Journal of Loss Prevention in the Process Industries 26 (2013) 1542–1548

Contents lists available at ScienceDirect

Journal of Loss Prevention in the Process Industries

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

Suitability of ignition source "exploding wire" for determination of dust explosion characteristics in the 20-L-sphere

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ARTICLE INFO

Article history:
Received 31 December 2012
Received in revised form
29 August 2013
Accepted 30 August 2013

Keywords:
Dust explosions
Explosion characteristics
Safety characteristics
Exploding wire
Fuse wire
Dust explosion testing

ABSTRACT

Several safety characteristics of dusts are determined in the 20-L-sphere (also known as SIWEK Chamber) according to international standards. Dust cloud ignition is carried out using pyrotechnical igniters. Due to various disadvantages of such igniters the need for alternative ignition sources arises again and again. An alternative could be an ignition source which is known as "exploding wire" or "fuse wire". The paper presents test results of a comparative study between both ignition sources for the determination of the safety characteristics "Maximum Explosion Pressure" and "Maximum Rate of Explosion Pressure Rise" of five selected dusts in the 20-L-sphere. In addition to that the ignition mechanisms of both ignition sources were analyzed by high speed camera recordings and the ignition energy was determined with electric and calorimetric recordings. The paper shows results of measurements of the ignition energy of both ignition sources as well as sequences of the flame propagation.

1. Introduction

Safety characteristics are essential for the determination of explosion hazards during handling of combustible dusts and for the design of safety measures. Since they strongly depend on the determination method these methods have to be described precisely. Explosion characteristics of dusts are safety characteristics which describe the explosion behavior of dusts. The explosion characteristics Maximum Explosion Pressure p_{max}, Maximum Rate of Explosion Pressure Rise $(dp/dt)_{max}$ and Lower Explosion Limit LEL are determined in closed vessels such as the 20-L-sphere (also known as SIWEK Chamber). Tests are preformed according to international standards, for example the EN 14034 series or ASTM E1226. In order to determine the explosion characteristics the dust samples are dispersed in air and ignited using two pyrotechnical igniters with energy contents of 1 kJ or 5 kJ. Because the igniters could have an influence on the test results they are defined in the standards.

Due to various disadvantages of the pyrotechnical igniters such as high energy input in comparison to most ignition sources in practice, high costs and legal requirements concerning its storage and use, the need for alternative ignition sources arises again and again. Such alternative ignition sources should be cheap, readily available and the operator should be able to use it without a certificate of competence. In addition to that, the ignition energy should be adjustable over a wide range and if possible allow energy amounts less than 1000 J. In comparison to the ignition energies described in the test standards such energy amounts are more realistic for most ignition sources found in practice, such as electrostatic discharges, mechanical sparks or hot surfaces.

An alternative ignition source which fulfills these requirements is the so called "exploding wire" or "fuse wire". This type of ignition source is already used for the determination of explosion characteristics of gases. It is described in the European standard EN 1839 (2003).

This paper presents test results of a comparative study in order to find out, if the explosion wire is suitable as an alternative ignition source for the determination of explosion characteristics of dusts and if it makes sense to start validation tests. For this study maximum explosion pressure and maximum rate of explosion pressure rise values from 5 different dusts were determined with both ignition sources in the range of 100 J to 1 kJ. The dusts were selected such that different combustion mechanisms were considered. In addition to that high speed recordings allowed comparison of the propagation of the flame fronts generated from both igniters.

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http://dx.doi.org/10.1016/j.jlp.2013.08.017

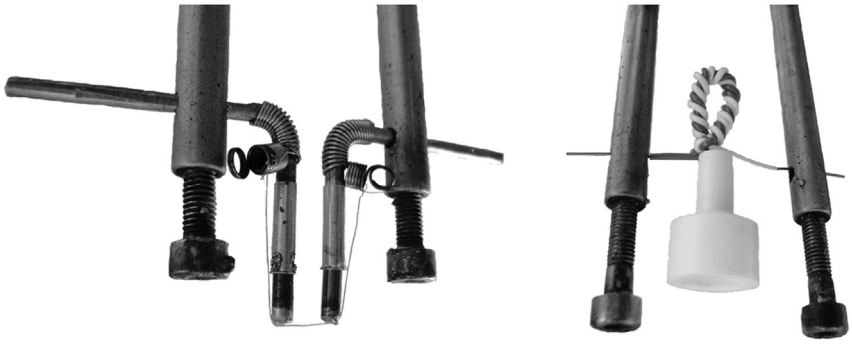

Fig. 1. Exploding wire with electrodes (left side) and pyrotechnical igniter (right side).

