The assessment of fire suppression capability for the ammonium dihydrogen phosphate dry powder of commercial fire extinguishers

Chung-Hwei SU*, Chan-Cheng CHEN, Horng-Jang LIAW, Shiuan-Cheng WANG

Department of Safety, Health and Environmental Engineering, National Kaohsiung First University of Science and Technology
No.1, Daxue Rd., Yanchao Dist., Kaohsiung City 82445, Taiwan, China

Abstract

The fire extinguisher is one of important fire safety equipments in Taiwan. The ABC powder fire extinguisher is a common fire safety equipment as it can extinguish different kinds of fire, such as papers, gasoline, electrical fire etc. The main constituents of ABC powders are ammonium dihydrogen phosphate and ammonium sulfate. The principal components of ammonium dihydrogen phosphate extinguishant are inspected according to the molybdenum-vanadium phosphate colorimetry in Section 4 and the volumetric method of quinoline in Section 3.1 of Taiwan's CNS 8450-1992 Method of Test for Fertilizers – Determination of Phosphorus Content, which major project is the determination of phosphorus content. The DSC was used in this study to inspect the ABC powder of fire extinguishers, the thermal decomposition values of constituents of powder were analyzed directly. Not to determine the phosphorus content indirectly is the key concept in this study. The results showed that the variation curves of ammonium dihydrogen phosphate and ammonium sulfate have their particularities, and they will not disturb each other.

1. Introduction

1.1. Introduction to importance and extinguishing mechanism of fire extinguishers

The fire extinguishers are the one of important fire safety devices for building safety, and should be set up in shopping malls, offices, restaurants, houses, or even cars. The commercial ABC type powder fire extinguisher has stifling and cooling effects. It suppresses the free ions of chain reaction, and extinguishes fire quickly. The extinguishable types include general inflamers, oils and electrical fires. Therefore, it was extensively used in the past 50 years.
The mechanism of interaction between dry powder and flame was seldom studied in the past. After the Halon 1301 extinguishant was forbidden for its adverse effect on the environment in recent years, research has been focused on dry powder extinguisher [1, 2]. Ewing et al. proposed the extinguishing mechanism phenomenon. They demonstrated that the heat capacity of dry powder results in heat absorption, and the vaporization and decomposition of dry powder particles are the dominant mechanism of extinguishment. The extinguishing ability of dry powder depends on the particle size and chemical reaction, smaller particle size structure and higher heat absorption capacity represent better extinguishing ability [3-6].

Fleming et al. conducted extinguishment test for NaHCO₃ (principal component of BC dry powder) and KHCO₃ (principal component of KBC dry powder) in diameter of 38 to 75 μm. The findings showed that before a threshold value was reached, smaller powder particles require less amount. The two materials had this phenomenon [7, 8]. In Taiwan's dry powder inspection, the power fineness requires that more than 90% of powder passes through the 80 sieve mesh of CNS 386 test sieve, the micro structure is not inspected in details [9, 10].

1.2. Inspection of ABC type powder fire extinguisher in Taiwan

The main constituents of ABC powders are ammonium dihydrogen phosphate and ammonium sulfate. The ABC powders can be used for electrical fires for it is not conductive. The ammonium dihydrogen phosphate is a white crystal, its molecular formula is NH₄H₂PO₄, soluble in water, slightly soluble in ethanol. It is mainly used for producing fertilizer and extinguishers. The thermal decomposition equations are expressed as follows:

\[
\begin{align*}
\text{NH}_4\text{H}_2\text{PO}_4 & \rightarrow \text{H}_3\text{PO}_4 + \text{NH}_3 \\
2\text{H}_3\text{PO}_4 & \rightarrow \text{H}_2\text{P}_2\text{O}_7 + \text{H}_2\text{O} \\
\text{H}_2\text{P}_2\text{O}_7 & \rightarrow 2\text{HPO}_3 + \text{H}_2\text{O} \\
2\text{HPO}_3 & \rightarrow \text{P}_2\text{O}_5 + \text{H}_2\text{O}
\end{align*}
\]

The ammonium sulfate is colorless rhomboidal, freely soluble in water. The thermal decomposition equations are expressed as follows:

\[
\begin{align*}
\text{(NH}_4\text{)}_2\text{SO}_4 & \rightarrow \text{NH}_4\text{HSO}_4 \\
\text{(NH}_4\text{)}_2\text{SO}_4 & \rightarrow 2\text{NH}_3 + \text{H}_2\text{SO}_4
\end{align*}
\]

In order to strengthen the extinguishing function of fire extinguishers, Taiwan's fire authorities issued the "Fire Extinguisher Agent Replacing and Filling Operation Specifications" in 2011, so as to perfect the operating mechanism of fire extinguisher agent replacing and filling [11]. The content specifies that the principal components of agent shall conform with the inspection mode of the Basic Specifications of Approval to Extinguishing Agent of Fire Extinguishers [12].

