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Thermal Distribution Analysis of a Corn Dryer Using CFD Simulation

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***Abstract**. This study presents a computational analysis of a corn drying system using SolidWorks simulation tools. The main objective is to understand the thermal and flow behavior within a silo-type corn dryer powered by a wood-fueled horizontal furnace. The simulation covers thermal distribution, air velocity, and flow trajectories using finite element analysis and computational fluid dynamics (CFD). The model includes a vertical silo with embedded piping systems and air inlets driven by blower-induced convection. The heat source, simulated at 500°C from the furnace, is transferred through ducts into the drying chamber. The results indicate that air temperature reaches up to 100°C within the chamber with a velocity of up to 5 m/s. Temperature and velocity distributions show a good potential for uniform drying, although lower regions exhibit heat accumulation. These findings highlight the effectiveness of the system design in enhancing drying efficiency.*

***Keywords** Corn dryer, SolidWorks, heat transfer, CFD, thermal analysis*

INTRODUCTION

Drying is a critical post-harvest process in corn production that ensures grain quality, longevity, and market value. Traditional drying methods often suffer from inefficiency and uneven heat distribution. To overcome these challenges, the use of computational simulations such as those available in SolidWorks has become increasingly common. This research aims to simulate the thermal and air flow behavior in a silo-type corn dryer, evaluating how heat moves through the structure and affects the drying environment. The results of this study will contribute to more energy-efficient and effective dryer designs.

METHODS

The finite element method was also applied in this study to analyze the heat distribution in the corn dryer system with a silo-type structure. The simulation process involved dividing the dryer model into small finite elements using SolidWorks Flow Simulation. The software version used was SolidWorks Premium 2018. This application allows the modeling of real-world conditions such as heat transfer and airflow within the drying system. Major components such as the furnace, hot air inlet ducts, and silo chamber were designed in three-dimensional format to facilitate accurate analysis.

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The thermal simulation was conducted by applying an initial furnace wall temperature of 500°C, with hot air flowing through a horizontal pipe into the drying chamber. Hot air entered the chamber through a triangular duct at the base and moved upward through vertical pipes inside the silo. Parameters such as ambient temperature, thermal conductivity of air, and inlet air velocity from the blower were incorporated to generate realistic results. The range of temperatures analyzed was between 30°C and 100°C, which is effective for the corn drying process.

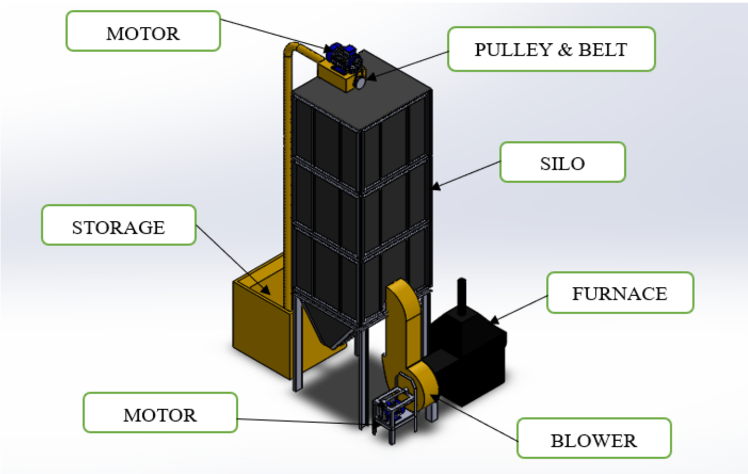

Figure 1. Rotary Dryer Machine Frame Structure Design

In addition to thermal distribution, airflow velocity was analyzed to observe the speed and direction of hot air circulation within the chamber. The simulation results showed an upward flow pattern with a maximum velocity of 5 m/s. Data from the simulation were interpreted using contour plots and vector flow diagrams to identify potential hot spots, stagnant zones, or imbalances in airflow.

