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INERTIZACE HYBRIDNÍCH SMĚSÍ PRACHOVÝMI INERTY

INERTING OF HYBRID MIXTURES USING DUST INERTS

Abstrakt

Článek se zabývá tvorbou hybridní směsi a její inertizaci různými prachovými inerty. Při měření byl zkoumán vliv tří inertních prachů bentonitu, vápence a furexu abc- 40 na meze výbušnosti hybridní směsi hnědé uhlí - metan - vzduch a zjišťovalo se jejich množství potřebné k inertizaci této směsi. Porovnáván byl hlavně bariérový a antikatalitický účinek jednotlivých inertních prachů.

Klíčová slova: inertizace, hybridní směs, prach, výbuch.

Abstract

The article focus on the matter of hybrid mixture formation and its inerting using various dust inerts. The influance of addition of inert dusts bentolit, limestone, and furex abc- 40 on explosion limits of brown coal - methane - air mixture was measured and the required amount needed to inert the mixture was inquired. Mainly the barrier and anticatalitic effect of particular inert dusts was compared.

Key words: inerting, hybrid mixture, dust, explosion.

Introduction

Practically we experiecence not only the explosion of substances of various state of matter - gaseous state, solid state or liquid state; but in many cases we deal with combination of these states, called hybrid mixtures. The hybrid mixtures are very dangerous because any small addition of combustible gas or vapor of combustible liquid into the mixture of combustible dust and air cause rapid decrease of lower explosion limit and expansion of explosive range. At the same time the minimal ignition energy and the optimal concentration are decreasing rapidly, therefore the mixture is easily set on fire. As an exemple of danger of hybrid mixtures we can mention the explosion of methane in coal grainer in Elkford in Canada or the explosion of methane which occured in reservoir of coal in San Bernardin in California. One of the methods of explosive protection is inertization, where the initial explosive substance is transformed into inexplosive by the influence of addition of inert matters. Supposing balanced dispersion of dust elements in whole protected area and use of high amount of dust inert material it is possible to reache the inexplosivness by addition of inert dusts into the explosive atmosphere.

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Dispersed explosive systems

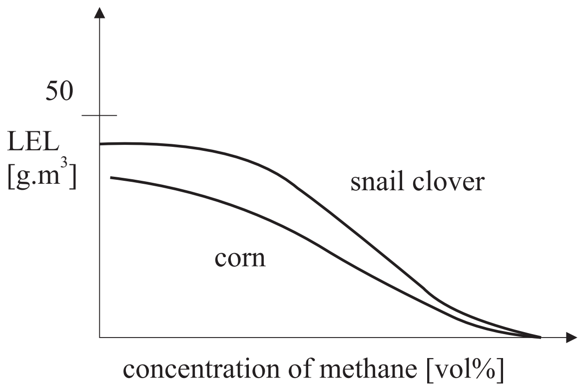
The concentration of dust in the air is usually more difficult to control than the concentration of gaseous systems. Besides dispersed dust which form the explosive concentration of dust and air, the sedimentary dust must be taken into account. In the state of dust almost all metters burn except purely anorganic matters, such are calcite, dolomite and other oxides and metal salts. Dangerous are above all metal dusts (aluminium, magnesium) which have high maximal pressure and maximal rate of pressure rise. From the non-methal dusts the dangerous one is for example suplhur dust (low temperature of ignition) or coal dust.

Theory of burning of dispersed systems

The burning of dispersed systems differs from burning of gaseous systems. The explosive burning is influenced by the transmission of heat from the reaction zone to the layers of systém, which have not reacted so far. With dispersed systems the emission of heat is the main mechanism for transmission of heat from the reaction zone to the dust particles and therefore during the explosive burning the thermal looses are relatively small. The complex physical and chemical procedures in microstructure of the system occurs at ignition and burning of dispersed systems. In gaseous phase the burning resemble to burning of gaseous mixtures. Firstly there is an evaporation of solid phase or the creation of gaseous product by pyrolysis and the flame is created in close range of solid particle surface. The surface of the particles is heating up and there happen another gasification of the solid phase. The gasses mix with oxygen and rapid reaction and flame emerges. The explosivness of combustible system is influenced by the size of dust particles, concentration of oxygen in the area, pressure, amount of dust, temperature, humidity, inert substances, turbulence, size and form of container.

