EXPERIMENTAL STUDY ON POOL FIRE EXTINGUISHING WITH MULTI-COMPONENT COMPRESSED AIR FOAM

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ABSTRACT

A compressed air foam system (CAFS) was developed with a newly prepared multi-component foaming agents, and experimental study on pool fire extinguishing had been performed under different conditions, such as foam concentration, forepart structure of mixing chamber and working pressure. It is found that the foam concentration has a great impact on fire extinguishing efficiency, and an optimized concentration value exists. For instance, to diesel oil pool fires, this value is about 2.2%. In addition, the system with coaxial mixing chamber has a better efficiency than the one with T-shape mixing chamber. The effects of working pressure on fire extinguishments are also evident in experiments, the higher the working pressure, the easier the fire can be extinguished.

KEYWORDS: Compressed air foam, Pool fire, Multi-component foaming agents, Pool fire, Fire Extinguishing

INTRODUCTION

It is well known that the compressed air foam was developed in the 1970s in Texas as an innovative approach for fighting grassland fires in areas where water is extremely scarce. During most of 1992 and the early part of 1993, the Boston Fire Department participated in a field test of the compressed air foam system[1]. Since the first version of the Montreal Protocol was introduced in 1987, it has become a beacon of international commitment to protect the earth's ozone layer from further damage by chlorinated fluorocarbons (CFCs). This commitment has driven almost a decade of testing to develop alternative fire suppression technologies to replace the chlorine- or bromine-based gaseous fire suppressants known as Halons. Therefore, the research on compressed air foam technology is receiving a considerable attention as one of the potential methods for Halons replacement due to its merits of high fire extinguishing efficiency and anti-reburn performance, significantly less water damage, capability for large fire suppression, far distance of agent discharging, and environmentally friendly[2-6].

The CAFS combines two technologies, an agent to reduce the surface tension of water and compressed air, to produce an expanded volume of fire extinguishing agent. The surface tension reduction, which makes water much more efficient as an extinguishing agent, is accomplished by introducing a small percentage of foam concentrate into the water stream. Compressed air is then injected into the solution to expand the foam, creating a mass of foam bubbles to provide a much greater volume of extinguishing agent. Studies on optimization of foam performance and suppression test of varies fires had been done in recent years all over the world, especially in Canada, Australia and USA. For instance, Kim et al. compared the Fire Suppression Performance of Compressed-Air-Foam with Foam-Water Sprinkler Systems for Class B Hazards[7]. Experimental test on fire protection for files in electrical cabinets and housing units in remote areas were also performed by Kim et al.[8,9] Dlugogorski verified the consistency of effective-viscosity and pressure-loss data for designing foam proportioning systems[10].

Important progress has been made in compressed air foam technology for fire fighting, and it can now be used to effectively suppress various types of industrial fires at vast cost savings while the water requirement has been reduced. However, few studies had been done on compressed-air foam technology, especially on the development of foam agent, an experimental test on its performance and its fire suppression capabilities. Therefore, in order to investigate the fire suppression capability of a newly developed foam agent and get experimental data for CAFS optimization, the experimental study on pool fire extinguishing with a newly developed foam system had been performed under different conditions, such as foam concentration, forepart structure of mixing chamber and working pressure.

EXPERIMENTAL APPARATUS

As shown in Fig. 1, the experiments were conducted in a 3 m × 3 m × 3 m glass-walled enclosure. The CAF nozzle was installed 2.8 m above the fuel pan, and its height can be adjusted according to experiment needs. The steel stainless fuel pan has 0.43 m diameter and 0.05 m depth. To each case, about 200 ml diesel oil was used as fuel and 10 ml alcohol was used for ignition. Some K-type thermocouples with 1.0 mm diameter were arrayed along the centerline of the fuel pan to obtain the flame local temperature. A smoke analyzer was located 1.5 m above the ground to indicate the gas variation before and after the application of CAF, while a digital video camera was used not only for visualizing the dynamical process of fire suppression, but for determining the extinguishing time. The fire was allowed to burn for 60 seconds to make quasi-steady burning before the foam injection.

