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Experimental Study of Oil Shale and Olive Cake Dust Explosion by Burning Mixtures of Coarse and Fine Particles

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Abstract

The inhibition effect of using different mixtures of coarse and fine particles of oil shale and olive cake solid fuels were investigated. Measuring the maximum permissible oxygen concentration that is required to ignite the mixtures of each type of fuel was carried out. In general, it was found that olive cake might be ignited easier, than oil shale fuel over all mixtures range of coarse and fine particles. Further, it was found that the mixture with 30% coarse particles is the most probable to explode among all other particle sizes for both oil shale and olive cake.

Keywords: Oil Shale; Olive Cake; Dust Explosion; Solid Fuel.

1. Introduction

Combustible solid materials, which are commonly used in industry, should be handled with care against explosion, which is a phenomenon of ignition and flame propagation between solid particles suspended in air. Generally a dust explosion occurs only when it is dispersed in air, or can be dispersed by some means whilst the source of ignition is present. Dust explosions have been known for many years. In spite of considerable research world wide, their hazards have not been eliminated. Eckhoff [1] reported good database on the damage caused by mines explosions and fires in many countries.

The ignition of a dust cloud in a heated environment has been investigated by extending the Frank Kamenetskii theory of steady state thermal ignition to a combustible dust cloud [2]. It was shown that the temperature required for ignition of a dust cloud is lower than the ignition temperature of a single particle. Also an expression for the ignition of dust clouds was proposed. The expression shows that the ignition temperature decreases as the dimensions of the dust cloud increase. The minimum ignition temperature, maximum pressure, and maximum rate of pressure rise for three fractions of wheat and grain sorghum at five concentrations [3]. It was found that the accepted minimum explosive concentrations are lower than actual concentrations required for propagation of an explosion.

Oil shale dust explosion experiments showed that the fine particles in the range from 63 to 75 microns are the most probable to explode among all other particle sizes. [4].This was achieved by studying the minimum ignition temperature and minimum explosive concentrations of oil shale.

Coal dust explosion was studied to improve safety in mining and other industries that process or use coal. The tests were conducted in the USBM 20-liter laboratory explosibility chamber. The parameters measured included minimum explosible concentrations, maximum explosion pressure, maximum rates of pressure rise, minimum oxygen concentration and the amount of limestone rock dust required to inert the coals. The dust explosibility data have been compared to those of other hydrocarbons, such as polyethylene dust [5]. It was found that for various coals the higher volatile and finer sized coals and more hazardous. Further the ignitability of coal dust air and methane coal dust air mixtures was studied by conducting an experimental investigation of coal dust explosion in a 26 L spherical chamber [6]. The experiments showed that the ignitability of dust reduces with the presence of methane

The combustible dust hazards pose a serious industrial safety problem in the United States [7]. It was found that hundreds of combustible dust incidents resulting in large losses of lives, numerous injuries and significant business loss. These incidents occur nationwide involving many different industries and materials. Three fatal dust explosions that all occurred in 2003 in the United States were investigated [8]. These explosions caused the deaths of 14 people and injured hundreds more. Two of the facilities were damaged beyond repair, and several

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hundred employees lost their jobs. The dust explosion state-of-the-art was presented [9]. Illustrative case studies and past accident analyses reflect the high frequency, geographic spread, and damage potential of dust explosions across the world. The sources and triggers of dust explosions and the measures with which different factors associated with dust explosions can be quantified and are reviewed alongside dust explosion mechanism. This promotes research on relevant dust explosion fundamental phenomena and development of the practical means for preventing and mitigating dust explosions in industry [10]

In this work, the effect of adding coarse particles to the fine ones of both oil shale and olive cake fuels on the maximum permissible oxygen concentration will be investigated. This will be carried out by studying the ignition possibility of mixtures with different percentages of coarse particles from certain values of dust concentration.

In the next few years, Jordan will start using oil shale as fuel. Because of the low hydrocarbon content in Jordan's oil shale, direct burning method is one of the most appropriate methods to make use of it. Also olive cake is produced and used in Jordan. This study comes as a preliminary study to reduce the explosion hazards of using these two materials as fuel.

2. Experimental Setup

In this work a well established apparatus, Godbert-Greenwold Furnace Apparatus with slight modifications, is used [11]. The general layout of the furnace apparatus is shown in figure 1.