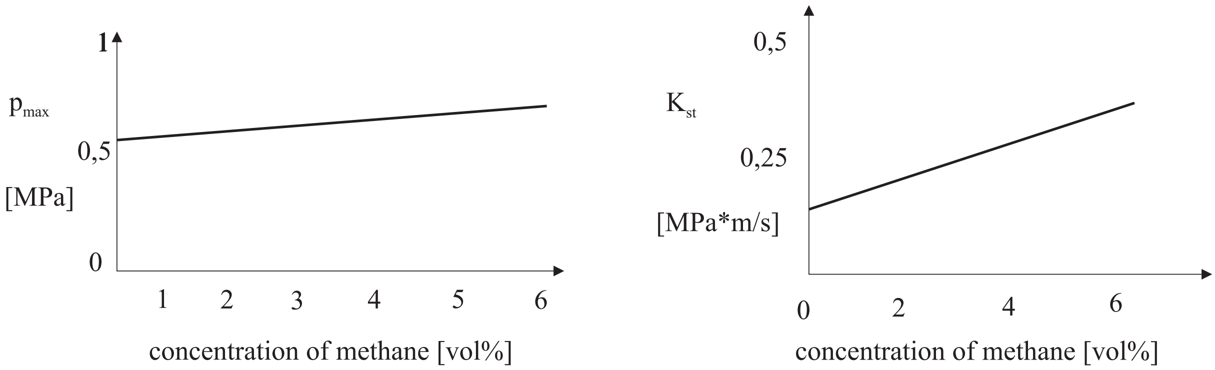
Hybrid mixture

Hybrid mixture is the mixture of an air and combustible matters of different physical states, for exemple methane + coal dust + air (mining). The concentration of solid phase in this mixture is within the range of upper and lower explosion limit. The addition of small amount of gas or vapor of combustible liquid into the mixture of combustible dust or drops of combustible liquid with air results in an expansion of explosive range.



Picture 1: *The influence of additional substance of combustible gas to LEL of combustible dust*

The maximal explosive parametres are increasing, minimal ignition energy, optimal concentration and lower explosive limit are rapidly decreasing. The explosion can occur even in the case where neither the lower explosive limit of mixture of gas with air and mixture of dust with air is not reached.

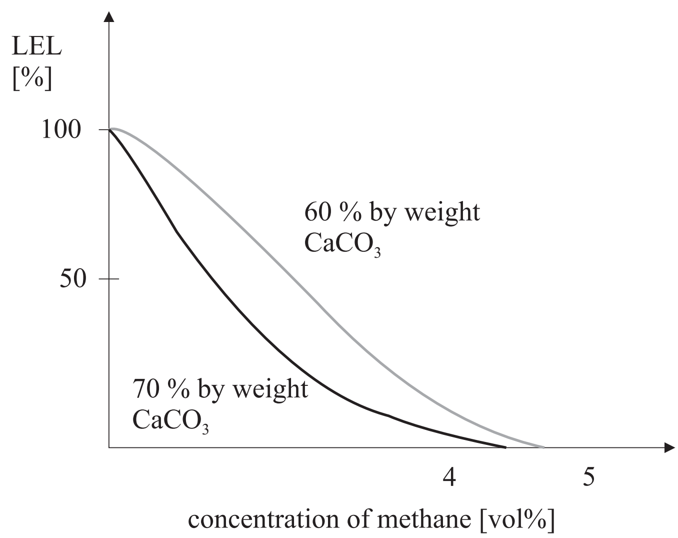


Picture 2: *The influence of additional substance of methane to maxiaml explosive parametres of brown-coal dust*

Hybrid mixture can be ignited by much lower energy than is the initial mixture of dust with air. The most significant decrease occurs by dusts which have high minimal ignition energy and low burning speed in the air.

Inertization

The principle of inertization is in elimination or decrease of the amount of oxidizer, where the initialy explosive mixture is transformed into the inexplosive one. This is caused by addition of inert matters. The effect of inert dusts depends on the kind of explosive mixture and on the kind of dust. The balanced distribution of dust particles in whole area and persistance in this dispersed state is important. The barrier effect occures. At extinguishing powders on the basis of ammonium phosphate besides barrier effect the anticatalitic effect occures.



