Hydroxy Propyl Methyl Cellulose 분진의 운상자연발화에 관한 연구

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A Study on The Spontaneous Ignition of a Hydroxy Propyl Methyl Cellulose Dust Cloud

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Abstract : The minimum ignition temperature at which the dust cloud can spontaneously ignite is considered to be very important in industries to prevent explosion occurring in hot surfaces. This paper has dealt with the experimental study of the determination of minimum ignition temperature of Hydroxy Propyl Methyl Cellulose (HPMC) dust cloud. We have used the Godbert-Greenwald Furnace Apparatus to determine the ignition temperature and limiting oxygen concentration for dust could.
The experimental determinations on the minimum ignition temperature were carried out with various particle size with nominal diameters 45, 75 and 106㎛. The limiting oxygen concentration of dust cloud was determinated for the smaller size(45㎛) HPMC. Minimum ignition temperature of dust cloud was at 364℃ for the concentration of 2.5g/L in the air and became higher with the increasing of nitrogen concentration. It was also found that the ignition didn't occur when the oxygen concentration was below 10%, and the limiting oxygen concentration is at 11%.

초 록 : 최근 산업현장에서는 제품의 품질과 성능을 향상시키기 위해 나노 기술로 나아가는 추세에 있으며, 이러한 연구들로 인해 많은 화학제품의 원료들이 더욱 미세한 상태로 가공 및 취급되어지고 있다. 이에 분진의 특성상 그 위험성이 따라 증가하고 있으므로, 분진폭발의 발생을 예방하기 위해 분진운의 발화온도와 폭발한계산소농도 등을 찾아내는 것은 매우 중요한 일이다.
따라서 본 연구에서는 현재 국내에서 생산되고 있는 Hydroxy Propyl Methyl Cellulose (HPMC)을 가지고 실험을 하였으며, 생산 및 취급과정에서 뜨거운 표면으로부터 발생될 수 있는 화재 및 폭발을 예방하고자, Godbert-Greenwald Furnace장치로 실험하였다. 그 결과 분진 입자의 크기가 작아짐으로서 발화온도는 낮아지는 경향을 나타내었으며, 분진입자의 크기가 45㎛에서 HPMC 분진운의 최소발화온도는 364℃로 나타났으며, 폭발한계산소 농도는 11%로 나타났다.
Key Words : dust cloud, minimum ignition temperature, limiting oxygen concentration, Hydroxy Propyl Methyl Cellulose, Godbert-Greenwald Furnace Apparatus

1. Introduction

The amount of use of the combustible dusts which are polymer substances has recently been increasing, and the hazards of dust explosion are always in the production processes. Powder handling process, such as grinding mill, dryer, dust collector, transportation device, etc. is always exposed to the risk due to dust explosion, particularly in dealing with coal, cereal, metal, and plastic[1-3].

Dust explosion has been studied experimentally with the combustible dusts for several independent items ;

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autoignition temperature, minimum explosible concentration, minimum ignition energy, minimum oxygen concentration, rate of pressure rise, etc. Also, the minimum temperature at which dust cloud can spontaneously ignite is considered to be very important in industries to prevent explosion occurring in hot surfaces.

The study on the dust cloud has been actively performed by Manju Mittal and B.K. Guha[4], Y.S. Mok and J. S. Kim[5].

The dust explosion process has been considered as follows. (1) Heat is supplied to the surface of a particle to elevate its temperature. (2) Oxidation occurs on the particle surface, so that the temperature may be further elevated. For some materials the promoted reaction produces inflammable gas as a result of thermal degradation. (3) Inflammable gas thus produced is mixed with ambient air leading to ignition to produce flame. (4) Heat generated due to the flame promotes the oxidation and ignition of other particles[4]. This theory, the dust explosion process and dust cloud process are similar to combustible style. From this point of view, the basis for the autoignition prevention of dust clouds should be known the minimum ignition temperature of particle sizes and the limiting oxygen concentration. These are important factors at dust cloud.

In this study, the minimum ignition temperature and the limiting oxygen concentration of the dust cloud of Hydroxy Propyl Methyl Cellulose (namely HPMC), which was manufactured at OO Fine Chemicals Ltd. in Korea, investigated by using the Godbert-Greenwald Furnace.

HPMC which is widely used in the fields of paint, food, paper, pharmaceuticals and cosmetics industries, has not yet been studies about the minimum ignition temperature and the limiting oxygen concentration. But we already study out the LEL(lower explosive limit) 180 g/m^3 and MIE (minimum ignition energy) 9.8mJ. Several dust explosion accidents at OOFine Chemicals Ltd. have been in recent years. However, small accidents and troubles still be accompanied with the power handling. So, the obtained data will be offered in order to prevent the industrial fire and explosion in powder industry.

2. Experiment

2.1. Experimental Apparatus

The experimental apparatus for ignition a dust cloud in this study is the developed Godbert-Greenwald furnace[6] and this is composed of an electric furnace, a combustion tube(quartz tube), the supplier of compressed gas, a temperature controller and the others.

