International Journal of Applied Engineering Research ISSN 0973-4562 Volume 12, Number 20 (2017) pp. 10107-10109

Research of Gas-Dispersion Systems Burning

Anatoly Shapoval[1] , Nickolay Kurilenko[2], Boris Aksenov[3], Oleg Stepanov[4] and Boris Moiseev[5]

[1-5] Industrial University of Tyumen, 625000 Volodarskogo str. 38, Tyumen, Russia.

[1]ORCID: 0000-0001-5644-4186, [2]ORCID: 0000-0002-1329-1623,
[3]ORCID: 0000-0002-4789-4908, [4]ORCID: 0000-0002-4692-8993
[5]ORCID: 0000-0002-8213-4437

Abstract

This article reveals the results of examining formation and inflaming of materials with high calorific capacity, namely gas-dispersion systems. The purpose of the research is to study inflammability concentration limits and flame-front propagation at sites where gas-dispersion materials are formed. That will make it possible to exclude inflaming of such materials and explosions indoors.

It has been found out that flame propagation in metal particles suspended in gas flows is possible at such a concentration of powder, which provides the breadth of burning zone no less than the average distance between powder particles. It has also been noted that unlike gas mixtures (in which fuel and oxidizer are homogeneous, and inflammability limits can be easily defined) concentration of solid component in gas-dispersion systems changes over time. Thus, it is difficult to form a cloud with the sustained concentration of particles.

Keywords: experiment, gas-dispersion system, coal and gas flow, polydisperse powder, grain-size distribution, flame-front propagation, concentration limits.

INTRODUCTION

Nowadays manufacturing dispersion materials is widely practiced in industry. Such manufacturing generates producing gas-dispersion systems. If an initiator is present, such systems can inflame and explode indoors.

This article reveals the results of examining formation and inflaming of materials with high calorific capacity. The purpose of the research is to study inflammability limits and flame-front propagation at sites where gas-dispersion materials are formed. That will make it possible to exclude uncontrolled situations from now on.

Up to nowadays flame-front propagation in laminar coal and gas flows has not been properly examined. Researchers are more interested in burning processes and flame propagation in conduits. No doubt, it is necessary to study burning processes in metal particles suspended in gas flows from the theoretical as well as practical points of view. When combustible metal-powder mixture inflames by the open end of a pipe, which is see-through in an experimental device, flame-front propagation is even at first. That means the speed of flame propagation is constant for the given mixture under steady pressure and temperature. Thus, if the speed of flame-front propagation is equal to the speed of combustible mixture movement, the flame is stable. But, in practice local waving of the combustible mixture flow violates flame stability [4, 7]. Flame stabilization by laminar and turbulent flows is of great interest and in most cases is provided by a fixed source of continuous combustion initiation with combustion products.

The research of powder-air flows burning in pipes is not widely discussed in publications. Some authors studied burning processes with different powder density in combustible mixtures in tubes with a laminar flow. Some tests recorded speeds of flame-front propagation with different powder concentrations. In the experimental device used by the authors (Fig.1) there is an electric valve installed near the ignition source. This leads to the two-component flow turbulence while passing through the narrow space between walls of the tube and the valve. To make the flow laminar on its way towards the flame igniter that far seems to be impossible.

The authors have worked out their own strategy of experimental determination of limiting concentration and critical speed of flame spreading in a powder-air flow containing particles less than 50 mc. The researchers use the effect of particle separation in vertical tubes with a laminar airflow followed by inflammation and dust control of the powder-air flow. The effect has been described in the work [1, 8, 9].

THE RESULTS OF THE SERIES OF EXPERIMENTS AND THEIR ANALYSIS

Polydisperse powder is poured into a feed container which is tightly installed into the lower part of a vertical separating tube fixed in a framework. When some definite quantity of air passes through a layer of the powder, a fluidized layer appears [2, 3, 6]. To prevent polydisperse powder layer on the walls of the feed container a jolting vibrator with a plastic hammer is set in. The vibrator`s speed is measured with an autotransformer. Varying air volume which is forced into the system, one can separate the particles with the hovering velocity not exceeding maximum speed of the gas flow in a tube cross-sectional area at the height where the powder-air flow becomes stable. The air forced into the system is controlled with the variable area flow meter. Air volume in the system is regulated by the autotransformer by means of changing stress and, correspondingly, rotor speed of the pressure unit. There is a constant voltage regulator installed into the system to prevent stress fluctuation. The two-component flow formed above the fluidized layer passes through the tube to the ignition source. The length of the ignition source is determined by the stability of velocity distribution in the tube cross-sectional area. The inflammation initiator is a Ni-Cr helix. The electrical network makes it possible to change temperature of the helix in a wide range due to changing rate of flow with the help of the autotransformer. The rate of flow is controlled by the ammeter (Fig.1).

The suggested techniques provides for appearance of hypergolic powder-gas mixture with the flame front independent of changes in the concentration and critical speed of flame-front propagation. The method allows to study kinetics of powder concentration changes in a reaction tube and to perform a sedimetric analysis of the powder fraction in question [3, 10]. Weight amount and air consumption were determined for each of the examined powder fractions in an experimental way. After the system has been prepared to function, the ignition source, pressure unit, vibration generator are switched on and over some definite period of time, set by a programming timing relay, the air is let into the feed container.

