient Conditions

Investigators

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Outputs/Research Updates

The research integrates on-site data collection, numerical simulation, and model validation. Bin geometry and aeration system characteristics were documented for four full-scale grain silos. Hourly environmental data, including ambient temperature, relative humidity, wind speed, solar radiation, and precipitation, were obtained from a nearby meteorological station and used as boundary conditions for the model. The 3D Maier–Lawrence–Plumier Finite Element (MLP-FE) model solves the coupled governing equations of mass, momentum, energy, and moisture transport within the grain mass. Modifications to the original formulation include the incorporation of inertial resistance through the Darcy–Forchheimer model, which enhances the accuracy of airflow predictions during aeration. Numerical solutions are obtained using a fourth-order Runge–Kutta scheme over a three-dimensional hexahedral mesh. Initial grain temperature and moisture conditions were assigned using spatially matched sensor data from the AGI Suretrack cable-based system. Model verification focuses on ensuring physically realistic responses to environmental conditions, while validation is conducted by statistically comparing predicted and observed grain temperature and moisture content values across multiple silo locations and storage scenarios.

Outcomes/Impacts/Deliverables and updates of studies initiated in 2025

This research is expected to demonstrate that a validated 3D CFD-based ecosystem model can accurately predict grain temperature, moisture, and CO₂ dynamics in full-scale storage bins. By integrating weather forecasts with real-time or historical sensor data, the model has the potential to support improved aeration management strategies, reducing fan run time and associated energy costs while maintaining safe storage conditions. Comparisons between the predictive model, traditional cable-based systems, and emerging cable-free technologies will provide critical insights into the effectiveness, reliability, and economic viability of alternative grain monitoring approaches. Ultimately, the outcomes of this work will contribute to the development of less intrusive, more cost-effective, and data-driven grain storage monitoring and management systems for the global grain and feed industries.

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