

MATHEMATICAL MODELS OF AN AUTOMATIC SYSTEM FOR LOCALIZING DUST EXPLOSIONS

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Abstract. The problem of dust explosion localization in corn processing enterprises is analysed. Condition of flame spread limiting in pipes is defined. Mathematical models of explosion processes are presented, which enable us to choose a mathematical expression form, with regard to desirable process identification accuracy and the complexity of analytic expressions.

Key words: automatic systems for localizing dust explosion, conditions of localization of a primary explosion, mathematical model, software.

1. Introduction. The organic dust (flour, bran, mills, elevators, combined fodder enterprise dust) of corn processing enterprises mixed with air (aerosol) usually bursts. It occurs when there is a certain dust concentration and high enough temperature and a thermo-energetic source. The initial explosions arise because of the excessive heat of the friction in the damaged parts of a technological equipment or sparkles emitted by them owing to metallic things getting in to the rotating technological machinery, damaged electricity apparatus, incorrectly used welding equipment, etc (Vasiljev and Semionov, 1983).

Primary explosions are usually weak, but the wave of explosion, spread by the spaces of the technological equipment and by pipes, blows the rest of the dust from the walls, and the fire spreading afterwards sets fire to new aerosol masses and provokes severe explosions. If the technological machinery or pipe walls are incapable to withstand the increased pressure and fall into pieces, the fire reaches the production premises. There is always some dust on the edges of constructions, technological walls or on the floor. The wave of explosion raises it, and the fire, spreading from the aspiration system burns it up. The destructive power of explosions rises: the windows are broken, the technological equipment is damaged, capital constructions are ruined.

In order to limit the number of accidents, it is necessary to use the automatic system for localizing dust explosions, which prevents heat and fire in the center of weak initial explosions (Fig. 1) from spreading on to the aspiration systems, silos, bunkers where the secondary destructive explosion arises (Poška, 1995). These systems (Fig. 1) consist of high-speed damper with a linear induction electric drive and system controlling machinery with dispensers, which react upon the fire (explosion) parameters.

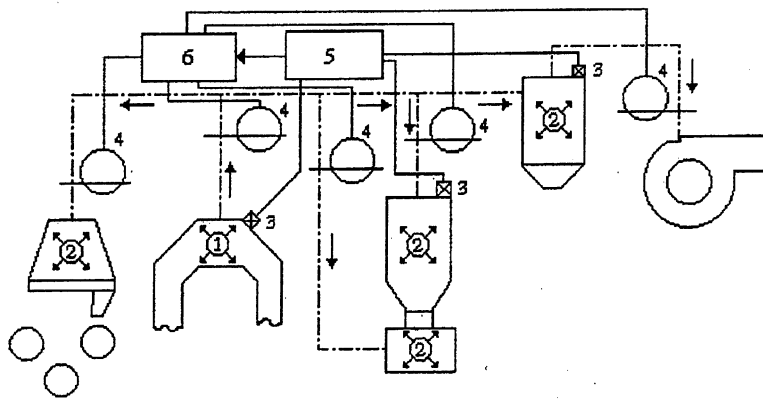


Fig. 1. The fire spreading (→) in an aspiration network of pipes: 1 – centre of primary explosion; 2 – powerful secondary explosions; 3 – explosion parameter sensors; 4 – dampers; 5 – automatic equipment; 6 – control equipment.

2. The conditions of localization of the primary explosion. After having arranged the dampers and dispensers according to the scheme in Fig. 1, to primary explosion 1 dispenser 3, situated on the noria should react. Having received such a signal all dampers 4 should react and thus it might be possible to avoid the accident or to reduce the consequences.

It was established that pressure dispensers react to the explosion more quickly than photo dispensers, which are screened by not burned aerosol during the first part of explosion.

It is necessary to use pressure discharges in order that the technological equipment or pipes be not disintegrated. A damper will block the flame, if this

condition is accomplished:

$$t_{\Sigma} = k(t_{\text{disp}} + t_k + t_{\text{damp}}) < \frac{s}{v}, \quad (1)$$

here t_{Σ} – the whole time needed for the automatic system for localizing dust explosions to react;

k – stock coefficient;

t_{disp} – pressure sensor reaction time;

t_k – commutation apparatus reaction time;

t_{damp} – damper closing time (drive reaction time);

s – the distance between a possible initial explosion place and a damper building place (flame path);

v – flame speed.

The dust explosion test shows that the pressure sensor reacts to the initial explosion at the very beginning of explosion, so it is considered that $t_{\text{disp}} \approx 0$.