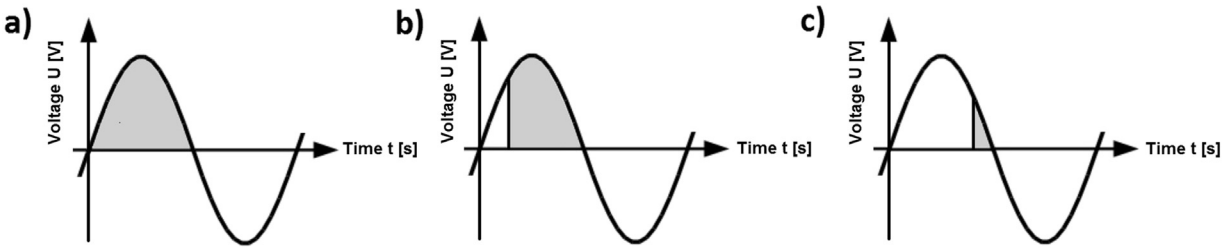

Fig. 2. Description of phase control technique.

Calorimetric and electric measurements obtained information on the ignition energy of both igniters.

2. Experimental

2.1. 20-L-sphere

Main component of the test assembly is the 20-L-sphere (Cesana & Siwek, 2012a, 2012b; EN 14034 1–3, 2011). It consists of a spherical test chamber with a volume of 20 L and a storage chamber with a volume of 0.6 L. After filling the storage chamber with dust and closing it the chamber was pressurized to 21 bar absolute. Parallel the test chamber was evacuated to 0.4 bar absolute. This allows standard pressure after dispersion of the dust into the test chamber. In order to reach almost homogeneous dust dispersion into the test chamber the so called "rebound nozzle" was used (Cesana & Siwek, 2012a, 2012b; EN 14034 1–3, 2011). Nozzle and storage chamber were connected by a fast acting electro-pneumatic valve which was opened and closed for the dispersion of the dust. Sixty ms after the valve had started to open the ignition source was activated, such as described in the standards for determining maximum explosion pressure and maximum rate of explosion pressure rise. Two piezoelectric pressure sensors in the test chamber allowed pressure time measurements.

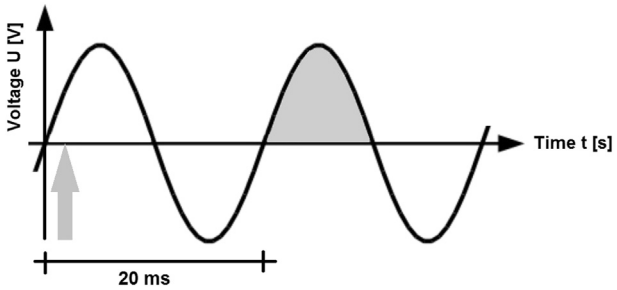

Fig. 3. Additional ignition delay due to phase control technique for maximum power rate.

The tests in which pyrotechnical igniter were used as ignition source were performed using the standard control unit of the 20-L-sphere. For tests with the exploding wire an external ignition unit was necessary in addition to the standard control unit. Depending on the ignition energy two different ignition units were used. One uses an isolating transformer, the other one uses capacitors. An isolation amplifier allowed the determination of the ignition energy by measuring current and voltage. It was installed between ignition unit and exploding wire.

2.2. Ignition source

The main difference between the two ignition sources pyrotechnical igniter and exploding wire is the ignition mechanisms. While for the exploding wire an electric arc is generated the pyrotechnical igniter emits flames and burning solids.

Table 1
Ignition energy of igniter determined with the isolation amplifier; ignition source isolating transformer adjusted on maximum power (100 J).

Experiment-no.	Determined ignition energies		
	Outside the apparatus [J]	Inside the apparatus without dust [J]	Inside the apparatus with dust [J]
1	93.61	98.42	98.88
2	86.84	94.19	84.14
3	90.92	89.27	88.24
4	89.80	101.59	48.85
5	91.62	82.96	94.13
6	84.46	98.58	83.89
7	90.40	94.74	100.63
8	94.41	91.37	74.36
∅	**90.26**	**93.89**	**84.14**
SD	**3.30**	**5.97**	**16.67**