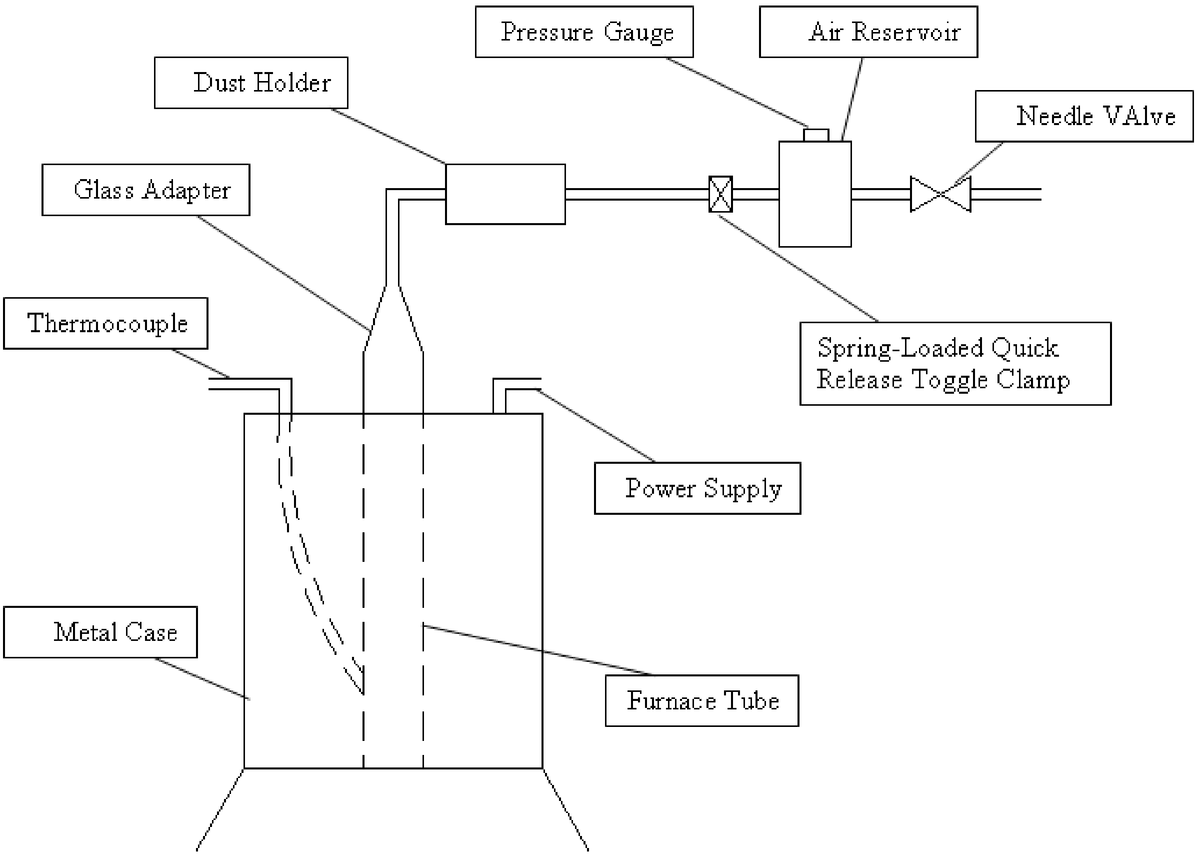

Figure 1.Experimental apparatus.

It consists of a silica furnace tube 21.6 cm long and 3.75 cm inside diameter. The furnace tube is heated externally by an electric winding of 20 SWG, 80/20 nickel/chrome wire with a resistance of 1.3 ohm. A thin layer of heat resisting cement (Alsrax) is used to cover the electric winding. The furnace tube is mounted vertically in a mild steel case lined with asbestos wood and filled up with bulkwool (Triton Kaowool) to act as a thermal insulation. The top of the furnace tube is fitted to Pyrex glass adapter with a right angle bend, which in turn is connected to the dust holder. The dust holder is 10.2 cm long and contains a stainless steel barrel of 0.94 cm inside diameter. The dust holder is connected to the air reservoir of 460 cm^3 capacity. The modifications are that the reservoir is supplied by two inlets, one for air and the other for Nitrogen. The furnace space is filled with air/nitrogen mixture; also the air nitrogen mixture is used to disperse the dust into the furnace. The temperature of the furnace is held constant. By varying the composition of air/nitrogen mixture, the maximum permissible oxygen concentration is obtained.

3. Experimental procedure

The experimental procedure involves measuring of the maximum permissible oxygen concentration of a dust cloud needed to prevent oil shale and olive cake explosion by using air/nitrogen mixture as the dispersing gas. The following steps were followed for each sample.

