Final Dissertation Defense
Chemical Engineering

THE UNIVERSITY OF KANSAS
Chemical & Petroleum Engineering

Nicholas Reding

Metal Dust Combustion Dynamics & Novel Concepts of Explosion Protection Application

Abstract

Combustible dust explosions continue to present a significant threat toward an extensive range of industries processing, storing, or pneumatically conveying metal dust hazards. Upon ignition within a contained enclosure volume and propagation of flame toward interconnected vessels, metal dust deflagrations demonstrate an extremely reactive explosion risk relative to organic dusts due to well-documented amplified heat of combustion, burning temperature, flame speed, rate of pressure rise, maximum explosion overpressure, and ignition sensitivity. Addition of non-combustible inert material to combustible dust mixtures, either through pre-mixing or high-rate injection as the incipient flame front begins to develop, is common practice for preventative inhibition or explosion protection via active suppression, respectively. However, inhibition efficiency of suppressant agents utilized for active mitigation is shown to be reliant on comparative explosibility, discrete burning mechanism, and combustion temperature range, and thus may be increasingly variable depending on the fuel in question. For this reason, mitigation of metal powder deflagrations at moderate total suppressed pressures (relative to the overall strength of the enclosure) and at low agent concentrations has remained challenging. This report reviews applicable thermal analytical techniques and large-scale suppression testing in Fike Corporation's 1 m^3 sphere combustion chamber to evaluate the efficacy of multiple suppressant agents for the mitigation of contained iron and aluminum powder deflagrations.

Through recent years, investigations have thoroughly observed the influence of particle size, polydispersity, and chemical composition on dust explosion sensitivity and severity. However, studies characterizing the effect of particle shape (or morphology) on metal dust explosibility are limited and merit further consideration in order to better define the hazard and understand unique allowances for implementation of protection. In this work, high-purity aluminum dust samples of three unique particle morphologies were examined (spherical, irregular, and flake). Investigations performed in a Kühner MIKE3 minimum ignition energy apparatus and a Siwek 20 L sphere combustion chamber resulted in the direct characterization of explosion sensitivity and severity, respectively, as a function of suspended fuel concentration and variable particle morphology. Such fuel reactivity shall be modeled as a means of predicting hazardous potential for distinct metal dust processing methods. Applying the shrinking particle theory with reaction and species diffusion limitations, previously reported pressure evolution outcomes were verified through development and implementation of closed-vessel numerical modeling reliant on fundamental mass and thermal balance equations.

Committee Chair:

Prof. Mark B. Shiflett

Monday, November 22nd

Begins at 2:00 PM

Location: Beren Conference Center (G192 Slawson)