Research paper

The study of new aerozol generator of extinguisher

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Abstract

Potassium nitrate is an inorganic salt and it is very difficult to release potassium radicals as a chain reaction inhibitor in burning fires. An aerosol generator with organic potassium carboxyrate was found to be efficient at releasing potassium radicals and was also effective as a novel type of aerosol extinguisher.

Keywords: aerosol, extinguisher, K/SMOKE

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1. Introduction

Long ago, the classical aerosol generant of extinguishers comprised typical explosives with potassium nitrate as an oxidizer. Conventional extinguisher reagents are water, powder, foam, and gas. After dispersal, extinguisher reagents such as water, powder, and foam dirty the area and damage the devices, whereas inflating gases such as carbon dioxide or halon are toxic for the human body. In this study, we examined an "aerosol" type of extinguisher ; "aerosol" differs from water, powder, foam, and gas as it consists of a system of colloidal particles dispersed in gas; simply, an "aerosol" is smoke or fog. Thus, "aerosols" do not dirty the affected area or damage any devices, and are safe for the human body. Aerosol extinguisher technology is not new but has been conventionally used worldwide. Usually, aerosol generants comprise explosives such as potassium nitrate (KNO_3) as the source of potassium for extingushing fires and dicyandiamide or nitrocellulose as the fuel compound[1)−4)]. In Japan, use of such aerosol extinguishers is unusual because of explosives that are difficult to treat and manufacture for extinguishing as the manufacturer has to maintain safety without control of pyrotechnic technology.

The mechanism to suppress fire using "aerosols" is as follows[5),6)]: First, free radicals are formed, and fires propagate by a chain reaction of free radicals such as hydrogen, oxygen, and hydroxyl radicals. After heat decomposition, an aerosol generator forms pottasium radicals and ions as "K"and these attack the free radicals in fire, leading to complete fire suppression and stabilization.

An aerosol generator in an extinguisher is based on a solid propellant suited for suppresion applications. The aerosol is discharged directly into the fire zone of the protected area to suppress the fire.

Combustion radical scavengers such as "K", are produced during propellant combustion in the form of solid particles as an "aerosol". Thus, a good aerosol generator must have a compound that easily releases potassium radicals or ions as "K".

2. Simulation approach

To determine novel compounds that easily release potassium radicals or ions as "K", an ab initio Molecular Orbital method (MO) calculation using GAUSSIAN03/6-31 G* was used to determine the dissociation energy between potassium and oxygen or halogen as typical organic potassium salt models (Figure 1 upper). Thus, the bond dissociation energy between K and O of organic potassium carboxylate was found to be lesser (Figure 1 lower), and athylenediaminetetraacetic acid (EDTA) was found to be the best compound for easily releasing potassium radicals or ions; however, EDTA is expensive. Therefore, tripotassium citrate was chosen as the source of potassium radicals or ions in the aerosol generant[9)].

3. Experimental approach

3.1 Aerosol generant

The aerosol generant was manufactured following the process based on our knowledge.

