Journal of Loss Prevention in the Process Industries 52 (2018) 108–112

Contents lists available at ScienceDirect

Journal of Loss Prevention in the Process Industries

journal homepage: www.elsevier.com/locate/jlp

Novel method for hybrid gas-dust cloud ignition using a modified standard minimum ignition energy device

Haitian Han[a,b], Purvali Chaudhari[a,b,1], Pranav Bagaria[a,b,1], Chad Mashuga[a,b,*]

[a] Artie McFerrin Department of Chemical Engineering, Texas A&M University, College Station, 77843-3122, United States
[b] Mary Kay O' Connor Process Safety Center, Texas A&M University, College Station, 77843-3122, United States

ARTICLE INFO

Keywords:
Minimum ignition energy
Dust explosion
Hybrid explosion
Kühner MIKE3 MIE device

ABSTRACT

Hybrid dust-gas explosions are a persistent problem in the process industries because of their low ignition energy and serious consequences. The probability of ignition of a hybrid dust-gas mixture is quantified by its minimum ignition energy (MIE). This study aims at improving the MIE measurement of hybrid dust-gas systems using a modified Kühner MIKE3 MIE apparatus. The modification includes an add-on device in order to purge the Hartmann tube with the gas of the hybrid mixture before the dust dispersion and ignition attempt. This ensures the gas composition in the Hartmann tube is the same as that of the gas used for dispersing the dust.

In this study, the MIE for a hybrid system consisting of Pittsburgh Pulverized Coal (PPC), methane and air was examined. MIE testing was conducted for the two cases: case (a) followed the ASTM E2019-03 standard procedure, while case (b) applied a pre-dispersion purge of the Hartmann tube with the methane-air mixture. In addition, this hybrid system MIE study was conducted with two different particle sizes of PPC, having equivalent polydispersity. Certified cylinders consisting of methane (1, 2, and 3 vol %) blended with ultra-high purity (UHP) air (21.00% oxygen and 79.00% nitrogen) were used.

Significant differences in the MIE values of the hybrid dust-gas system were found between the two cases for both particle sizes. The hybrid MIE values obtained with a pre-dispersion purge of the Hartmann tube were found to be lower than those without the purge (which is the most common testing approach); while a smaller particle size also resulted in a lower hybrid MIE. Additionally, it was found that for experiments with or without pre-dispersion purge, and for both particle sizes, the greater the methane concentration, the lower the MIE.

This study proves that many of the previous hybrid MIE studies in the Hartmann tube are non-conservative. Future studies should be conducted by including a pre-dispersion purge in the testing procedure. This work lays the foundation for improving the existing ASTM E2019-03 or developing a standalone standard for hybrid dust-gas system MIE testing.

1. Introduction

Dust explosions are a persistent problem in solid processing industries and can result in catastrophic damage to property and loss of life. Since 1980, the rate of occurrence of dust explosion incidents is more than 1 per month in the U.S. (Bagaria et al., 2017). Dust explosions have been studied for more than 200 years (Bartknecht, 1989). However, studies on hybrid dust-gas systems, which are generally more hazardous than dust explosions (because of lower ignition energies), have not been examined accurately due to the limited capability of experimental instruments. The earliest documented hybrid dust-gas explosion study was recorded in 1885, when Engler ignited mixtures of methane and dusts (soot and charcoal dust), obtaining explosions of these hybrid mixtures even though neither the gas nor dust components were explosible by themselves (Bartknecht, 1989). This observation has been supported by numerous studies in recent years (Addai et al., 2015a, 2016; Denkevits and Hoess, 2015; Sanchirico et al., 2015).

Minimum ignition energy (MIE) of a dust is one of the many characteristic parameters of a dust explosion and is associated with the probability of ignition of a dust cloud. For hybrid explosions, the hybrid MIE can be described as the lowest energy required to ignite a hybrid dust-gas cloud (Randeberg and Eckhoff, 2007). In 1980, Franke studied the MIE for coal dust/methane/air, where results indicated a decrease in MIE for different types of coal as methane concentration increased (Franke, 1980). Pellmont (1980) conducted MIE testing of various combustible dusts in the 1-m^3 vessel and observed that the MIE of

* Corresponding author. 3122 TAMU Room 205, College Station, TX 77843-3122, United States.
E-mail address: mashuga@tamu.edu (C. Mashuga).
[1] Equal contribution by the authors.

https://doi.org/10.1016/j.jlp.2018.02.005
Received 4 December 2017; Received in revised form 15 February 2018; Accepted 15 February 2018
Available online 16 February 2018
0950-4230/