The principal components of ammonium dihydrogen phosphate extinguishant are inspected according to the molybdenum-vanadium phosphate colorimetry in Section 4 and the volumetric method of quinoline in Section 3.1 of Taiwan's "CNS 8450-1992 Method of Test for Fertilizers—Determination of Phosphorus Content". The major project is the determination of phosphorus content. In the "test by volumetric method of quinoline", the ethanol is used as moisture proofing solvent for phosphate extinguishant [13].

This study uses Differential Scanning Calorimetry (DSC) to test the decomposition heat property of dry powder, the endothermic change in the decomposition course of ABC dry powder is discussed, the characteristics of ammonium dihydrogen phosphate extinguishant are tested directly.

2. Introduction to experimental apparatuses

2.1. Introduction to principle of DSC

The DSC is a technology for observing the matter energy change. The sample and reference substance are put in different labwares, in the same heater, heated or cooled at fixed rate, or heated at constant temperature to measure the enthalpy change. The data are recorded in "energy" difference function continuously [14,15].

The experimental apparatus for discussing the dry powder thermal properties in this study is the DSC821e of Switzerland METTLER TOLEDO. The equipment is shown in Fig. 1. The container is 40μl aluminum crucible
The dry powder weighing instrument is the balance (A0245) of Switzerland METTLER TOLEDO, as shown in Fig. 2. The precision is 0.0001g.

2.2. Experimental method

For the thermal decomposition experiment, the temperature control condition is set in the operation procedure, the temperature difference between the material and reference substance is measured. When the test specimen is evaporated, molten, crystallized or decomposed, there is endothermic or exothermic change. The reaction heat, melting point and kinetic parameter data of sample are measured according to the variation of energy with temperature or time. The measurement modes include constant pressure and constant volume [16].

The test items are described below:
- Ammonium dihydrogen phosphate powder
- Ammonium sulfate powder
- Mixed powder of ammonium dihydrogen phosphate and ammonium sulfate
- Commercially available ABC dry powder

The constant pressure method (one atmosphere) is used for measurement, and the range of temperature rise is 30°C to 500°C. The heating rate is 5°C/ min in the testing process. The laboratory sample weight is 2 to 3mg each time, and the heat value curve of ABC dry powder thermal decomposition is obtained.

3. Results and Discussion

Fig. 3 shows the heat value curve of thermal decomposition of ammonium dihydrogen phosphate powder. It is observed that the decomposition behavior of ammonium dihydrogen phosphate is endothermic reaction. The initial temperature of decomposition is 200°C. Fig. 4 shows the heat value curve of thermal decomposition of ammonium sulfate powder. It is observed that the ammonium sulfate decomposition course has two stages of endothermic reaction. The initial temperatures are 230 and 360°C respectively.

If the ammonium dihydrogen phosphate is mixed with ammonium sulfate, the thermal decomposition curve of mixed powder in Fig. 5 can be obtained. It is observed that the change in the curve of the mixture is identical with the changes in Figs. 3 and 4. There is slight change in the initial temperature, meaning the DSC is reliable for the thermal decomposition of extinguishing material to some extent.

Fig. 6 shows the thermal decomposition curve of commercially available ABC dry powder. The variation in the curve is similar to that in Fig. 5. It is obvious that using DSC to test the thermal decomposition of extinguishing material can check whether the chemical constituents of ABC dry powder include ammonium dihydrogen phosphate and ammonium sulfate.
Fig. 3. Ammonium dihydrogen phosphate powder thermal decomposition value.

Fig. 4. Ammonium sulfate powder thermal decomposition value.
4. Conclusion

The fire extinguisher is one of important fire-fighting equipments whether public or private buildings in Taiwan. The ABC powder fire extinguisher is a common fire safety equipment since the function of extinguishing different kinds of fire. Therefore, the effectiveness of dry powder is a great important issue. Taiwan's fire authorities specify that the principal components of ABC powder agent should conform to the inspection mode of Basic Specifications of Approval to Extinguishing Agent of Fire Extinguishers, but the phosphorus content is measured
indirectly for inspection.

The DSC was used in this study to inspect the ABC powder of fire extinguishers, the thermal decomposition values of constituents of powder are analyzed directly. Not to determine the phosphorus content indirectly is the key point in this study. The results showed that the variation curves of ammonium dihydrogen phosphate and ammonium sulfate have their particularities, and they will not disturb each other. This study further proves that the method and equipments used can test whether the thermal decomposition value of commercially available ABC power containing ammonium dihydrogen phosphate and ammonium sulfate effectively.

References