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Fire Extinguishing Efficiency of Magnesium Hydroxide Powders under Different Particle Size

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Abstract

After Montreal protocol, more and more new materials have been applied as the substitutes of Halon. Much attention has been paid to fire extinguishing efficiency of alkali metal salts and ammonium phosphate salts, but the effects of particle sizes have not been studied sufficiently. The fire-extinguishing efficiency of a new kind of agent based on magnesium hydroxide of different particle size was studied in this paper. Four different size powders have been used to study their fire-suppression efficiency through laboratory scale experiments in a confine space of 1*1*1m. The physical and chemical characteristics of the magnesium hydroxide powders were characterized by scanning electron microscopy (SEM) and thermal gravity analysis (TGA). The results have exhibited that these four kinds of powders are all high efficient for the fire suppression efficiency and there is a threshold value of 5μm for the fire suppression efficiency of magnesium hydroxide. The efficiency can be affected by the morphology of powders and particle size. The powders of larger specific surface area and smaller particle size are more efficient to suppress fire. Fire extinguishing and possible fire-suppression mechanisms have also been analyzed from three aspects: chemical inhibition, cooling effect and asphyxiation effect.

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Keywords: fire suppression, dry powders, magnesium hydroxide, particle size

1. Introduction

After Montreal protocol was signed, the rapid phase-out of Halon has become impending. Researches on Halon substitutes have become hot spots in the whole world. Compared to other fire extinguishing agent, powder agents have many advantages, such as short fire suppression time, low environment toxicity, easy long-time storage, suitable for water deficient areas and so on. Consequently, more and more scholars have paid more attention to research on powder chemicals, including alkali metal, phosphate salts and so on[1-5].

Moore and Tedeschi, et al. [6-7] have studied the efficiency of some powders and discovered that the fire-suppression efficiency of powders increased obviously with the decrease of the particle size. But in the experiment of Fleming and his co-workers[8], a different conclusion has been reached, which states that the fire-suppression cannot be improved again with the decrease of the powders' size, when the particle size have decreased to a threshold value.

It is generally believed that fire extinguishing efficiency of chemical powders will be improved with the decrease of the particle size. However, now there is still some dispute about this conclusion. Some scholars assumed that if there was a critical ratio for the large and small powders, the fire extinguishing effectiveness was higher. Thus, now there is still no final

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solution for this dispute [9].

In the 21st century, more and more new materials have been made. Thence, finding new chemical suppressants has become necessary and significant. And many chemicals have been evaluated as high efficient chemical powders, because of their characteristics of low cost, high efficiency and environment-friendly. Magnesium hydroxide ($Mg(OH)_2$) is one of such chemical powders. A comparison of fire suppression effectiveness between $Mg(OH)_2$ and commercial chemical powders has been made. Zhang and Zhou[10] have presented magnesium hydroxide has the potentiality as a good substitute in the future and it has much more advantages compared with other chemical powders. Kuang[11] and his co-workers have reported that the fire suppression efficiency of magnesium hydroxide in a bench-test has better performance than that of other commercial BC powders. The fire suppression efficiency of superfine magnesium hydroxide has been studied compared with the commercial ABC powders by Wang [12]. Most of researchers have paid much attention to the comparison of fire suppression efficiency between $Mg(OH)_2$ and commercial powders. The effects of particle sizes to the fire extinguishing efficiency have not been studied sufficiently. Thus, detailed study of influence of particle size should be conducted in order to investigate the capability of fire suppression under different particle size.

A bench-scale fire suppression experimental apparatus has been set up in order to study the fire suppression effectiveness of $Mg(OH)_2$ powders under different particle size. The structure and the thermal decomposition process have been also obtained by scanning electron microscopy (SEM) and thermal gravity analysis (TGA), respectively. The fire extinguishing efficiency of magnesium hydroxide powders under different particle size has been explored in this paper.

2. Experiment

2.1 Materials and Characterizations

Four different sizes of chemical powders, which are 2μm, 5μm, 10μm and large particle size (over 20μm called as PT), were manufactured by HeFei ZhongKe Flame-Retardant New Material co., LTD.

The particle size and particle surface shape of $Mg(OH)_2$ powders were acquired by scanning electron microscopy (SEM) (XT30 ESEM-TMP SEM). The amplification factors are 2000, 5000 and 1000. Thermal decomposition characteristics of $Mg(OH)_2$ powders were measured by TGA-Q5000 IR instrument. $Mg(OH)_2$ powders were heated at the heating rate of 20 ℃\min from 50℃ to 800℃ under air.

2.2 Fire Extinguishing Tests

2.2.1 Experiment Apparatus

A bench scale experiment apparatus of confined space has been built, as shown in Fig. 1, including the oil pans, powder container, driving gas system (compressed air or nitrogen) and data measurement system. The parameters of temperature changes and fire-extinguishing time have been measured.

N-heptane has been used as fuel in the square oil pan, with the length of 10cm, 15cm, 20cm and 25cm, respectively. Eight thermocouples（k type, 1mm diameter） have been installed to measure the temperature changes when the chemical powders were discharged in this system. Six of them have been set up at the vertical axes of the oil pan, with the spacing of 10cm. The other two thermocouples have been fixed at the distance of 4cm from the vertical axes of oil pan , to measure the boundary temperature of flame and the oil temperature.

The chemical powders have been filled into a portable fire extinguisher with two steel tubes at the top. One tube is connected to the driving system (compressed nitrogen); the other is linked to a powder nozzle through a flexible pipe with a 12cm internal diameter. In this system there are two ball valves. One valve has been applied to control the compressed nitrogen and the other has been used to control the mixture of the nitrogen and the chemical powders and the release time of the powders.

A cone-shaped nozzle has been installed at the ceiling of the confined space, at the vertical axis of oil pan. Its cone angle was 60°.

2.2.2 Experiment Procedure

50g of $Mg(OH)_2$ powder and about 50g of n-heptane have been poured into the powder container and oil pan, respectively. A certain pressure was adjusted as the driving force and then the fuel was ignited. After about 30-90s pre-ignition, the powders were sprayed out when the temperature kept stable. When the fire was extinguished, the ball valve was turned off immediately and then the measurement parameters were recorded. The steps above would be repeated under