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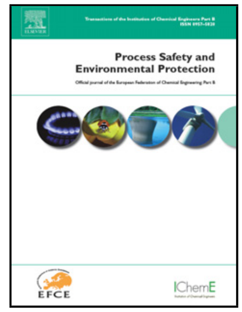

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Lower Flammability Limits of Hybrid Mixtures Containing 10 Micron Coal Dust Particles and Methane Gas

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Abstract

Mixtures of combustible dust and flammable gas pose an increased explosion risk in processing equipment due to reduced flammability limits over the dust and gas alone. Although correlations have been proposed based on experimental testing for predicting the flammability limits of hybrid mixtures from those of the dust and gas, none appear to be applicable across a range of fuel mixtures. The objective of this work is to use computational fluid dynamics to explore the lower flammability limits of 10 µm coal dust particles and methane gas under laminar, free-flame conditions, and to compare the limits to the experimentally determined mixing rules. This comparison gives an understanding of the baseline behaviour upon which different fuel mixtures, equipment geometry, and various operational conditions can be added in the future. The results from the computational model suggest that Le Chatelier's Law, which proposes linear mixing between the dust and gas limits, is applicable for the small particles studied. Bartknecht's curve, which proposes wider flammability limits than linear, appeared to be overly conservative, while new relations that predict narrowing of the limits did not appear to delineate flammable mixtures under the conditions investigated.

Keywords: Lower Flammability Limit, Coal Dust, Methane Gas, Hybrid Mixtures, Laminar Flame Propagation

1. Introduction

A hybrid mixture is defined in NFPA 69 as a mixture of combustible dust and flammable gas, where the dust concentration is above 10 percent of the minimum explosible concentration (MEC) and the gas is above 10 percent of the lower flammability limit (LFL) (NFPA 69, 2014). These mixtures arise in several processing operations including grain storage (Abuswer et al., 2016), spray drying (Febo, 2013), textile manufacturing (Marmo, 2010), and pharmaceutical production (Hossain et al., 2015). In addition to increased rates of pressure rise over the dust alone, hybrid mixtures may explode at concentrations below the limits of the two fuels individually (Eckhoff, 2003).

The engineering design guidance in NFPA 69 and NFPA 654, specifies that the combined concentration of the combustible dust and flammable gas stay below 25 percent of the combined lower flammability limit to avoid a deflagration hazard (NFPA 69, 2014; NFPA 654, 2017). However, a difficulty is that the number of tests required to outline the entire flammable region may be large as the amount of flammable gas present may not be known beforehand. In this light, correlations to interpolate hybrid flammability limits from the MEC of the dust and LFL of the gas are useful in process safety design.

The current study uses a computational fluid dynamics (CFD) model to investigate the combined lower flammability limits in hybrid mixtures of 10 µm coal dust particles and methane gas. The focus is on laminar free-flame propagation at ambient temperature, and comparing the simulation results to lower flammability limit correlations available in the literature. This will give an understanding of the fundamental baseline behaviour on which the

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