As a first step in this work oil shale and olive cake were crushed and then sieved using sieves with the appropriate mish to obtain the desired particle size ranges. Then mixtures of coarse particles (250 μm<d<355 μm) and fine particles (d<63 μm) were made up. Each mixture has a certain percentage of coarse particles. These percentage values are: 0.0, 30, 50, 70 and 100%. After preparing the oil shale and olive cake samples, and in order to measure the maximum permissible oxygen concentration of the dust cloud, the furnace tube was electrically heated to a fixed desirable temperature which was recorded by a thermocouple. Then air reservoir was charged up to 70 kN/m^2 with the required air/nitrogen ratio, then the mixture was released to fill the furnace space instead of air, and the bottom open mouth of the furnace was closed, then a known quantity of the dust was placed in the dust holder, and the air reservoir was again charged up to desired dispersion pressure (70 kN/m^2) with the same air/nitrogen ratio. Finally the dust was dispersed through the furnace by an air blast (after opening the bottom open mouth of the furnace).

The occurrence of an explosion was indicated by direct observation of a flame at the bottom of the furnace. If explosion occurs, i.e. observation of a flame at the bottom mouth of the furnace, the nitrogen amount is increased and the same procedure was followed until mixture is reached at no explosion occurs. At this air/nitrogen ratio experiment was repeated three times to make sure that no explosion occurs at this mixture. The lowest nitrogen amount at which no explosion occurs was taken as the maximum permissible oxygen concentration. The concentration of oil shale and olive cake dust samples was varied between 0.3 and 5 g/L, and the furnace tube was cleaned after each test by blowing air through it.

4. Results and Discussion

If a dust is shown to be explosive, further information on the extent of the explosion hazard may be required when considering suitable precautions for the safety and handling of the dust. One of the main parameters to be considered is the maximum permissible oxygen concentration of the atmosphere to prevent ignition in a dust cloud. In this study, the effect of adding coarse particles to the fine ones of both oil shale and olive cake fuels on the maximum permissible oxygen concentration were investigated and the obtained results are presented in curves. It should be noted that each of the obtained curve represents a boundary, below which dust explosion is not possible, while above it explosion is possible.

The variation of maximum permissible oxygen concentration with dust concentration for several mixtures of coarse and fine particles of both oil shale and olive cake is shown in figures 2 and 3, respectively.

Each point on these curves represents the maximum permissible oxygen concentration at which no explosion occurs for the corresponding concentration. The general behavior of these curves is that the maximum permissible oxygen concentration decreases with dust concentration to a minimum value, beyond which it starts to increase.

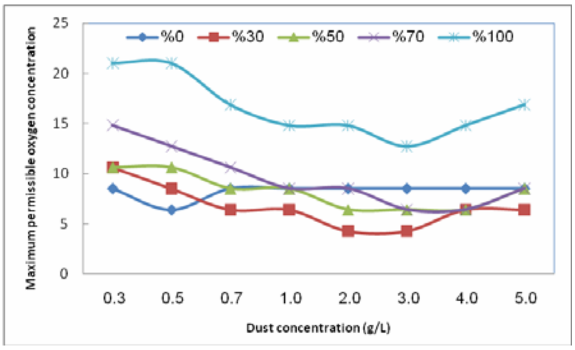

Figure 2. Variation of Maximum permissible oxygen concentration with dust concentration of oil shale for different weight percents of coarse particles in the mixture.

This is due to the fact that any increase in concentration (in the amount of solid fuel) makes the occurrence of the explosion easier, and consequently the maximum permissible oxygen concentration is reduced to prevent the explosion. Further increase in concentration leads to the decrease of the oxidant (air) in the mixture, this makes the occurrence of the explosion harder and consequently the maximum permissible oxygen concentration is increased.

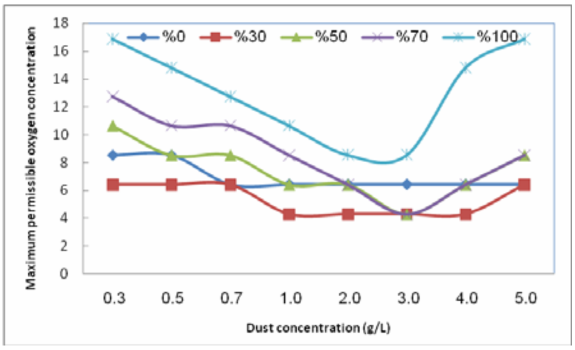

Figure 3. Variation of Maximum permissible oxygen concentration with dust concentration of olive cake for different weight percents of coarse particles in the mixture.

