Journal of Loss Prevention in the Process Industries 29 (2014) 8–12

Contents lists available at ScienceDirect

Journal of Loss Prevention in the Process Industries

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

Short communication

Approach determining maximum rate of pressure rise for dust explosion

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ARTICLE INFO

Article history:
Received 26 June 2013
Received in revised form
30 December 2013
Accepted 30 December 2013

Keywords:
Dust explosion
Maximum rate of pressure rise
Computational method
Recursive fitting method

ABSTRACT

The risk assessment requires the knowledge of dust explosion hazard data. Maximum rate of pressure rise is an important parameter of explosion severity characteristics. Its accuracy depends on the experimental conditions and the approach determining maximum rate of pressure rise. Previous method determining maximum rate of pressure rise is to draw a tangent on pressure time history profile and the tangent is approximated maximum rate of pressure rise, which has a poor repeatability and great error. This paper presents a new method used to calculate the rate of pressure rise for dust explosion which is called Recursive Fitting Method (RFM). Compared with previous methods, this new method (RFM) has better repeatability and higher accuracy.

1. Introduction

Dust explosion accidents have occurred frequently in recent years. It almost takes place every day in Europe. It has caused huge casualties and property losses, so it attracted a lot of attention. Many studies were carried out on dust explosion (Amyotte, Soundararajan, & Pegg, 2003; Matsuda, Yashima, Nifuku, & Enomoto, 2001; Sun, Dobashi, & Hirano, 2003). Data on dust explosion could be found in various publications which mostly focused on the determination of explosion parameters (Cashdollar, 1994, 2000; Jacobson, Cooper & Nagy, 1965; Pilão, Ramalho, & Pinho, 2006; Radandt, Shi, Vogl, Deng, & Zhong, 2001; Zhihua & Baochun, 2005). However, few involved the parametric studies on the effects of the approach determining maximum rate of pressure rise.

The risk assessment requires the knowledge of dust explosion hazard data. The explosion severity parameters include p_{max}, maximum pressure, and $(dp/dt)_{max}$, maximum rate of pressure rise. Maximum rate of pressure rise is an important parameter which characterizes explosion severity. The parameter $(dp/dt)_{max}$, cannot be measured directly, but can be obtained through differential calculation of pressure time curve measured in experiments. The obtained maximum rate of pressure rise relates not only to experimental conditions, but also to the approach determining maximum rate of pressure rise.

The approach determining maximum rate of pressure rise has a significant impact on its accuracy. Tangent Method is known as a common approach determining maximum rate of pressure rise. However, there are two problems for Tangent Method. One is that the point at which the slope is steepest on the pressure-time history curve is found by the manual, and that will lead to the greater randomness of results. Therefore, it has a poor repeatability using this method. For the same pressure time history data, the results obtained may be different by one person when repeating experiments, and not mention to by different operators. So these experimental data bear no comparison. Moreover, it is difficult to obtain the changes of rate of pressure rise with time using Tangent Method.

This paper presents a new method to calculate the rate of pressure rise by numerical calculation. It is conducive to enhancing the comparability of different test results for dust explosion.

The essence calculating the rate of pressure rise is the finite difference of pressure time history. But, direct difference of pressure time data is not a feasible method. The measured pressure time history curve in the dust explosion experiment is shown in Fig. 1. The measured pressure time history curve appears smooth globally (a) in Fig. 1). But, in fact, it is not smooth locally (b) and (c) in Fig. 1). The measured pressure time history curves in the dust explosion experiments cannot be absolutely smooth. Therefore, to complete numerical differentiation, the measured pressure time history curves must be processed. (Fig. 2)

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http://dx.doi.org/10.1016/j.jlp.2013.12.002

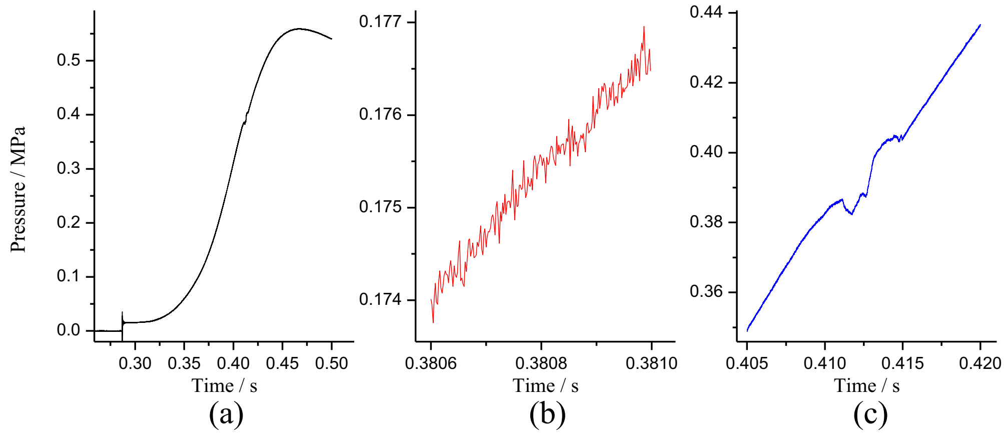

Fig. 1. Measured pressure rise front for dust explosion: (a) measured pressure time history curve; (b) high local enlargement (c) low local enlargement.

