An Experimental Investigation into the Dust Explosion of Bulk Solids

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Abstract- Bulk solids/ air mixture have been studied in a vertical experimental combustion chamber of dimensions 10×10×50 cm. The minimum ignition concentration and maximum ignition concentration required for burning of bulk solids is a main safety parameter when dealing with combustible bulk solids in industries. Two different kind of bulk solids (dust) wheat husk and wood dust of size less than 300 µm were tested in order to determine their maximum and minimum concentration required for burning. The experimental results shows that the minimum and maximum concentration required for wheat husk is 63 g/m^3 and 3610 g/m^3 and for wood dust it is 70g/m^3 and 3160 g/m^3 respectively under the ambient temperature of 293 ±7 K. Further it was also found that at concentration of 1232 g/m^3 and 1088 g/m^3, wheat husk and wood dust respectively is more hazardous. The conclusions striate from the experimental results are of ample significance for the safe application of combustible bulk solid.

Index Terms- Coal, dust, explosion, combustion

1. INTRODUCTION

Dust explosion is a common safety risks in process industries (chemical, metallurgy, wood, food etc.) those dealing with combustible dusts. More than 70% dusts processed in industries are combustible [1]. This implicit that most of industrial plants that have dust processing equipments are adaptable to dust explosion. Dust explosions are found in literature since 1785. Dust explosion occurred at Leiden, the Netherlands; on 12 January 1807 is one of the earliest recorded dust explosion. It is believed that the attempts of four member group prepare their food on stove, ignited the dust cloud leading to a detonation, evaluate to 9000 Kg of exploding TNT [1]. In china approx 10 dust explosions occurred in 4 years (2008-2011) in different industries [2]. In comparison to developed countries in India, the studies on the dust explosion started relatively too later and consciousness on harm of dust explosion is very less. Industrial technology of India is very similar to develop countries (Japan, USA, Germany) but information sensible to dust explosion occurring in India is almost negligible because in most of accidents that occurring in India, broad term explosion is used and recorded while the type of explosion goes unpublicized [1]. It is impossible to stop the dust explosions but prevention from dust explosion is possible. Prevention of dust explosion is possible by inerting cloud, using flameless vents, magnetizing surfactants, use of pressure relief vent holes etc [3, 4, 5]. Dust explosion can also be prevented if characteristics (MEL, LEL) of dust are known. Lot of experiments were done to control explosions occurring due to dusts and other processing industries, but explosions are still occurring in different countries due to different dusts, accidents impart that there are still some technical problems unsolved.

In this paper work, experiments on two dusts wheat husk, wood dust has been conducted in a 10×10×50 cm vertical chamber. To form dust cloud inside combustion chamber a vacuum unit and dust feeding unit was used. With vacuum pump vacuum was created, with the help of hopper dust was fed into the chamber. Combustion of dust/ air mixture was ignited by an electric spark produced by ignition coil. Thermocouples were used to find sudden temperature of flame after explosion. The objective of the research was to make enquires about ignition properties of wheat husk and wood dust. The effective mode to prevent bulk solids (dust) explosions are admired in this study.

2. SAMPLE PREPARATION

Sieving operation was executed to collect desired sample size of bulk solids, samples of different weights were collected with the help of digital

weighing machine. Samples were dried at the temperature of 313K, contains moisture content of 0.5gm.

Fig: 1 Wheat husk

Fig: 2 wood dust

3. EXPERIMENTAL

3.1 Experimental apparatus

An experimental set-up is schematically shown in Fig.3. It consists of an explosion chamber, Vacuum creating unit, dust feeding unit, ignition unit and data acquisition system. Explosion chamber is 50cm high and rectangular cross-section of 29 cm high, made up of plexiglass is used to observe ignition process conveniently. Vacuum creating unit was used to create vacuum up to 0.65 bar with the help of vacuum pump. Dust feeding unit was used to make a cloud inside the combustion chamber. The ignition unit consists of a pair of 0.4 mm diameter tungsten electrodes. Electrodes were fixed at the middle of the chamber, locates 13cm above from the bottom of ignition chamber. A high voltage produced by ignition coil (23KV) was used to produce spark between the tungsten electrodes.