Picture 3: *The ifluence of additional substance of methane to LEL of inert mixtures of coal dusts and air*

Description of the test equipment

The measurement were examined on VK - 100 explosion chamber. VK - 100 is universal explosion chamber for measurement of lower and upper explosion limit of liquid, gases, dusts, hybrid mixtures and its inertization by gaseous or dust inerts. It consist of explosion vessel itself, carriage unit, pneumatic system and a remote PLC control. The gas cylinder, control eletronics and pneumatic air distribution systems are built in vessel carriage unit. These are schematically ilustratd in the picture no.4. Explosion vessel has a cylinder form of 0,1 m^3 capacity and it is made by 2 mm of stainless steel. In the bottom of the vessel , there ale four dispersion nozzles, in which the tested sample of dust is placed and then is dispersed by pressured air. In the middle part of the chamber, electrodes for both chemical ignition (low-voltage) and high-capacitive inductive spark ignition (high voltage) are placed. In the upper part of the chamber stirrer and windows from hardened safety glass are situated. Upper ledge is equiped with flange, in which breakable paper wafer is placed. Static overpressure, at which the membrane brokes is between 6100 - 6700 Pa.

The matters examined

The measurement focused on the inertization of hybrid mixtures of brown-coal dust and methane. The examined inert matters were Limestone, Bentonit and Furex abc - 40.

Calcite - Limestone is a rock, composed mainly by mineral called calcite. The content of calcium carbonate is often over 95 %. For dusting can be used only calcite dusts which were approved by test room approved by Czech mining office, which cannot contain unbound silicon dioxide in the amount exceeding 3 % and no other fibroplastic or toxic matters and those, that maintains ability to disperse even in mine and ability to persist dispersed in air for longer time.

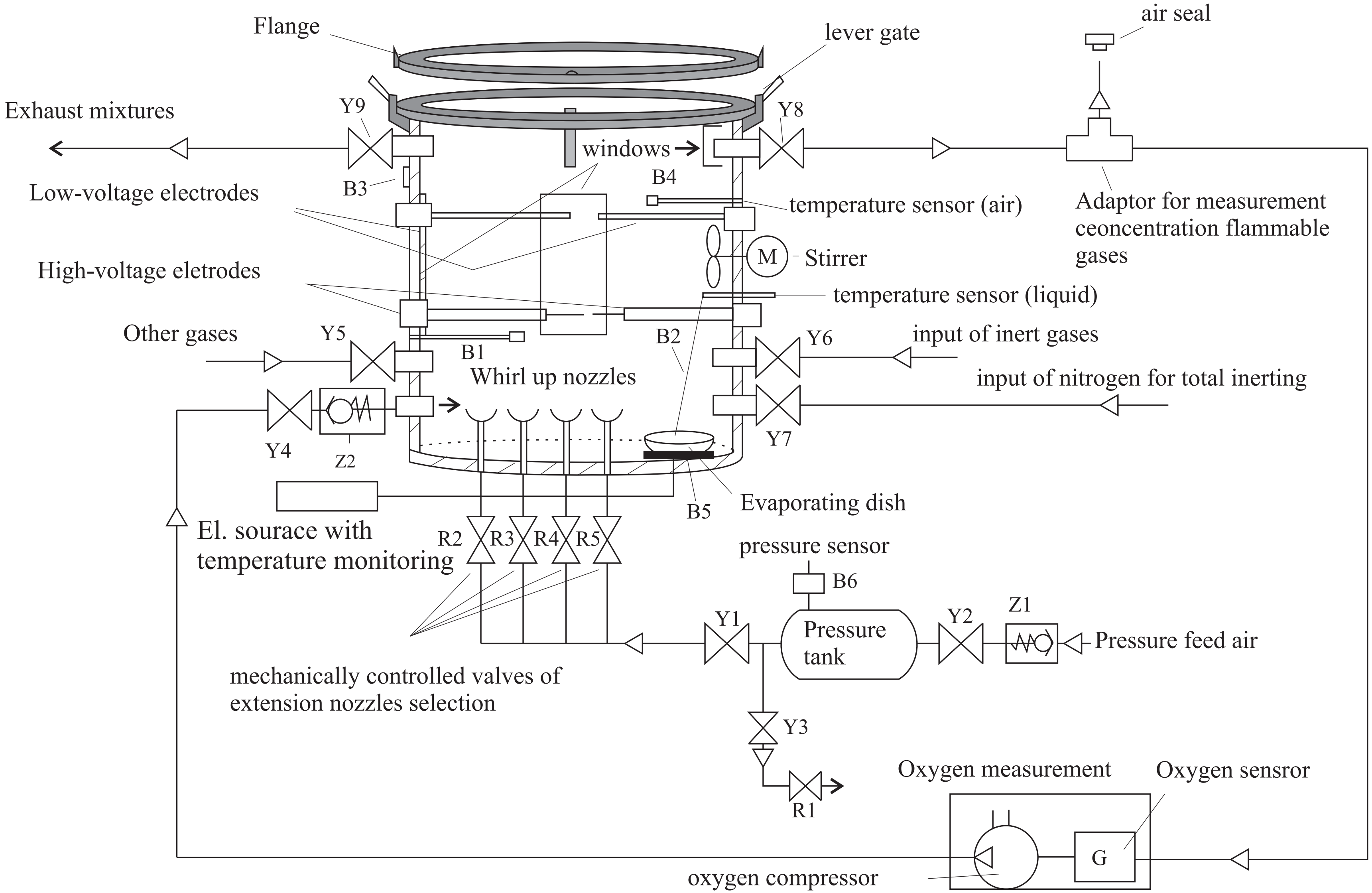
Bentonite - Bentonit is rezidual, non-removed clay rock with huge sorptive capability, high ability to exchange cations, swelling and high plasticity. Bentonite has these characteristics due to clay minerals, especially due to montmorillonite. The characteristics depend mainly on the kind and content of supplement matters (level of bentonization). For the measurement the gray bentonite in powder state was used.

