Considerations of Scale for Studying Dust Explosion Phenomena

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ABSTRACT

The physical and chemical processes involved in dust explosions range from sub-particle to factory scale. As the size of the problem under investigation increases, the emphasis placed on the smaller spatial and temporal scales is generally reduced. This is true in both phenomenological and numerical modeling and may lead to inaccuracies or misunderstanding of the hazards and risks involved. The focus of the current study is to examine what scales are important in dust explosions and to detail the phenomenological and numerical models currently found in the literature in relation to these scales.

The effect of geometric scale is important in understanding dust explosion phenomena. A practical example can be drawn from the recent Hoeganaes incidents, in which a metallic dust was involved in fire/explosion-related events, leading to destruction and loss of life. During investigation by the US Chemical Safety Board, the dust produced an explosion in a 20-L vessel but not in a larger 1-m\textsuperscript{3} vessel. In this case, determination of the relationship between the 20-L, 1-m\textsuperscript{3} and factory scales will lead to a better understanding of the explosion incident.

In conjunction with a pragmatic understanding of the phenomena, the scale of the explosion plays an important role in modeling methodology. When determining numerical methods for risk and consequence modeling, a decision must be made about which physical processes can be resolved, which must be approximated, and which can be neglected. Although particle heating, melting, volatilization, and reaction are fundamentally based on particle size, the scale of the industrial application generally dominates the modeling method selection. Turbulence, gas dynamics, confinement, and obstacle blockage all add other scales which may be important to consider. In general, as the problem size increases, the smallest scale physical processes are approximated instead of resolved, and some may be neglected altogether. In this view of modeling, information learned from the smaller scales can be fed forward to develop global models for the larger scales. This suggests that a multi-scale approach may be beneficial for dust explosion problems and that determining the relationship between the phenomena and models involved is important to consider.