Table 1. Simulation Parameters for Thermal and Flow Analysis

Simulation Type	Steady-state thermal & CFD	Units
Air Inlet Temperature	90 – 100	°C
Furnace Surface Temperature	500	°C
Ambient Temperature	27	°C
Air Inlet Velocity	5	m/s
Material Thermal Conductivity	42.07	W/(m·K)
Specific Heat Capacity (air)	477	J/(kg·K)
Air Density	1.225	kg/m³

Simulation Setup

The corn dryer model was created in SolidWorks and comprises a vertical silo with a blower, pulley system, and a wood-fired horizontal furnace. The furnace is positioned at the base and connected to the drying chamber via an inlet duct. Hot air enters from the bottom triangular duct and flows upward through embedded vertical tubes.

Property	Value	Units
Elastic Modulus	2.05e+11	N/m^2
Poisson's Ratio	0.285	N/A
Shear Modulus	8e+10	N/m^2
Mass Density	7850	kg/m^3
Tensile Strength	745000000	N/m^2
Compressive Strength		N/m^2
Yield Strength	470000000	N/m^2
Thermal Expansion Coefficient	1.23e-05	/K
Thermal Conductivity	44.5	W/(m·K)

Figure 2. Mechanical Properties of AISI 4130 Steel

Thermal Boundary Conditions

- Furnace wall temperature: 500°C
- Inlet air temperature: 90–100°C
- Ambient temperature: 27°C
- Thermal conductivity of air: 0.026 W/m·K
- Material: Mild steel structure, corn thermal properties assumed constant

CFD Parameters

- Mesh: Tetrahedral fine mesh
- Solver: Steady-state, incompressible air
- Turbulence model: k-epsilon
- Flow inlet velocity: 5 m/s (blower induced)
- Outlet: Atmospheric pressure condition

Simulation Tools

- SolidWorks Flow Simulation Module
- Thermal Study for steady-state heat transfer

RESULTS

Temperature Distribution

The temperature simulation showed that the air inside the vertical tubes reached up to 100°C at the lower section and gradually cooled down toward the upper section. The hottest region was near the triangular inlet where the furnace heat first enters. The overall chamber showed effective heat spreading, though minor gradients were seen near the upper corners.

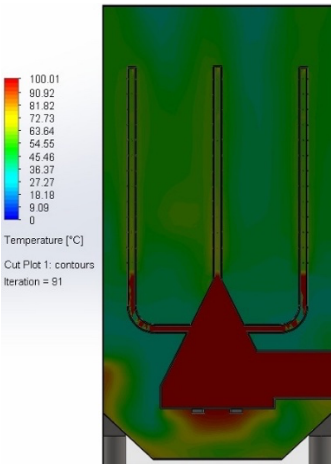

Figure 3. Front View of the Corn Dryer Assembly

This image shows the complete front view of the corn dryer unit modeled in SolidWorks. The design consists of a vertical silo structure, supported by a frame, with a blower system mounted at the top to facilitate forced convection. The triangular base section indicates the location of the hot air inlet connected to the furnace.

Velocity Field

As shown in the velocity cut plot, the air speed reached a maximum of 5 m/s within the vertical tubes. Lower zones exhibited slower flow (0.5–1.5 m/s), which suggests good residence time for heat exchange. The airflow remains laminar within pipes and transitions to more turbulent in the main chamber.

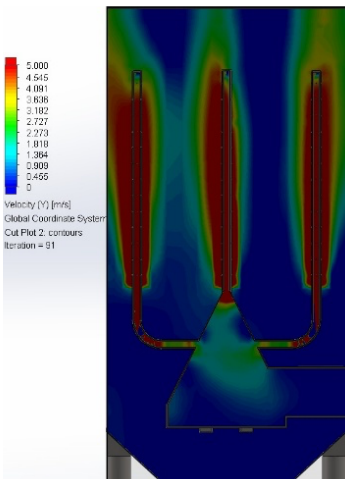

Figure 4. Thermal Distribution on Heat Inlet Section

This figure illustrates the thermal simulation result of the hot air inlet section where heat enters the drying system. The temperature gradient ranges from approximately 117°C to 250°C, represented by a color spectrum from blue to red. The hottest region appears near the furnace outlet, showing effective heat conduction to the base structure.