3.2 Experimental procedure

Vacuum was created inside chamber, using vacuum pump up to 0.65 bar by closing valve 3. After creating vacuum inside container, close valve 1 and 2. Certain mass of dusts (wheat husk or wood dust) weighed by a balance was put in the hopper, valve 4 must be closed. The dust concentration was determined from the volume of combustion chamber and dust mass. Open valve 3, valve 4 must remained close. As valve 4 opened, dust cloud will form cloud inside the chamber, switch on the ignition unit.

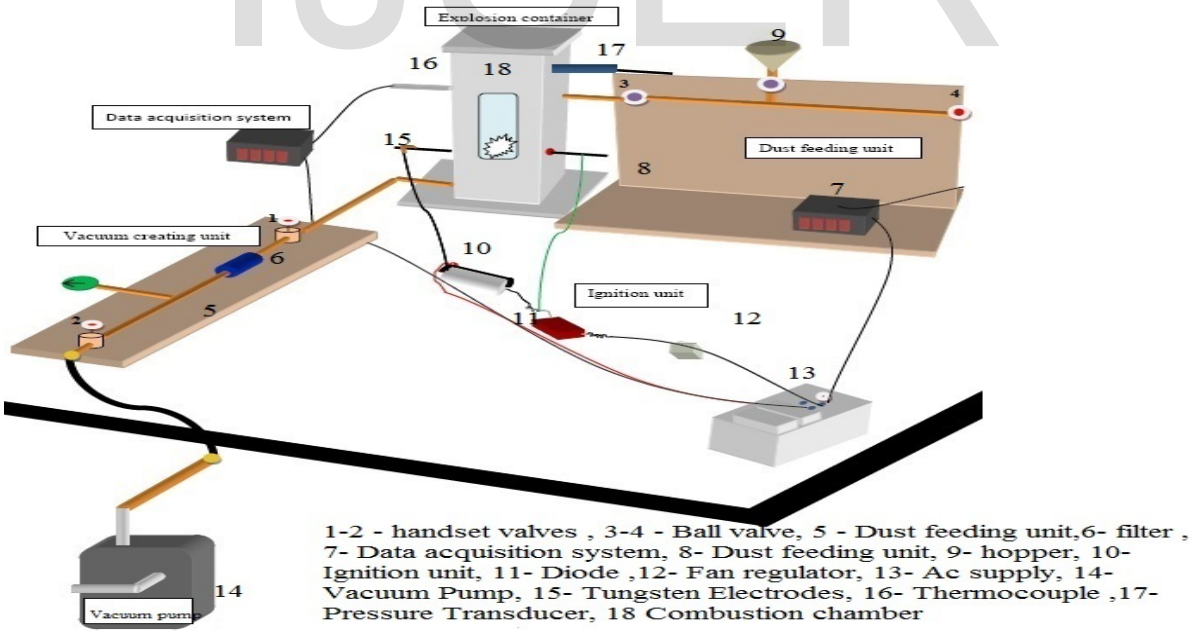

Fig 3: schematic experimental setup

As switched on the ignition unit, spark between the electrodes starts. After a delay of certain time period, burning will start inside chamber and flame propagation from spark location to upper end will takes place. Burning of air and dust mixture will only occur if dust concentration is between LEL (lower explosive limit) and MEL (maximum explosive limit). If dust concentration

is below than LEL or more than MEL, burning will not occur. By weighing dust, different concentrations per unit volume were made, after performing same steps of experiment, LEL and MEL for wheat husk and wood dust were found.