The reaction time of contact or semiconductor control apparatus t_k refers to the apparatus certificate (technical documentation). The methods can be used for modeling a damper rectilinear electric drive path transition process (Poška, 1992).

3. Mathematical models of explosion. The distance s can be arbitrarily chosen or it is settled by the manufacturers technological scheme. The flame speed v is a function of explosion overpressure ΔP and the overpressure is a function of a number of pressure discharger membranes (resistance of discharge):

$$v = f_1(\Delta P); \quad (2)$$

$$\Delta P = f_2(n) \quad (3)$$

Functions (2) and (3), i.e., mathematical models of explosion, can be formed according to the data of experiment (Poška, 1995). The results of experiment are created by using the method of least squares. To make modeling more convenient, there was created the program IDENT.EXE for PC, which gives us coefficients and power indices of such functions:

$$y_1 = k_1 e^{\alpha_1 x}, \quad (4)$$

$$y_2 = k_2 x^{\alpha_{21}} e^{\alpha_{22} x + \alpha_{23} x^2}, \quad (5)$$

$$y_3 = k_{31} + k_{32} x; \quad (6)$$

here y_i ($i = 1, 2, 3$) – function (2), (3);

k_j ($j = 1, 2, 31, 32$) – coefficients;

a_k ($k = 1, 21, 22, 23$) – power indices;

x – argument (independent variable).

The results of calculations according to experiment (Poška, 1995) data are given in Fig. 2 and Fig. 3 (theoretical curves on the colour display are shown in priority colours).

According to the method of least squares, the green colour means the least summary error, blue – average, red – the biggest summary error.

During modeling of our automatic system for localizing dust explosion, you can choose a more complicated and more precise function or a simpler and less precise function.

For experimental system modeling it is purposeful to choose (4) type functions, which exactly reflect (2) and (3) dependences:

$$\nu = \nu_{\min} e^{C_2 \Delta P}, \quad (7)$$

$$\Delta P = \Delta P_{\min} e^{C_1 n}; \quad (8)$$

here $\Delta P_{\min} = 6.24kPa$ – theoretical overpressure, which corresponds to an open (without membranes) pressure discharge hole;

$C_1 = 0.39$ – a power index;

$\nu_{\min} = 16.26 \text{ m/s}$ – the minimal flame speed;

$C_2 = 0.02 \text{ 1/kPa}$ – a power index.

4. Conclusions. 1. The given methods and mathematical expressions enable us to choose parameters of an automatic system for localizing dust explosions (distance between the explosion center and the damper building place; the number of discharger membranes; necessary damper high-speed).

2. The created dust explosion process identification program gives modelling such an alternative: one can choose the expression of a model with regard to the desirable identification precision.