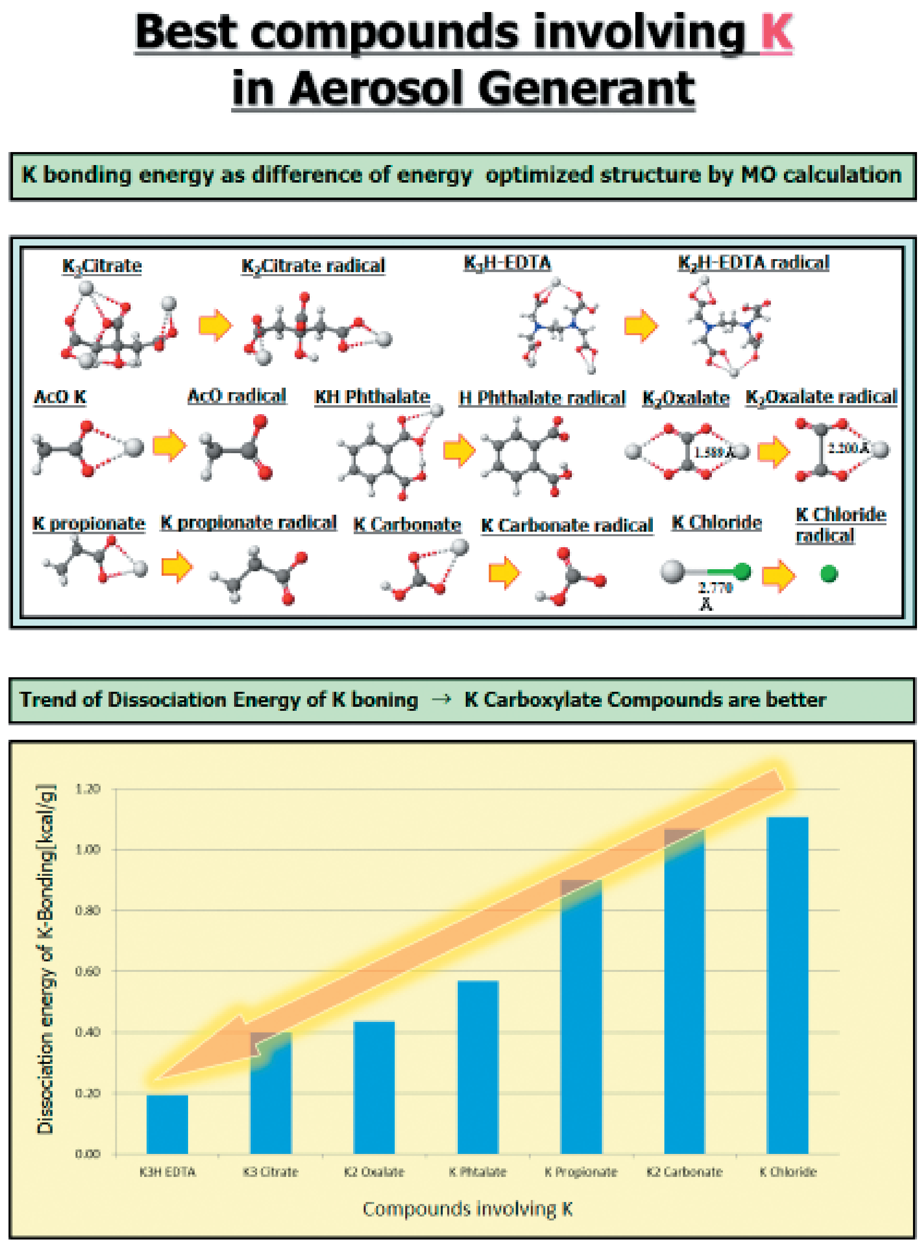

Figure 1 Trend of dissosiation energy of K-bonding.

Raw materials such as powders of organic potassium carboxylate, inorganic salt as an oxidizer and binder were mixed together with the solvent, pressed to the target shape, and dried to remove the solvent in a high temperature oven. According to the vessel size or use, this shape could be controlled to form various types as shown in Figure 2.

For example, disk type, 100 g: $\Phi 65 \times 25$ mm; cylinder type, 2 g: $\Phi 10 \times 20$ mm; bar type, $\Phi 10 \times 300$ mm; donut type, $\Phi 50 - 30 \times 25$ mm; and sheet type: A4 size $\times$ 1 mm.

3.2 Composition screening of aerosol generant by fire supression test

Screening of a small sample as $\Phi 10 \times 20$ mm type was performed for fire supression to research the composition of the novel type of aerosol generant as shown in Figure 3. The screening sample was placed on SUS mesh on n-heptane burning in a $\Phi 30$ ceramic vessel covered with a 3 L glass beaker. After the sample was placed and smoke was produced, a lighter was inserted in the smoky beaker, and the lighter's fire was found to be extinguished repeatedly.