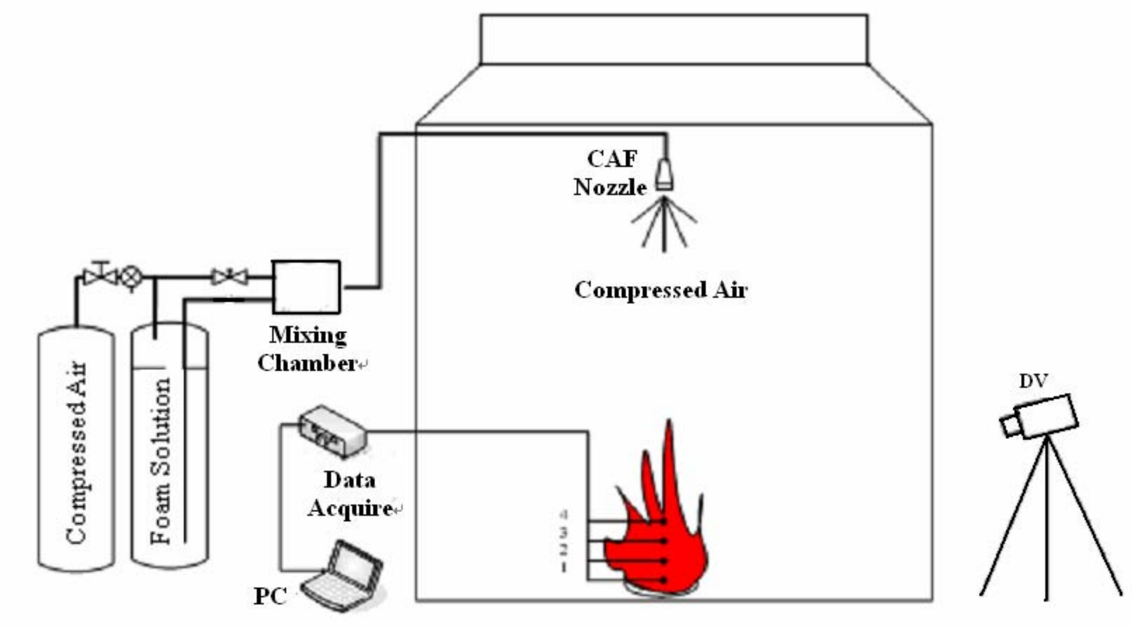


FIGURE 1. Schematic diagram of the experimental apparatus

The foam agent which used in these experiments was recently developed by our group. It mainly consists five components, the first one is a fluorocarbon surfactant (molecular formula, $(C_2F_5)_2(CF_3)C(CF_3)C{=}C(CF_3)\text{-}OC_6H_4SO_3Na$), which can form a thin layer of film on the liquid or solid fuel surface after injection from the nozzle. The second is a viscosity modifier (molecular formula, C8H17C6H4O(CH2CH2O)10H), which can improve the blanketing and runoff of water. The third is an organic metallic compound (molecular formula, CH_3COONa), which can produce active radicals to enhance the process of fire extinguishing. The fourth is carbamide, which can absorb energy from flame and generates a great amount of inert gases by decomposition. The fifth is an N,N-dimethylformamide, which acts as an anti-freeze and dissolves to all of the components. Every component is non-toxic and non-corrosive tested by the Jiangsu Provincial Supervising Testing Center for Products Quality[11].

Two types of mixing chamber were used to investigate the influence of chamber structure on CAF fire suppression performance, one is the general used T-shape chamber, the other is a coaxial chamber which was improved by our group (see Fig. 2).

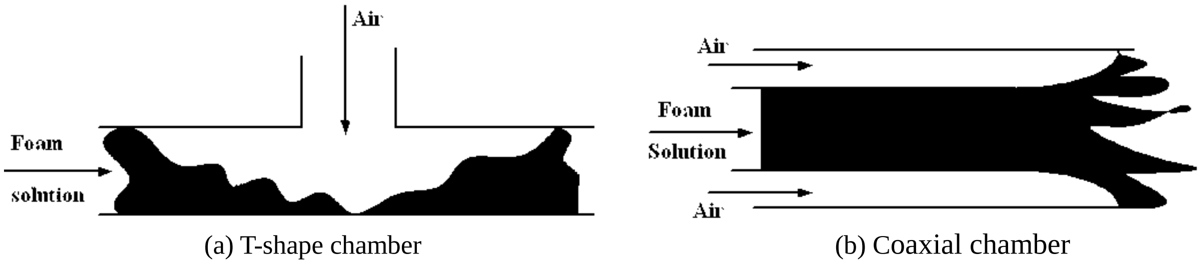


FIGURE 2. Schematic diagram of the mixing chamber

RESULTS AND DISCUSSION

Effects of Mixing Chamber Structure

It is well known that the mixing chamber is the crucial part of the CAF system, since it directly influences the foam performance. In order to investigate the effects of the chamber structure on its fire suppression capability, a general used T-shape chamber and a coaxial one were used in our experiments. As a typical example, Fig. 3 gives the test results with working conditions of 0.3 MPa pressure and 2.8 m distance between the nozzle and the fuel pan. It shows that the CAFS with coaxial chamber has a better performance than the one with T-shape chamber. These indicate that the air and the foam agent can be well mixed with the coaxial structure chamber, and then uniform and stable foam can be produced.

