Materials Today: Proceedings 57 (2022) 1422–1426

Contents lists available at ScienceDirect

Materials Today: Proceedings

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

Investigation of the LDPE dust flame propagation effected by the ethylene concentration

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ARTICLE INFO

Article history:
Available online 31 March 2022

Keywords:
Dust
Flame
Propagation
Explosion
LDPE

ABSTRACT

The presence of ethylene (C_2H_4) gas in a low-density polyethylene (LDPE) combustion process increases the severity of the dust explosion. Understanding dust explosion propagation as influenced by C_2H_4 concentration is important to characterise the severity of the LDPE dust explosion. Therefore, this paper aims to study the explosion propagation mechanism as influenced by ethylene concentration in LDPE combustion using computational fluid dynamic (CFD) ANSYS FLUENT simulation. Results showed that ethylene concentration influenced the LDPE/C_2H_4 flame propagation mechanism by increasing the equivalence ratio (ER) to 1.2. The severity of LDPE/C_2H_4 explosion was also recorded at C_2H_4 concentration, at ER = 1.2 with explosion pressure = 5.5 bar respectively.

Selection and peer-review under responsibility of the scientific committee of the International Symposium of Reaction Engineering, Catalysis & Sustainable Energy.

1. Introduction

According to worldwide statistics, 89% of all dust incident fatalities up until the first half of 2018 were due to explosions. The breakdown of injuries and fatalities from fires and explosions due to dust is as follows: explosions contributed 28 injuries and 8 fatalities, while fires caused 12 injuries and 1 fatality [1]. These accidents are prevalent in the industry given that dust explosions could occur when fine combustible solids (particles with mean diameter less than 1 mm) dispersed in the air like a cloud (mass loading between 10 g and 1000 g of dust per cubic meter), in the presence of an activated ignition source in this mixture [2]. Recently, a more concerning phenomenon involving dust and flammable gas had arisen in the food, agriculture, coal mines, chemical and petrochemical industries, as both materials commonly coexist in the plant processing areas.

In the context of a petrochemical plant where products such as low-density polyethylene (LDPE) is produced, the location with a high probability of hybrid explosion occurring is the insides of the blender silos, where the product is degassed to reduce residual ethylene (C_2H_4) content from between 800 ppm and 1200 ppm to below 25 ppm, before being transported to final storage [3]. The produced pellets still contain and diffuse ethylene during transportation and storage. A fire incident may occur when the silo loses its aeration (air purging) during the filling of the product, causing a build-up of ethylene concentration to within the flammable limit, which could be ignited by the inherent electric charge from the polymer. If the ethylene concentration reaches a value within the explosive limits, a fire could occur if an ignition source is present.

The simultaneous presence of dust and flammable gas, such as LDPE and ethylene, may potentially form an explosive hybrid dust mixture that poses a more severe impact than dust or gas/vapour explosion alone. A hybrid dust mixture poses a higher risk severity because the presence of a flammable gas like ethylene reduces the minimum ignition energy (MIE) of the system. It is understood that ethylene could alter the rate-limiting step of the combustion reaction and boost the heat transfer rate from one burning LDPE particle to another, leading to the drop in MIE [4]. Recently, Badli et al. [5] investigated the severity of LDPE dust explosion in a 20-L spherical vessel. The experimental analysis showed that the presence of C_2H_4 during the combustion process has increased the explosion pressure. The consistent finding was also observed in another study [6] which reported that the synergistic effect would be the reason for the influence of C_2H_4 on the polyethylene combustion trend. Song et al. [7] also stated that the C_2H_4 concentration reactivity influenced the diffusivity effect, which was important in determining the explosion process. In addition, Zhang

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https://doi.org/10.1016/j.matpr.2022.03.273
2214-7853/
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