3.3 K/SMOKE as an aerosol generator system

The optimized composition of the aerosol generant was used as a $\Phi 65 \times 25$ mm shape in the main charge of an Aerosol extinguisher; when the temperature sensor detects a temperature above 70°C, the control panel gets an alarm signal, and flows current to the main charge. The main charge then works against the fire target. The entire system is reffered as the "K/SMOKE" Aerosol Generator System (Figure 4)[10].

The performance of "K/SMOKE" was as follows:
Figure 5 shows the Aerosol Generator System deploying "K/SMOKE".

The minimum quantities of reagents required for extinguishing fire in a 1 m^3 space were as follows: 1000 g of carbon dioxide, 550 g of HFC-227ea as hydrofluorocarbon (HFC) type, 300 g of Halon 1301 as halon type, and only 55 g (1/18 compared to the quantity of carbonoxide) of K/

Figure 2 Typical aerosol generants.

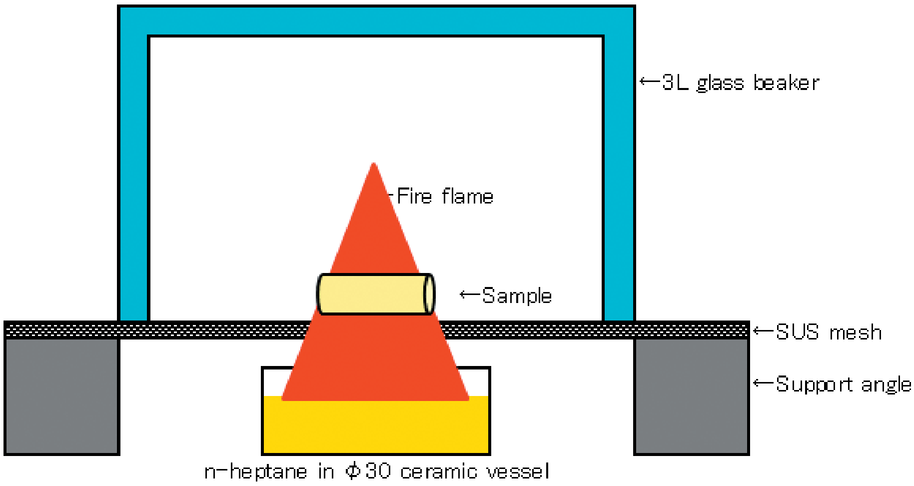

Figure 3 Composition screening method.

Figure 4 "K/SMOKE" aerosol generator system.

SMOKE aerosol generant (Figure 5).

Targets of K/SMOKE are as follows (Figure.6):

1) House
2) Computer server room
3) Control panel
4) Engine room in Automobiles
5) Machine tools
6) Power plant

Manufcturers of large parts of automobiles in Japan have already purchased the K/SMOKE system for machine tools, which are highly expensive, costing approximately $1 million.

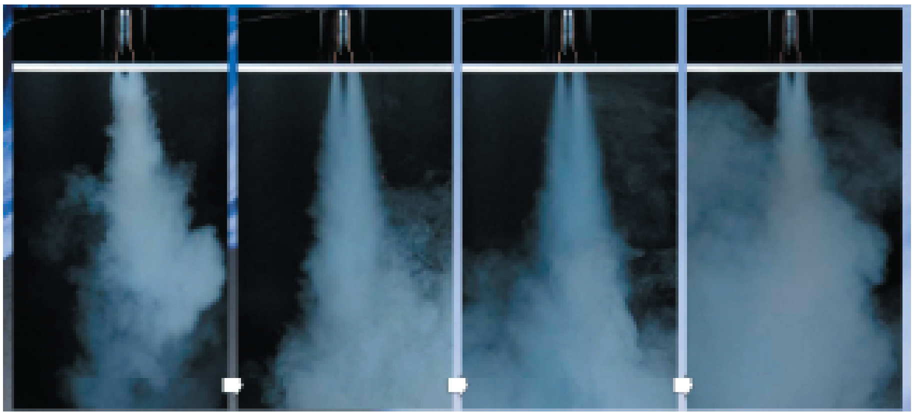

Figure 5 Aerosol generator system deploying "K/SMOKE".