A new computational method to calculate the rate of pressure rise has been developed based on gradual linear fitting in this study.

2. Recursive Fitting Method(RFM)

2.1. Theory

If the time span chosen on a pressure time curve is small enough, the straight line obtained by fitting the pressure data in the range of time can be approximated as the tangent line at the location. The slope of the straight line is approximate rate of pressure rise at the location.

But, the pressure time curve is globally nonlinear, as seen in (a) of Fig. 1. If the time span chosen for linear fitting to determine the rate of pressure rise is too long, the linear correlativity of data fitting will become poor. Meanwhile, if the time span is too short and the pressure data contained in the time span are too few, the slope of the straight line obtained by linear fitting cannot be approximated as the actual the rate of pressure rises. The error of data fitting is reciprocal proportion to number of data used for fitting.

According to the sample frequency in the dust explosion pressure measurement in the 5 L vessel and the variation of the explosion pressure with time, 0.4 ms time span which contains 400 pressure values was chosen in the data fitting of this work.

A pressure wave was recorded as a set of pressure time data in the dust experiment. The numbers of discrete pressure values contained in each set of data and in each time span are M and N ($N = 400$), respectively. To determine the variation of rate of pressure rise with time, the fitting starting point was respectively chosen as 0, 1, 2, ……, i,……,$M - N$ for a given time span.

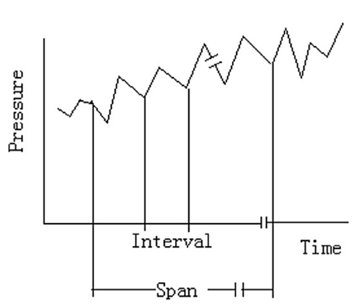

Fig. 2. Schematic diagram of time span and interval.

Table 1
Fitting steps determining rate of pressure rise.

Fitting steps	Time span		Rate of pressure rise (differentiation of linear regression equation)	Maximum rate of pressure rise
	Stating point	Ending point		
1st	0	N	$(dp/dt)_1$	$(dp/dt)_{max}$
2nd	1	$N+1$	$(dp/dt)_2$	
…	…	…	…	
ith	$i-1$	$N+i-1$	$(dp/dt)_i$	
…		…	…	
$(M-N)$th	$M-N-1$	$M-1$	$(dp/dt)_{M-N}$	

2.2. Numerical method

Numerical calculation is conducted as follows. Firstly, take the time span for linear fitting and determine N (the time span divided by the time interval corresponding to two adjacent discrete pressure values. Secondly, carry out linear regression for each time span which contains $(N+1)$ pressure values from the starting points 0, 1, 2,……, i, ……,$M - N - 1$, respectively. The differentiation of the linear regression equation is the rate of pressure rise. The numbers for the rate of pressure rise obtained by differentiation of the linear

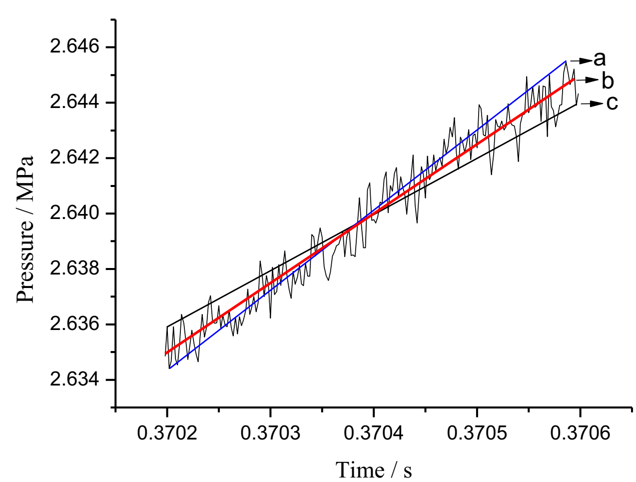

Fig. 3. Comparison between RFM and numerical differential method: curve b is the course of RFM; curve a and c are the two extreme courses of numerical differential method.