Initially the mixture with powder concentration 800 – 500 mg/l was used to define limiting quantity of powder particles and critical flame-front propagation speed. Inflammation happened as soon as a powder-air cloud got into the area where the ignition source had been set in. At a reduced flow speed the flame-front propagation speed becomes higher than that of the flow. In this case the flame front approaches the ignition source. When the concentration is reduced to a certain quantity, when heat elimination exceeds heat incoming into the area near the flame front, the flame dies out.

In each new test the see-through tube was blown through with pressed air, and a new portion of powder was poured into the feed container.

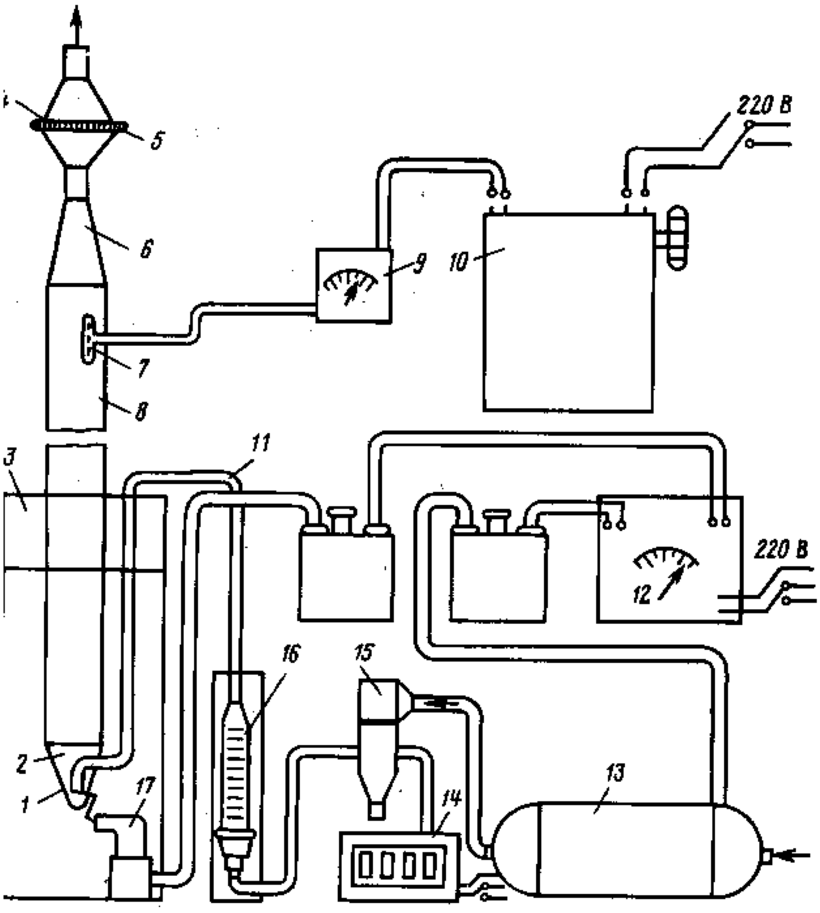

Figure 1: The scheme of the experimental device

1 – initial powder, 2 – feed container, 3 – framework, 4 – filter, 5 – filter element, 6 – adaptor, 7 - incendiary device, 8 – see-through tube, 9 – ammeter, 10 – autotransformer, 11 – air conduit, 12 - constant voltage regulator, 13 – pressure unit, 14 – timing relay, 15 – electric valve, 16 – variable airflow meter, 17 - vibration generator.

To regulate powder concentration changes over time intervals a powder intake unit is tightly attached to the vertical tube. The time for sample taking was based on the experiment, changing intervals of a programming relay holding. The researchers marked the time period since the switch-on moment to the moment when the powder-air cloud was approaching the powder intake unit. When the experimental device is switched on, the air blower lag causes time fluctuation from the start of the air blower till the flowing begins. That influences the results of the concentration control. In order to avoid low accuracy while defining the speed of particles removal from the initial material, an electric valve is installed in the air conduit. The valve provides smooth operation of the air blower. One should pour in the feed container as much powder as necessary to flow when the valve is turned on [2, 11].

Participate matter and vapor phase disengagement was performed with the help of filter AKFA – G8 which had been installed into the powder-intake unit. Powder weigh was determined on the assumption of the weigh difference in a clean filter and a dust-loaded filter. The time for taking a certain amount of powder necessary for one test was recorded by the programming relay which regulated the two-component flow feed as long as one minute by turning the valve on and off. The same way of getting the necessary amount of powder from the initial material is observed in all examined sorts of powder. But the time of getting a portion with the given fraction for different powders is different. It can be explained by a different percentage in weight of the initial powder of removed fractions [2, 5].

CONCLUSION

Flame propagation in metal particles suspended in gas flows is possible at such powder concentrations which provide the breadth of burning zone not exceeding the average distance between powder particles.

Unlike gas mixtures (due to homogeneity of fuel and oxidizer, the inflammability limits can be easily defined) concentration of solid component in gas-dispersion systems changes over time. Thus, it is difficult to form a cloud with even concentration of particles.

The researchers took the maximum current concentration near the ignition source (while the powder was being sprayed) for the sought concentration to define concentration limits of the examined powders.

Aluminium powder and alloys with aluminium as a component (AFCA - 100 mg/l and PA – 120 mg/l) have the maximum value of the concentration limits received while examining powders. Magnesium spherical has the minimum value (20 mg/l).

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