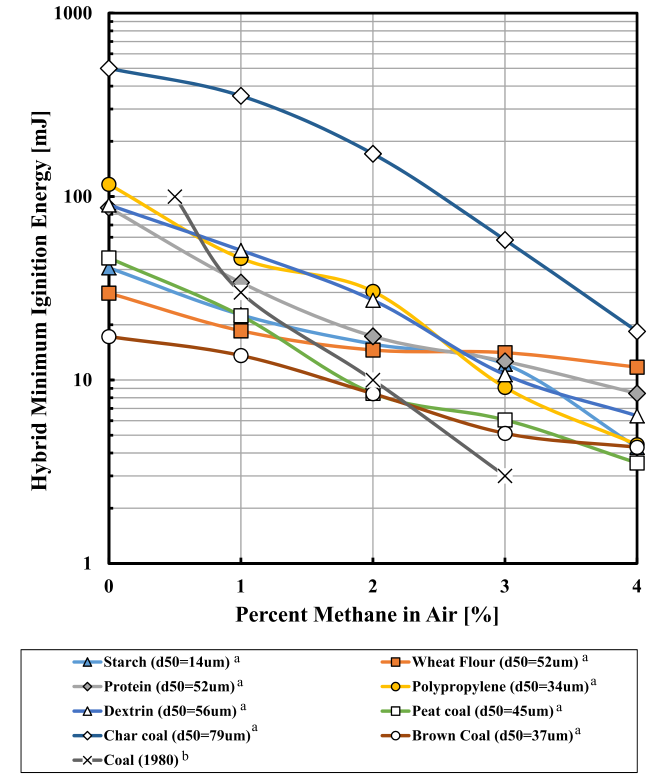

Fig. 1. Hybrid MIE of previous studies with methane ([a]Addai et al., 2016; [b]Franke, 1980).

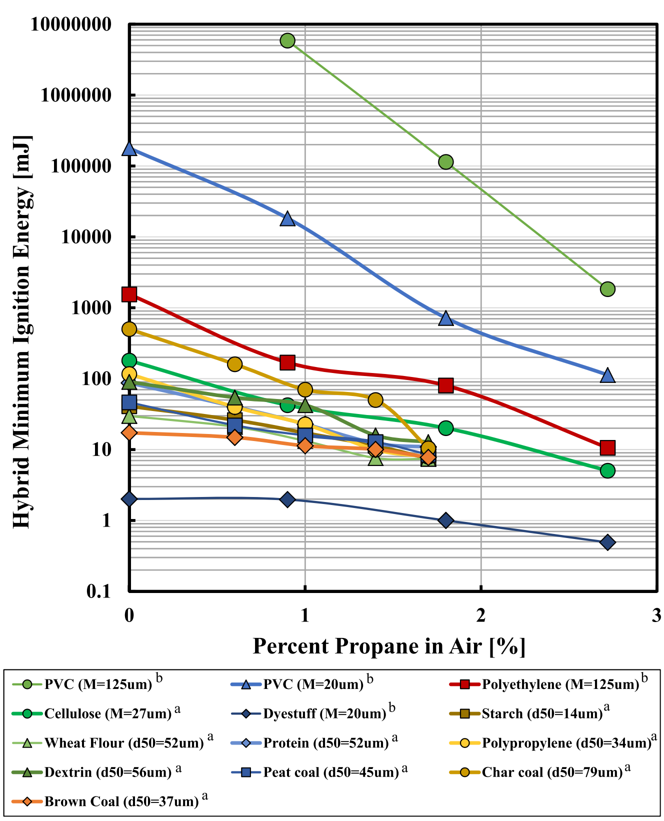

Fig. 2. Hybrid MIE of previous studies with propane ([a]Addai et al., 2016; [b]Pellmont, 1980).

Fig. 3. Kühner MIKE3 device.

hybrid mixtures decreases with the increase in propane concentration. Based on these results, Britton (1998) estimated the hybrid minimum ignition energy for dust/gas mixtures by developing an equation considering various dust and gas characteristics. This estimate applies only to the region below the lower flammable limit of the gas. Addai et al. (2016) tested the hybrid MIE for various combinations of flammable gases and combustible dusts in the Hartmann tube, where the comparison of experimental and modeling results indicated that minor quantities of flammable gas significantly affected the hybrid MIE. Figs. 1 and 2 summarize many of the previous hybrid MIE studies for common flammable gases (methane and propane) and dust systems (Franke, 1980; Pellmont, 1980; Bartknecht, 1989; Addai et al., 2016). While these studies investigated hybrid MIE testing, none of these have conducted testing by pre-purging the Hartmann tube before the dust dispersion and ignition, which is an important step in obtaining accurate MIE results (Chaudhari and Mashuga, 2017).

ASTM E2019-03 standard provides guidance on dust MIE testing procedure (ASTM E2019-03, 2013). However, no standard procedure exists for hybrid systems. The Kühner MIKE3 MIE device (Fig. 3) is widely used for measuring MIE of combustible dusts and has proven to be accurate in MIE testing as compared to other devices (Janes et al., 2008; Lepik et al., 2015). Chaudhari and Mashuga (2017) modified the Kühner MIKE3 device by introducing an add-on purging device and demonstrated the impact of this modification on the partial inerting MIE values of Niacin dust (Fig. 4). This testing method can be extended to hybrid dust-gas MIE testing which will result in an accurate assessment of the hybrid MIE values.

The objective of this study is to generate accurate, conservative hybrid MIE data using the modified Kühner MIKE3 MIE device. The testing procedure in this work involves purging the Hartmann tube in the modified Kühner MIKE3 MIE device (Fig. 4) with the desired premixed fuel-air mixture prior to dust dispersion. The dispersion is driven with the same premixed fuel-air mixture followed by an ignition attempt of the cloud. This study will provide insight into the proper way of testing hybrid MIE system so the explosion risk of combustible dust gas mixtures are not underestimated.