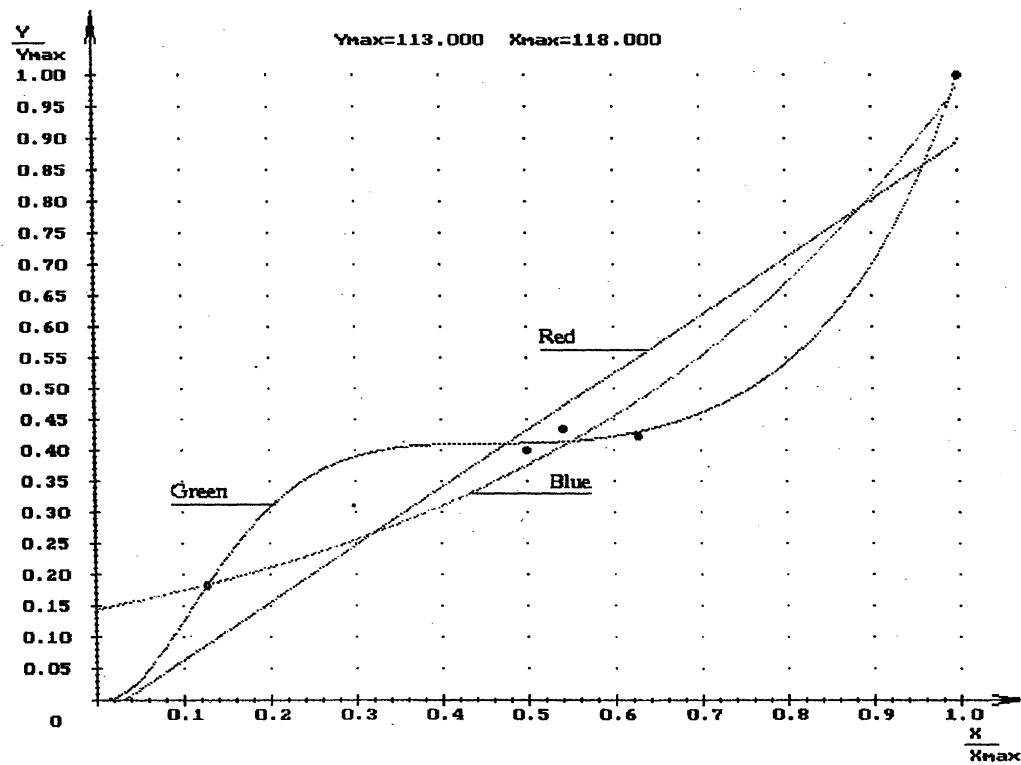


Fig. 2. $\nu = f(\Delta P)$ dependence diagram $k_1 = 16.26$; $\alpha_1 = 0.02$; $k_2 = 0.05$; $\alpha_{21} = 2.77$;
 $\alpha_{22} = -0.1$; $\alpha_{23} = 0$; $k_{31} = 0.88$; $k_{32} = -3.33$.

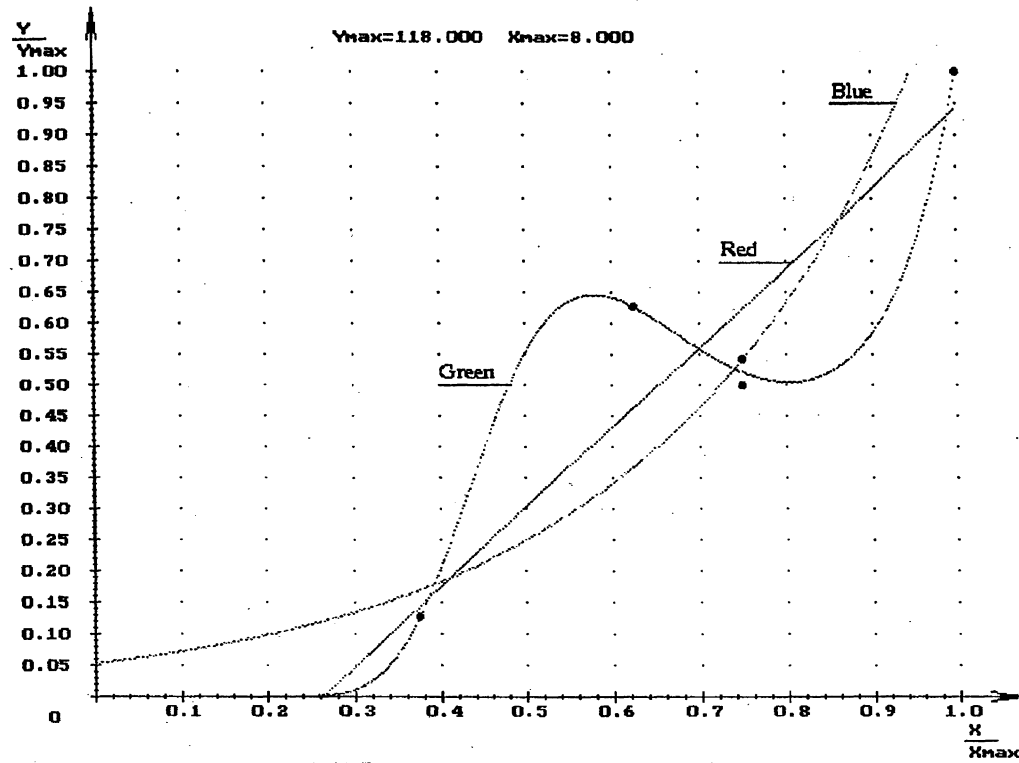


Fig. 3. $\Delta P = f(n)$ dependence diagram $k_1 = 6.24$; $\alpha_1 = 0.39$; $k_2 = 0.04$; $\alpha_{21} = 43.22$;
 $\alpha_{22} = -16.04$; $\alpha_{23} = 0.73$; $k_{31} = 18.86$; $k_{32} = -39.64$.

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DULKIŲ SPROGIMŲ AUTOMATINIO LOKALIZAVIMO SISTEMŲ MATEMATINIAI MODELIAI

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Analizuojama dulkių sproгимų lokalizavimo grūdų perdirbimo įmonėse problema. Apibrėžiama liepsnos plitimo vamzdynuose apribojimo sąlyga. Pateikiami sproгимo proceso matematiniai modeliai įgalinantys tyrėjui rinktis alternatyvią proceso matematinės išraiškos formą, atsižvelgiant į pageidaujamą proceso identifikavimo tikslumą ir jo analizinės išraiškos sudėtingumą.