The electric furnace is manufactured in the capacity of 4kW and can heat up to 1000℃, and the combustion tube(ϕ 4cm×L 26cm) is set up in the center of the furnace and the inside temperature of the tube is measured by the thermocouple(1.6mm) which is inserted in the center.

The temperature control is performed by the PID controller and the experiment is done after the temperature of the electric furnace and the inside temperature of the combustion tube is controlled with the same value.

2.2. Experimental Method

This experimental apparatus is shown in Fig. 1 and the inside of the combustion tube is sustained at the desired temperature by the temperature controller, and then sustained by oxygen-nitrogen (N_2-O_2) mixture gas.

The sample is charged in the sample tube and then blown down into the combustion tube in the controlled pressure(0.8kg/cm^2) of oxygen-nitrogen mixed gas. At this time the ignition is distinguished when the flame is effused from the end of tube as the sample is ignited.

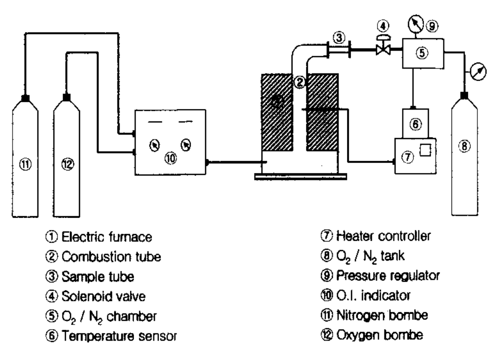

Fig. 1. Experimental apparatus for Godbert-Greenwald furnace of the ignition temperature of dust cloud.

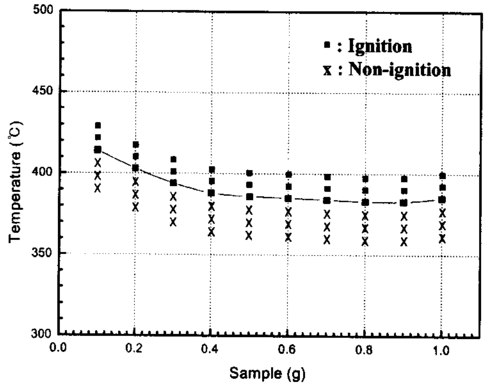

Fig. 2. Variation of ignition temperature with dust concentration for particle size 106μm HPMC.

When the flame is not effused, it is regarded as non-ignition. Then, the experiment is repeated after the residual dust is cleaned.

3. Results and Discussion

The minimum ignition temperature for various nominal particle sizes(45, 75 and 106μm) were measured for wide ranges of dust concentration (0.3, 0.6, 0.9, 1.2, 1.5, 1.8, 2.1, 2.5, 2.8 and 3.1g/L). The resulting data of the variation of ignition temperature with dust concentration for different particle sizes are shown in Fig. 2, 3 and 4. The figures show that the ignition temperature decreases with an increase in dust concentration in the lower range where as it rises with a further increase in ignition temperature.

The curves show the data obtained in the runs of multiple sets under ignition and non-ignition condition.

The minimum ignition temperature is quite high at very lean dust concentration of 0.3g/L. This is due to the fact that at low dust concentrations, the dispersed particles are devolatilized rapidly as like as combustible volatile component with the upper explosive limit value has low oxygen concentration.

Released at lower temperature is not sufficient to initiate and propagate the flame and hence a higher furnace temperature is required for autoignition of the dust cloud in high or low concentrations.

As increasing dust concentration, the vaporization rate reduces due to a shielding effect on the heat transfer. Ultimately, this situation is arrived at when the combustible vapor concentration reaches stoichiometric proportion, and when the oxidation is highest and the flame propagation is possible at lower temperature conditions.

The combustible volatile materials become the controlling factor for the rate of oxidation, as well as heat generation. This means that the limiting dust concentration will require a higher temperature.

Preliminary experiments data on minimum ignition temperature of HPMC is shown in Fig. 5, and the values ranges are from 0.3 to 3.1g/L for particle sizes 45, 75 and 106μm. It shows that the required minimum ignition temperature increases in proportion to the particle size.

This behavior may be explained by the fact that for HPMC dust ignition is preceded by volatilization which is the controlling reaction step in the process. The rate of this reaction is dependent on the exposed surface area of particles.

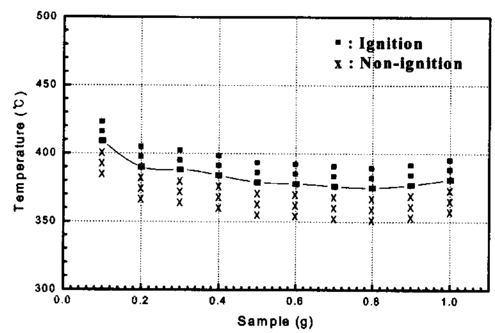

Fig. 3. Variation of ignition temperature with dust concentration for particle size 75μm HPMC.