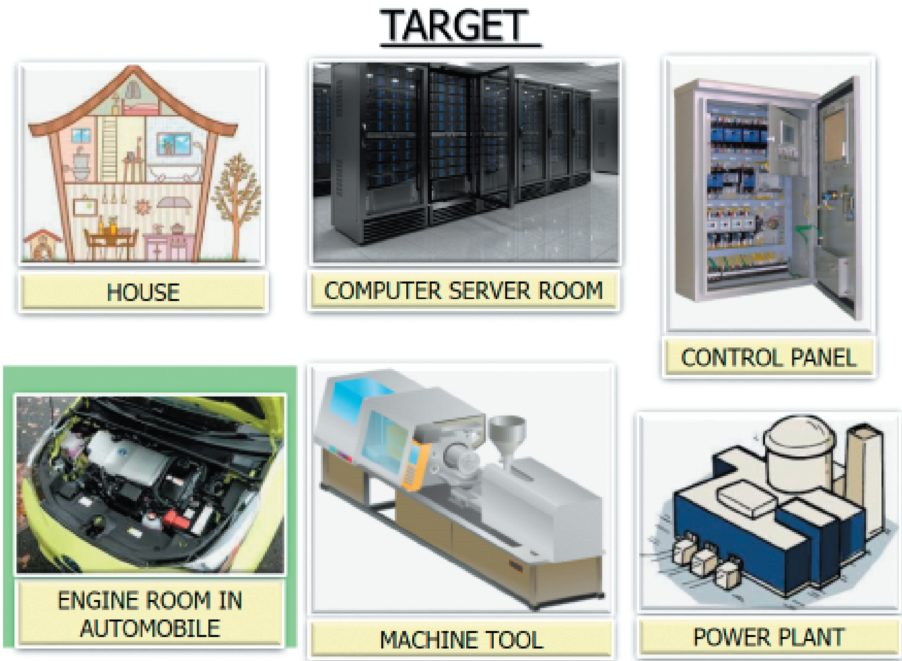

Figure 6 Targets of K/SMOKE.

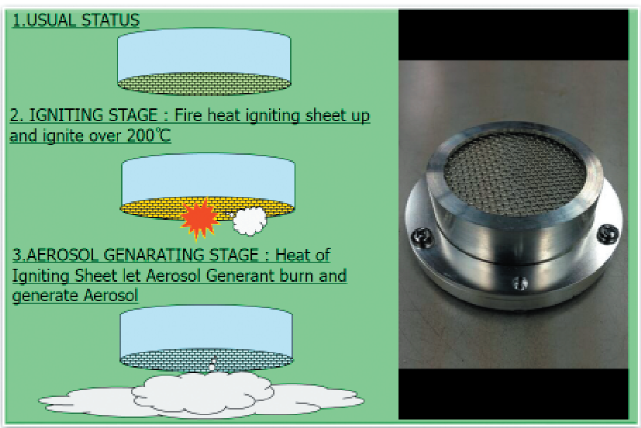

Figure 7 Non electrical aerosol generator.

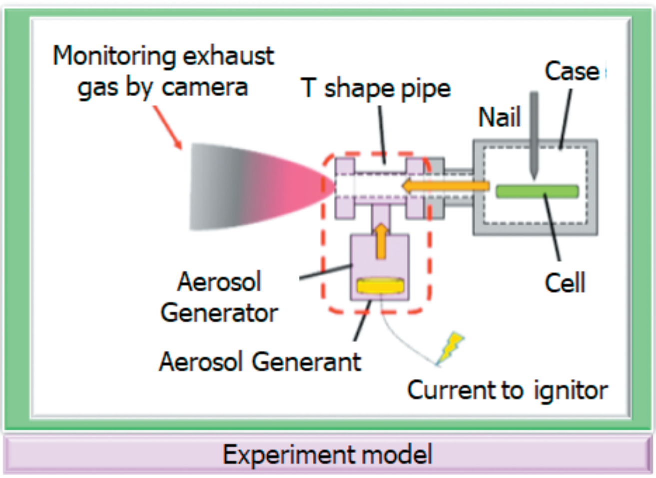

Figure 8 Experimental model of EV battery fire.