Furex abc - 40 - It is extinguishing powder on the basis of ammonium phosphate. This is made by neutralization of phosphoric acide using ammonia and then using crystalization or evaporation of solution. Extinguishing effect consists in its ability of thermal decomposition to NH_3 and H_3PO_4, which supports the cabonization of organic matters and so reduces the formation of combustible gases. Fruthermore, during the burning, the polymeric phosphoric acide creates continual layer on the surface of burning material, which is an isolator agains the surrounding oxygen and it prevents from re-ignition of warmed combustible matters.

Method of measurement

Before the measurement itself, the samples of dusts were prearranged during special preparation. We used brown coal from Most, Litvínovská uhelná a.s. grain class O_2 of particle size of 10 - 20 mm. For the measurement, this coal had to be grinded first to dust of particle size of 0,25 mm and dryed. All samples were dryed to the moisture of approximately 30 %.

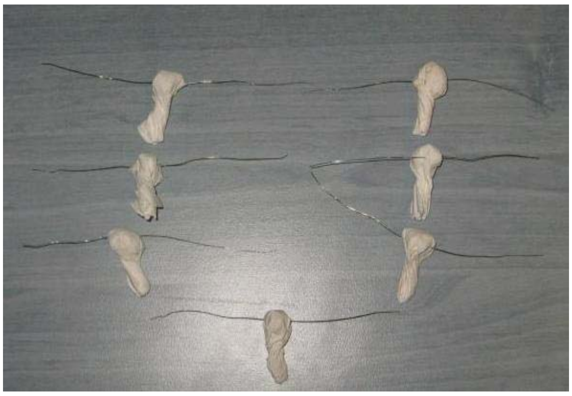
Firtsly was needed to measure lower explosive limit of coal dust itself. The sample of dried coal dust was placed equally in the four dispersion nozzles at the bottom of the chamber.



Picture 4: *VK-100 explosion chamber*

Legenda:

B1	- temperature sensor (air),	Y5	- electric valve - combustible gasses filling,
B2	- temperature sensor (liquid),	Y6	- electric valve - inert gasses filling,
B3	- remperature sensor (case surface),	Y7	- electric valve - total inertization,
B4	- temperature sensor (air),	Y8	- electric valve - oxygen bypass (input),
B5	- evaporating bowl,	Y9	- electric valve - mixture exhaust,
B6	- pressure sensor,	M	- stirrer engine,
G	- oxygen sensor,	Z1	- reverse valve - air income,
Y1	- electric valve - dispersion,	Z2	- reverse valve - oxygen bypass,
Y2	- electric valve - pressured air filling,	R1	- mechanical valve for pressure reduction,
Y3	- electric valve - pressure regulation,	R2-R5	- mechanically controlled valves of extension nozzles selection.
Y4	- electric valve - oxygen bypass (output),		