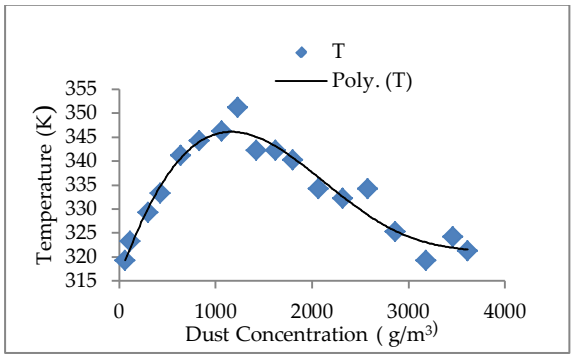

Fig 4: Variation of temperature with wheat husk dust concentration

Figure 4 shows trend line variation of flame temperature with dust concentration of wheat husk. Study of figure tells that below 63g/m³ or above 3610 g/m³ of dust concentration, explosion did not occur. Initially when dust concentration per unit volume was low (lean air dust mixture), improper combustion occurred, less temperature sensed by the thermocouple. As the dust concentration per unit volume increased, temperature sensed by thermocouple increased, 351.15 K maximum temperature found at a 1232g/m³ concentration due to proper mixture of air and dust. Again when dust concentration per unit volume increased (Rich air dust mixture) improper burning took place and less temperature was sensed by thermocouple.

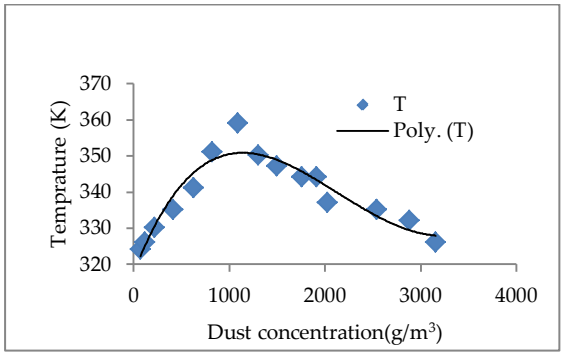

Fig 5: Variation of temperature with wood dust concentration

Figure 5 shows trend line variation of flame temperature with dust concentration of wood dust. Below 70 g/m³ or above 3160 g/m³ of dust concentration, explosion did not occur. At a concentration of 1088g/m³ proper burning took place and maximum temperature of 359.15K was sensed.

3.3 Results and discussion

It is impossible to stop dust explosion but prevention from dust explosion is possible. Prevention from dust explosion also be possible if dust chracterstics (LEL, MEL) are known. The set of experiments was developed to find minimum and maximum explosible concentration of dust. Minimum and maximum explosible limit for wheat husk is 63g/m³ and 3610g/m³ respectively, if cloud concentration will maintain below 63g/m³ or above 3610g/m³ dust explosions by wheat husk can be avoided. Maximum temprature sensed by thermocouple for wheat husk at a concentration of 1232g/m³, Signifies that wheat husk at this concentration is more hazardous than other concentrations. Minimum and maximum explosible limit for wood dust is 70g/m³ and 3160g/m³ respectively, if cloud concentration will maintain below 70g/m³ or above 3160 g/m³ explosion will not occur. At a concentration of 1088g/m³ temperature sensed was maximum signifies wood dust at this concentration is more dangerous than others. Further it was found that wood dust explosion is more hazardous than wheat husk; temperature rise in case of wood dust is more than wheat husk.

Fig 6: Experimental setup

Fig7: Flame propagation after burning

4. CONCLUSION

(1) The optimum ignition concentration of wheat husk is between (63-3610) g/m^3 at an ambient temperature of (293±7) k.
(2) The optimum ignition concentration of wood dust is between (70-3160) g/m^3 at an ambient temperature of (293±7) k.
(3) Wheat husk and wood dust is more hazardous at concentration level of 1232 g/m^3 and 1088 g/m^3 respectively.
(4) Wood dust is more hazardous than wheat husk.

5. REFERENCES

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