4. Updated development

4.1 Non electrical aerosol generator

We have successfully developed a "non-electrical aerosol generator" without a sensor and control panel. Such an aerosol generator system is unique and is shown in Figure 7.

1) Under normal conditions, the "non-electrical aerosol generator" is highly stable because of its nonelectrical system without a sensor and control panel; thus, this system is never activated accidentally.
2) In the case of a fire, the igniting sheet is heated to more than 200 °C as per our knowledge on the aerosol

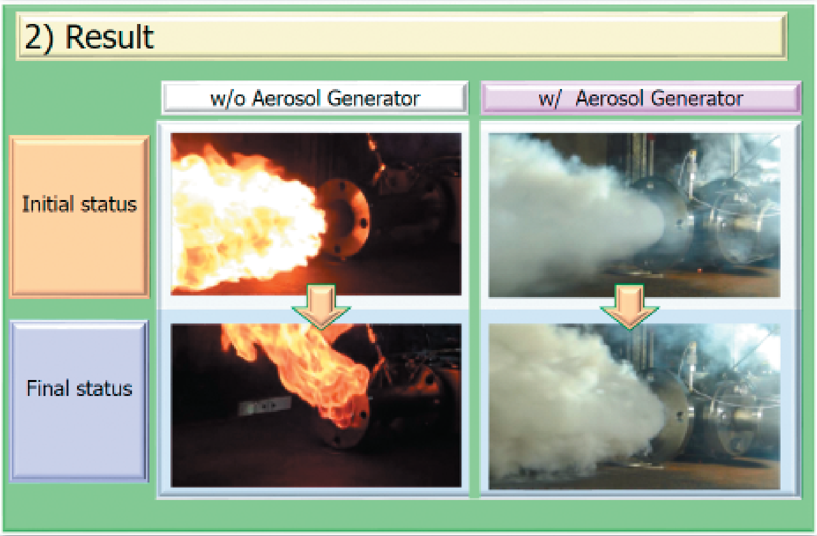

Figure 9 Result of extinguishing experiment model in an EV battery fire.

generant of "non-electrical aerosol generator".

3) In the aerosol generating stage, the heat from the igniting sheet allows the aerosol generant to burn and generate the aerosol as an extinguishing reagent.

4) Fire is then supressed by the generated aerosol.

A power plant company has already purchased more than 50 units of the "non-electrical aerosol generator" for wind power generation in Hokkaido and Chiba, Japan.

4.2 Aerosol extinguishing system for fire in Hybrid electric vehicle (HEV)/ Electric vehicle (EV) battery

We are developing an aerosol extingushing system for fire in a HEV/ EV battery, and are collaborating with a renowned car manufacturer in Japan. We have performed several experiments and have obtained good results. Figure 8 shows an experimental model of an aerosol generator attached to an EV battery case. When the nail is inserted into the battery cell in the battery case, fire from the cell reaches outside.

This triggers the aerosol generator, which supresses the fire effectively. In tests conducted without using the aerosol generator, a big fire was formed with possibly serious consequences. However, with the aerosol generator, fire was extinguished completely and only smoke was detected after its application (Figure 9). Efforts are underway to modify this new system.

We are also developing a new extinguishing system for HEV/ EV battery as well as for Fuel cell vehicles (FCV) with hydrogen, and are now collaborating with ISAS/ JAXA.

5. Summary

The novel aerosol generator with potassium carboxylate has been developed successfully. The shape of this aerosol generant is very flexible. The auto-iginiting system of the aerosol generator has been developed successfully and various uses are expected. The new aerosol system has possible applications as the second pyrotechnic automobile safety device after the airbag inflator.

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