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An experimental study on the interaction of water mist with vertical/horizontal spray flame

LIANG Tianshui[a,b], LIU Mengjie[a], WEI Xinli[a], ZHONG Wei[a,*]

[a]*School of Chemical Engineering and Energy, Zhengzhou University, Zhengzhou 450001, China*
[b]*State Key Laboratory of Fire Science, University of Science and Technology of China, Hefei 230026, China*

Abstract

Spray fire is a major disaster for gas turbines and aero-engine test facilities. Previous studies demonstrated that small spray fires were difficult to extinguish with water mist. An experimental study of the process of water mist interacting with the small size spray fire was conducted in an open space. Studies on suppression of vertical spray fire and horizontal spray fire were carried out, respectively. Experiment discovered that a horizontal fame was more difficult to extinguish compared with the vertical using the same scenario, and implied that the coupling the dilution of fuel in the gas phase with the reduction of radiant feedback plays a predominant role in fire extinguishment.

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Keywords: spray flame; water mist; fire suppression; fire extinguishment

1. Introduction

Oil spray catches on fire with a higher probability when compared to its vapour [1].The high heat fluxes to impinged or engulfed objects could lead to equipment damage or pipe work failure and possible further extension.

Spray fires represent a significant element of the hazard associated with a major type of fires on gas turbines or aero-engine test facilities. Gas fire-extinguishing systems (GFES), such as halons and carbon dioxide, were widely used to protect from this type of hazards in the past decades. Hirst [2] carried out experimental research on the

* Corresponding author. Tel.: 0371-56763348.
E-mail address: zhongwei@zzu.edu.cn.

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extinguishing of spray flame with methyl bromide in a small-scale wind tunnel for aircraft engine. Fire suppression performances of some new halon alternatives for aircraft engine were studied in a small-sized test bed [3].

However, GFES have some deficiencies, such as false actuation of GFES in the enclosed space may threaten the safety of occupants and emergency fire-fighting need evacuation. Research on the application of environment friend, safe and effective fire-fighting technology to such sites will have scientific significance and practical value.

The suppression performance of water mist have been studied and demonstrated by many previous researches [4−11]. Although water mist technology has been widely used in fire engineering, the fire suppression mechanisms of water mist are not yet fully understood. Liu [12] concluded that extinguishing mechanisms are change with the types of fires encountered. Researches on the suppressing of spray fires with water mist are reported relatively rarely, compared with pool fire. Dundas [13], Ural [14] and Dyer [15]conducted tests on fire suppression performance of water mist extinguishing large-scale spray fires in gas turbine installations. Shirvill [16] carried out research on water spray protection against jet fires impinging on LPG storage tanks. Previous studies [12−14, 17] indicated that larger spray fires in enclosed spaces are easily to extinguish, which result from the displacement of oxygen by the expansion of the water mist to steam. On the other hand, small fires are difficult to extinguish. This experimental study focus on the interaction processes of water mist with the smallest size spray fire under an unconfined space, and was expected to be helpful in further understanding the suppressing mechanisms of water mist.

The main objective of this study is to identify the effectiveness of water mist in extinguishing small size vertical/horizontal spray flame. Experiment show that a vertical spray flame is more easily to extinguish than the horizontal one under the same conditions.

2. Experiment

A pressure water mist nozzle used in the experiment has7-nozzle heads, each with an orifice diameter of 1.8 mm. The three component fiber Laser Doppler Velocimetry/Adaptive Phase Doppler Velocimetry System(LDV/APV system, TSI Incorporated) was employed to determine the characteristics of water mist generated by one of the nozzle heads. The volume mean diameter of the mist is about 200 μm at discharge pressure of 1.0 MPa, and about 160 μm at 3.5 MPa. Spray density is 0.08kg/(s·m^2) at 1.0 MPa, and 0.23kg/(s·m^2) at 3.5 MPa, respectively. The water mist was injected downwards. A water mist nozzle is placed 2.4 m above the fuel nozzle, as shown in Fig. 1. Experiments were repeated three times for each scenario.

The interaction process of water mists with spray flame was recorded by a digital video at 25 fps. A thermocouple with diameter of 1 mm was destroyed by a high temperature (about 1300 K) spray flame. Moreover hot metal surfaces can cause re-ignition [3], so thermocouples were not applied in the experiment.

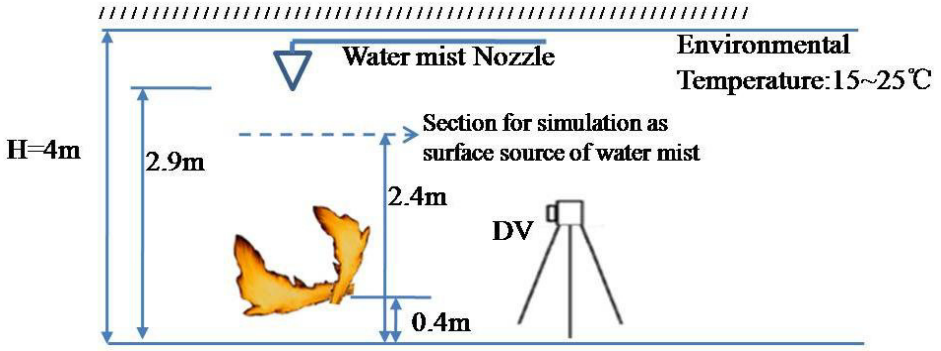

Fig. 1. Schematic of experiment setup.

Fuel spray equipment for the experiment was designed as shown in Fig. 2. Daqing RP-3 aviation kerosene, a typical jet fuel in China, was used as fuel in the experiment. Three Pressure-swirl nozzles were usedas fire source,