Picture 5: *nitrocellulose ball*

As ignition source was used nitrocellulose ball, which was ignited by nickeled steel resistance wire 0,25 mm stick with resistance of 9,879 Ω, which was placed between two low voltage electrodes. The ignition energy of this ball is 4,5 kJ. So prepared chamber was overlapped by thin paper breakable membrane 20 μm thick, which was used as an explosion vent. The result of the test was judged visually (flash, break of the membrane). If the result was not convincing, the experiment have been judged by the increase in the temperature on temperature sensors. The ignition itself has increased the temperature by c. 6 °C, considering this we were able to determine that during the increase over 10 °C the mixture burn-up will occur. By this conditions the lower limit of brown coal dust was determined to c. 50 $g.m^3$. Later measurement indicated that inertization of hybrid mixtures by dust inerts is not very efficient, therefore we have not tried to exceed the concentration of admixture of combustible gas by more then 3 %. For the comparison of inert dusts impacts we have used two hybrid mixtures:

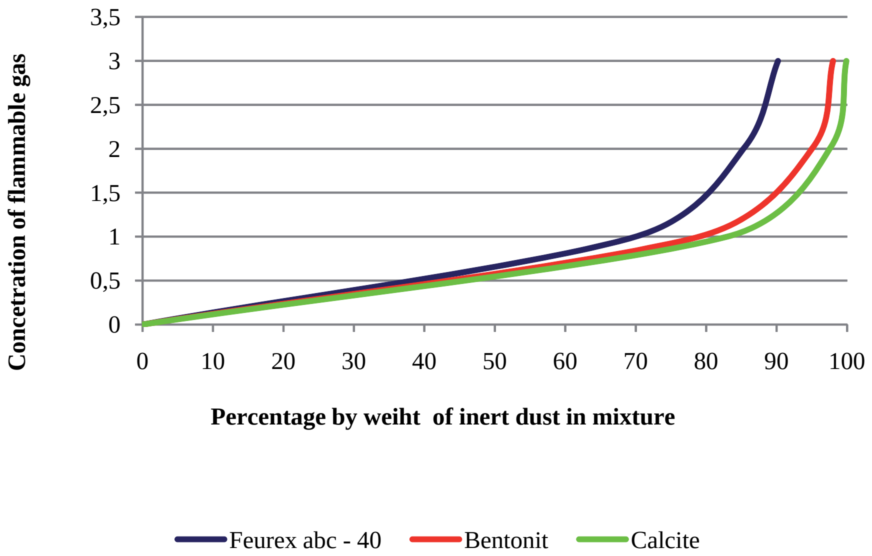
- hybrid mixture of 50 $g.m^3$ of brown coal dust with air + 2 % methane,
- hybrid mixture of 50 $g.m^3$ of brown coal dust with air + 3 % methane.

Measuring procedure was similar to the one we used to aquire LEL, only difference was, that we add methane to the chamber and add inert dust to the sample of coal dust. The concentration of methane was detected by ex - meter added to the equipment to measure oxygen in the chamber The amount of inert dust in the mixture was gradually increased until, under above described criteria, the mixture was inexplosive (no membrane breach or 10 °C temperature rise). These results were defined with 10 $g.m^3$ accuracy. The results we measured are summerized in following table 1.

Table 1: *The amount of inert dusts (percentage by weight) for full inertization of hybrid mixture*

Inert dust	Lignite [g]	Methane [% vol]	Quantity of inert dust [g.m^3]	Percentage by weight
Furex abc -40	50	2	290	85,29 %
Furex abc -40	50	3	460	90,2 %
Bentonite	50	2	1570	96,91 %
Bentonite	50	3	2150	97,73 %
Calcite	50	2	1980	97,54 %
Calcite	50	3	> 2300	> 97,87 %

Graph of dependence of quantity of inert dust on concentration of admixture of combustible gas



Picture 6: *Dependece on the amount of inert dust on LEL of hybrid mixture with addition of different percentage of methane*

Conclusion

The ability of inert dusts to inertize the hybrid mixture was verified by the measurement, assuming the usage of high amount of inert dusts. Goal of this measurement was an examination of the abilities of chosen inert dusts to inertize the hybrid mixture and mutual comparisons of the effectivness of particular inert dusts. Namely calcite, furex abc - 40 and bentonite. The hybrid mixture of 50 g.m^3 of brown coal with air and methane in 2 and 3 % concentration was inertized. According to the theoretical assumptions, furex abc - 40 on the basis of ammonium phosphate has the best extinguishing effect. Together with barrier effect also anticatalitic effect occured, causing that dust particles absorbs radicals originated from the burning process and stops chain reactions. Inerting of hybrid mixtures by dust inerts is possible, but the dust has to be perfectly dispersed and it is needed in big amounts, exceeding 90 % by weight, with addition of very small amount of combustible gas.

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