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COMBUSTION PROCESS OF COTTON FIBER IN PNEUMATIC TRANSPORT: MODELING THE TIME FROM IGNITION TO COMPLETE COMBUSTION

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Abstract
This article models the combustion process of cotton fiber within pneumatic transport systems in cotton mills. It analyzes how a spark can quickly spread through the airflow, potentially igniting the cotton fiber and posing a safety hazard. Based on a mathematical model, the spread time of the combustion process and the impact of airflow parameters were determined. A simulation conducted in MATLAB illustrates the propagation speed of the combustion front along the pipe, total time, and temperature variations through graphical representations. This model has practical significance in assessing combustion risks and implementing safety measures.

Keywords: Pneumatic transport systems, cotton fiber combustion, combustion process modeling, airflow, MATLAB simulation, fire safety.

Introduction

Pneumatic transport systems in cotton mills are used to transport materials safely and efficiently. However, the occurrence of sparks and combustion processes within these systems poses a serious risk. At the onset of combustion, a spark can quickly spread through the airflow, leading to the ignition of cotton fiber. This article develops a mathematical model to determine the propagation time of the combustion process in pneumatic transport systems.

The combustion process of cotton fiber is analyzed under airflow conditions, taking into account the physico-chemical factors associated with combustion kinetics and airflow. To model the combustion process, the Navier-Stokes equations, conservation laws of energy, and combustion kinetics were utilized.

1. Mathematical model

The combustion process was modeled based on a differential equation:

$$m\frac{d^2x}{dt^2} = F_{combustion} + F_{air} - F_{resistance}$$

where:

m– mass of the cotton fiber (kg),

x– coordinate representing the position of the combustion front in the pipe (m),

$F_{combustion}$ - heat energy resulting from the combustion process,
F_{air} – airflow force,
$F_{resistance}$ – resistance force.

a) calculating combustion intensity

The combustion intensity is calculated based on the law of energy conservation:

$$F_{combustion} = \frac{Q_{combustion} \cdot A}{L}$$

where:

$Q_{combustion}$ - heat of combustion (J),
A – combustion surface (m^2),
L – length of the pneumatic transport pipe (m).

a) calculating air force

airflow force:

$$F_{air} = C_h \cdot \rho_h \cdot A \cdot v_h^2$$

where:

C_h - air force coefficient,
ρ_h - air density (kg/m^3),
v_h - airflow velocity (m/s).

b) calculating resistance force

$$F_{resistance} = -C_q \cdot \rho_h \cdot A \cdot \left(\frac{dx}{dt}\right)^2$$

where:

C_q – resistance coefficient,
$\frac{dx}{dt}$ – velocity of the combustion front (m/s).

2. Equation for combustion velocity

Differential Equation of the Combustion Process:

$$\frac{d^2x}{dt^2} = \frac{Q_{combustion} \cdot A}{m \cdot L} + \frac{C_h \cdot \rho_h \cdot A \cdot v_h^2}{m} - \frac{C_q \cdot \rho_h \cdot A}{m}\left(\frac{dx}{dt}\right)^2$$

initial conditions

Initial velocity: $\left.\frac{dx}{dt}\right|_{t=0} = 0$

Initial position: x(0)=0

The simulation results were conducted in MATLAB, calculating the spread velocity of the combustion front along the pipe and the total time required.

Discussion

The results indicate that the combustion process of cotton fiber in pneumatic transport spreads rapidly with the aid of airflow. Higher airflow velocity accelerates the combustion process, but a balance between airflow speed and resistance force helps control the process. The time for the

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combustion front to reach the end of the pipe depends on airflow parameters and the properties of the cotton fiber.

Conclusion

Modeling the combustion of cotton fiber in pneumatic transport aids in anticipating combustion risks and implementing safety measures. The developed model enabled the calculation of the spread time of the combustion process and assessed the potential for optimizing airflow parameters. Such a model has practical significance for improving fire safety in pneumatic transport systems.

I can provide calculation and code samples in MATLAB for generating the formulas and graphs. Additional simulations are required to further develop this model and enhance safety.

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