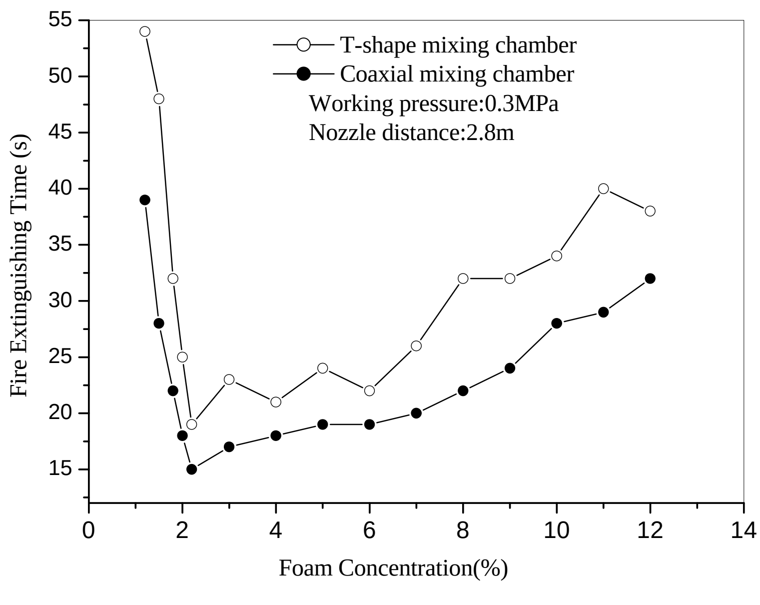


FIGURE 3. Effects of mixing chamber structure on fire extinguishments

Effects of Foam Concentration

As stated by Zhang Bo et al., that the foam concentration has a great impact on fire extinguishing efficiency, and a best value about 4% exists to suppress wood crib fires[12]. So in order to optimize the foam concentration value to diesel oil pool fires, a series of experimental tests were conducted with the foam concentration varied from 1.2% to 12% as shown in Table 1. The test results also can be seen in Fig. 4. It shows that the suppression efficiency of CAFS to diesel pool fires gets better when the foam concentration reduced, and then gets worse if the foam concentration is further reduced. The critical optimization value is about 2.2%. This can be explained that the sparser foam solution makes the bubble forming worse while the denser one makes the foam a little drier and causes less momentum. The fire suppression process can be partly seen from the video pictures as shown in Fig. 5 and Fig. 6, respectively.

TABLE 1. Fire extinguish time with different foam concentrations
(Working pressure: 0.3MPa, Distance between nozzle and fuel pan: 2.8m, Mixing chamber: coaxial)

Foam concentration(%)	Fire extinguishing time (s)
12	32
11	29
10	28
9	24
8	22
7	20
6	19
5	19
4	18
3	17
2.2	15
2	18
1.8	22
1.5	28
1.2	39

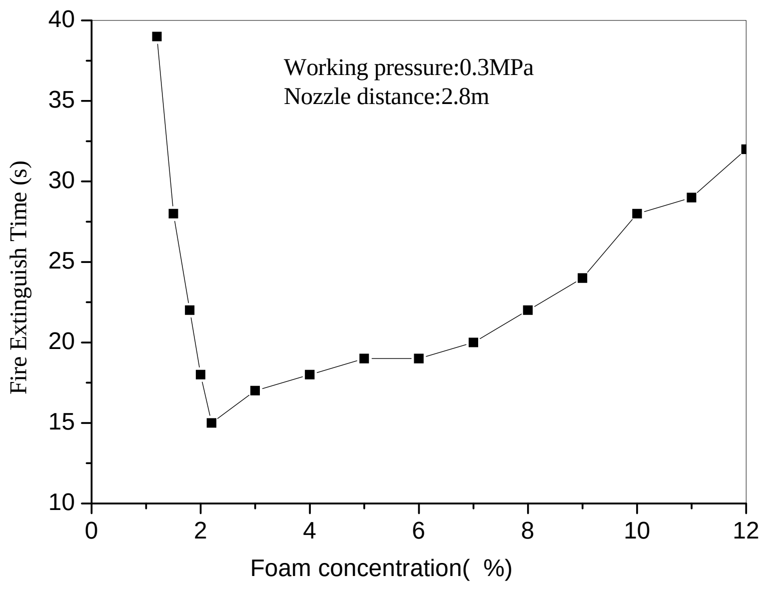
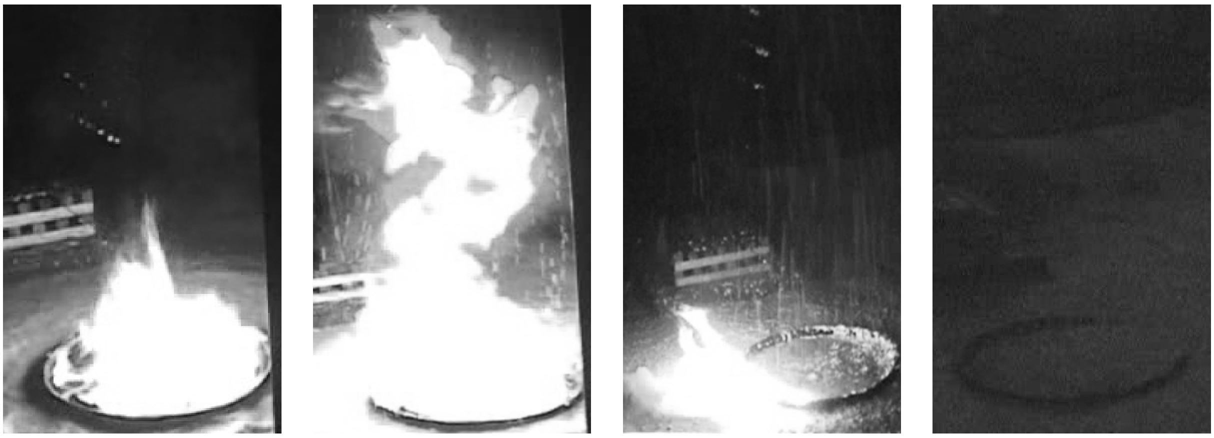