Flow Trajectories

Flow path visualization indicates that hot air is effectively distributed upward with streamlines forming dense clusters near the middle tubes. This uniform movement is essential for even moisture removal during the drying process. There are no major dead zones or recirculation pockets observed.

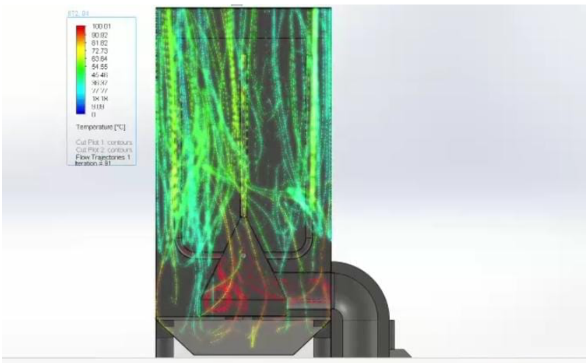

Figure 5. Velocity Contour Plot (Y-direction)

This image presents the velocity distribution of hot air inside the dryer, specifically in the vertical (Y) direction. The airflow enters from the base and travels through vertical pipes toward the upper chamber. Velocity ranges from 0 to 5 m/s, with red zones indicating higher velocities in the central pipes and green-blue zones showing slower movement near the walls.

DISCUSSION

The thermal and flow simulation highlights the efficiency of the current corn dryer design. The furnace and duct configuration allow heat to be distributed across the drying chamber with moderate losses. The simulation also shows that the blower's velocity is sufficient to carry heat upward effectively, ensuring most of the drying chamber reaches functional temperatures (above 60°C).

However, the results suggest that the system could be improved further by adding baffles or diverters to control temperature uniformity in upper regions. In comparison to previous studies, the achieved velocity and temperature distribution are within effective drying ranges, minimizing energy waste.

This simulation also demonstrates that using SolidWorks as a CFD tool can provide significant insight during the design phase without needing extensive physical prototyping.

CONCLUSION

This study demonstrates that computational simulation using SolidWorks is an effective approach for evaluating the performance of corn drying systems, particularly those powered by biomass-based horizontal furnaces. The temperature and velocity distributions observed in the simulation confirm that the system can provide adequate thermal energy and airflow throughout the drying chamber.

The airflow trajectory revealed a relatively uniform heat transfer mechanism with minimal recirculation zones, indicating that the existing design effectively supports consistent moisture removal. Moreover, the simulation confirms that the air entering at approximately 100°C successfully propagates upward through the silo structure, reaching areas critical to uniform corn drying.

Overall, the findings highlight the potential of this system as a cost-effective solution for post-harvest corn drying in rural or off-grid areas. With further design refinement, particularly in controlling heat distribution in the upper regions, the efficiency and reliability of the dryer can be significantly improved.

LIMITATION

Although the simulation results provide valuable insights, several limitations must be acknowledged. First, the thermal properties of corn and structural materials were considered constant, which may not reflect real-world variability due to moisture content changes during the drying process.

Second, the simulation employed steady-state conditions without incorporating transient thermal analysis or time-dependent airflow behavior. This simplification excludes the dynamic thermal response of the system as it heats up or cools down during operation, which could affect actual performance and energy consumption.

Lastly, the drying rate and moisture diffusion within corn kernels were not included in this study. Without modeling the interaction between heat transfer and mass transfer, the simulation does not provide a full representation of the drying kinetics. Future research should consider incorporating coupled thermal-moisture simulations and validating the model with experimental data.

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