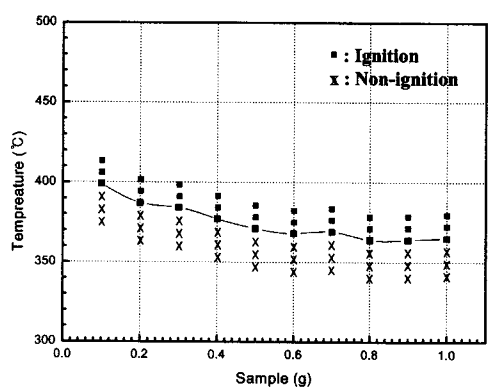

Fig. 4. Variation of ignition temperature with dust concentration for particle size 45μm HPMC.

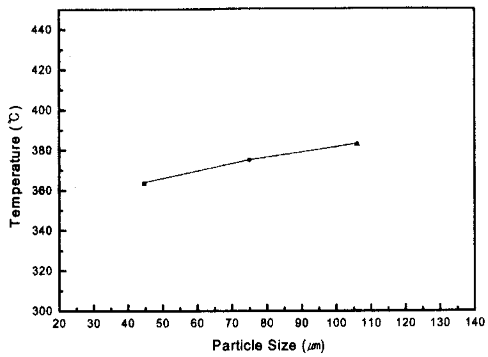

Fig. 5. Variation of minimum ignition temperature with dust particle sizes 45, 75 and 106㎛ of HPMC.

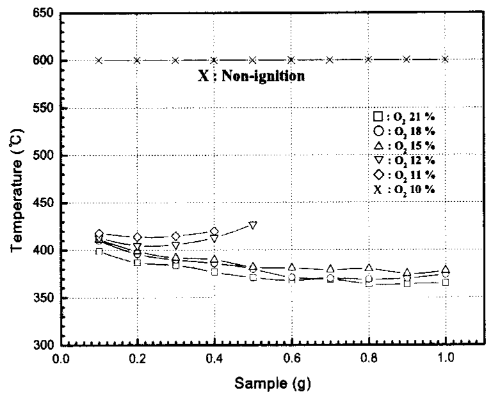

Fig. 6. Dust cloud autoignition temperature as the change of oxygen concentration.

For larger particles, the surface area per unit volume of dust is lower, hence a higher minimum dust concentration is required so that increased volatile combustible products are formed from devolatilization of a larger number of particle sizes.

Ignition temperature of dust clouds of HPMC with the concentration of oxygen is shown in Fig. 6.

The minimum ignition temperature of dust clouds in the air is obtained at 364℃ with the sample of 2.5g/L at particle size 45㎛ and the ignition temperature increases as decreasing of the oxygen concentration. The minimum ignition temperatures for 18%, 15%, 12% and 11% oxygen concentrations are 369℃, 375℃, 405℃ and 414℃ with the sample particle size 45㎛. It is also found that ignition doesn't occur when the oxygen concentration is below 10%, and the limiting oxygen concentration is at 11%.

4. Conclusion

This study was performed by the determination of ignition temperature and limiting oxygen concentration with the dust cloud of Hydroxy Propyl Methyl Cellulose(HPMC) which was used for various purpose with the development of industry.

The results are as follows:

1) Minimum ignition temperature with dust concentration for different particle sizes was 364℃ with 2.5g/L for 45㎛, 375℃ with 2.5g/L for 75㎛ and 383℃ with 2.5g/L for 106㎛.

2) The ignition temperature increases as increasing of particle size. But in the same size, the ignition temperature decreases as increasing of dust concentration.

3) The ignition temperature increases with the decreasing of oxygen concentration. So, the minimum ignition temperatures at 21%, 18%, 15%, 12% and 11% oxygen concentrations was 364℃, 369℃, 375℃, 405℃ and 414℃ in the sample particle size 45㎛.

4) It was found that ignition doesn't occur when the oxygen concentration is below 10%, and the limiting oxygen concentration is at 11%.

References

1) P. Field, "Dust Explosion", Elsevier Sci. Pub., Amsterdam, 1982.
2) Richard E. Cocks, "Dust Explosion : Prevention and control", Chemical engineering, pp. 94, 1979.
3) Waylcmd C. Griffith, "Dust Explosion" Ann. Rev. Fluid Mech, 1978.
4) Manju Mittal, B.K. Guha, "Study of Ignition Temperature of a Polyethylene Dust Cloud", Fire and materials, Vol. 20, pp. 97~105, 1996.
5) Y.S. Mok, J. S. Kim, S.H. Park, "A Study on the Ignition Energy of MBS Dust Explosion", Proceeding of the 1st Conference of the Association of Korean-Japanese Safety Engineering Society, pp. 172~175, 1999.
6) Norbert Jaeger, Richard Siwek, "Prevent Explosion of Combustible Dust", Chem. Eng. Prog., Vol. 3, pp. 25~37, 1999.