FIGURE 4. Effects of foam concentration on fire extinguishments

(1) 15s after ignition (2) 60s after ignition, injection started (3) 19s after injection (4) 22s after ignition

FIGURE 5. Diesel fire behavior before and after the injection of 8% CAF



(1) 15s after ignition (2) 60s after ignition, injection started (3) 13s after injection (4) 17s after ignition

FIGURE 6. Diesel fire behavior before and after the injection of 3% CAF

Effects of Working Pressure

The effects of working pressure on fire suppression efficiency of the CAFS were also tested with different conditions. Only the coaxial mixing chamber was used. The typical results obtained with 1.2% foam concentration, 2.8 m distance between the nozzle and the fuel pan are showing in Fig. 7. It indicates that the fire suppression efficiency of the CAFS is also mainly influenced by the working pressure, especially when the pressure is lower than 0.5 MPa. To this case, when the pressure is higher than 0.5 MPa, its influence becomes weaker.

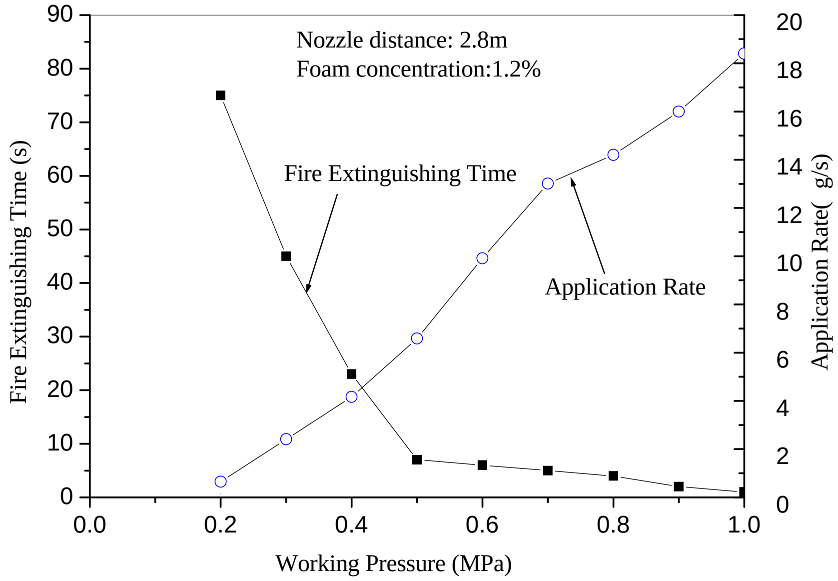


FIGURE 7. Effects of working pressure on fire extinguishments

CONCLUSIONS

A newly developed CAF system was used for a series of experimental tests on diesel pool fire suppression, and the test results show that this newly developed foam agent is efficient for diesel pool fire suppression. In addition, the coaxial mixing chamber can be recommended for practical applications because it can make the foam performance better than the T-shape one. Foam concentration has main effects on fire suppression, and to diesel pool fires, the optimized concentration value of 2.2% is found. Working pressure also mainly influences the performance of CAFS, i.e., the higher the pressure, the easier the fire can be extinguished, although its effects become weaker when the pressure is higher than 0.5MPa. Improving the performance of CAFS by using higher working pressure is not the best way in practical applications.

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