In order to show the effect of the fraction of coarse particles in the mixture on the maximum permissible oxygen concentration, Figures 4 and 5 were plotted for different values of dust concentration.

As it may be seen, and for values of dust concentrations, the general trend of these curves is that, initially the maximum permissible oxygen concentration decreases with the percentage of coarse particles to a minimum values, beyond which it starts to increase with the percentage of coarse particles in the mixture. This is due to the fact that at low percentages of coarse particles the mixture is dominated by fine particle size. Under such conditions the fine particles became more and more cohesive, and then they agglomerate together and behave as if they were effectively of greater size, hence ignition becomes more difficult. However, as the percentage of the coarse

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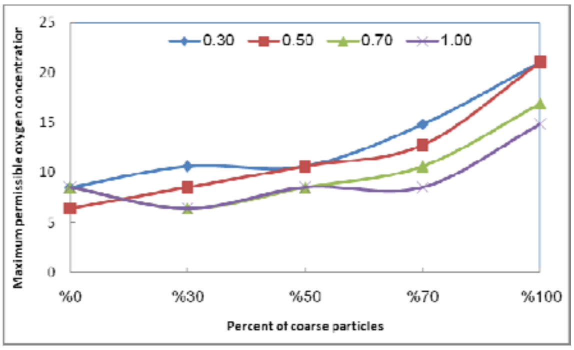

Figure 4. Variation of Maximum permissible oxygen concentration with percent of coarse particles in the mixtures of oil shale for different dust concentration

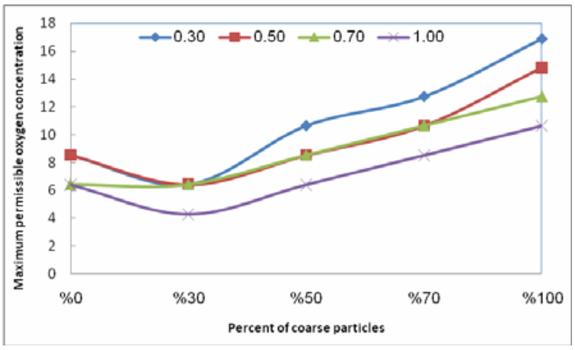

Figure 5. Variation of Maximum permissible oxygen concentration with percent of coarse particles in the mixtures of olive cake for different dust concentration

increases continuously, the average particle size in the mixture increases, ignition becomes easier, until a certain value is reached beyond which the surface area of the particles per unit weight is exposed to the oxidant increases, and consequently the maximum permissible oxygen required for ignition increases.

Figure 6 shows that olive cake is easily ignited compared with oil shale over all the specified mixtures and dust concentration. This is due that the percent by weight of the organic matter of olive cake is higher than that of oil shale.

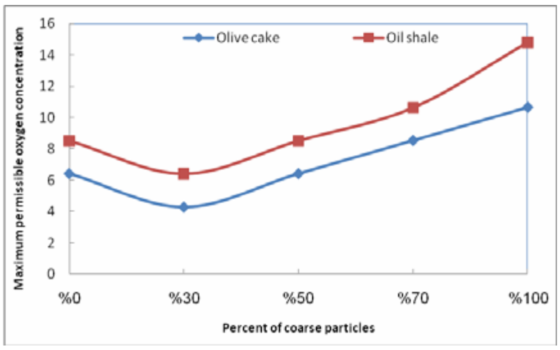

Figure 6. Variation of Maximum permissible oxygen concentration with percent of coarse particles in the mixtures for oil shale and olive cake for dust concentration of (1.0 g/L).

5. Conclusions

This study was carried out to investigate the inhibition of fine particles of oil shale and olive cake by mixing them with coarse particles of same fuels. This was achieved by introducing an explosive mixture of air and each fuel in Godbert-Greenwold Furnace Apparatus, which is electrically heated. Ignition of either fuel may be visually inspected at the bottom end of this apparatus. The study involved the measurement of the maximum permissible oxygen concentration to prevent ignition of both oil shale and olive cake under variable fuel concentration in the dust and under variable values of percentage amount of coarse particles in the combustible mixtures. It was found that, and for all values of coarse particles in the mixture, the maximum permissible oxygen concentration decreases with dust concentration to a minimum value beyond which it starts to increase. Further, the maximum permissible oxygen concentration was also found to initially decrease with coarse particles, and further increase of coarse particles leads to an increase in the maximum permissible oxygen concentration required for ignition. Finally, it was found that olive cake is easily ignited than oil shale all over the range of particle sizes and the fuel concentration in the dust samples.

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