ISSUES AND TECHNIQUES ASSOCIATED WITH THE MEASUREMENT OF PROPERTIES OF FIRE PROTECTION FOAMS

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Introduction

The objective of the present experimental research is to evaluate the performance of water-based foams that are used for protection of structures against fire damage. In order to completely understand its behavior, the different properties of the foam must be accurately determined.

As a part of recently concluded investigation, the performance of a water-based foam was determined under radiative heating conditions [1, 2]. This included determining the various properties of the foam which are discussed in detail both by Boyd [2] and Wang [3]. However, in this process, several challenges were encountered. These were found to be unique to water-based foams and, along the way, several techniques have been developed to tackle the problems associated with measuring the properties. This presentation is aimed at highlighting the unique aspects of measuring the properties of the foam and also the new techniques that have been envisaged to minimize some of the possible sources of errors.

Generation of Foam

The methodology of generating the foam, briefly discussed here, is discussed in detail in reference [3]. As opposed to chemically generated foams, the state of the art fire retardant foams are generated by mechanical agitation of water with a specified concentration of the foaming agent. In the laboratory, the foam is generated by passing the liquid (water and foaming agent mixture) through a narrow tube with the air flowing coaxially under pressure. The air flow rate is controlled by a flow control valve while that of the solution is controlled indirectly by controlling the pressure of the tank holding the solution. The mixture is then passed through a chamber filled with beads which break up and mix the air and liquid streams yielding a uniform foam flow.

Property Measurement

The purpose of the foam is to retard heat transfer to the structure. The foam does this sacrificially by evaporating. Earlier investigations have revealed that the primary mode of heat transfer to the foam is through thermal radiation [2]. The bubbles in the foam are filled with a mixture of air and water vapor. Water being a strong absorber of radiation of infrared wavelengths, increases the temperature of the moist air mixture inside the bubble thus expanding the bubble which eventually bursts, continuously changing the local structure of the foam. This leads to the first issue that arises in determining the properties of foams - the very nature of the foam changes with time. The rate at which the bubble grows is directly proportional to the amount of heat absorbed by the water. The amount of heat absorbed in turn, is a function of the amount of water present and the intensity of incident radiation. The amount of water present is again a function of the initial size of the bubble which is in turn a function of the density of the foam. Thus, density becomes the first of the properties that needs to be measured accurately. The generation of the foam should be such that the density can be accurately controlled. In the present experimental setup, this is achieved by controlling independently the air and liquid flow rates.

Another factor that determines the nature of the foam is the homogeneity of the foaming agent (the solution). Protein-based agents show a tendency to form clumps while synthetic agents are more homogeneous.

The study of a foam burn up is done in a furnace where the foam is exposed to a gas fired radiant panel. The primary challenge in testing the foam under these circumstances is to make the foam adhere to a vertical plate. A foam that does not stick and stay on a vertical surface defeats its purpose in these applications. Some of the foams that are currently being tested adhere only for certain density ranges. However a comprehensive evaluation is yet to be done.

The rate at which the foam expands is not only a function of the temperature to which it is exposed to (i.e., the intensity of radiation), but also of the temperature history. The rate at which the bubble grows depends upon the different temperature levels that the foam has been subjected to. The testing of the volumetric expansion rate of the foam is done by exposing it to known temperature levels for different durations.

The primary thermal properties that are of interest are the radiative properties (absorptivity, reflectivity and transmissivity) and the thermal diffusivity. The design of the experimental setup for determining the radiative properties poses several challenges. Since the burn up of the foam occurs faster at higher intensities of radiation, the evaluation of the radiative properties must be conducted at low temperatures in order to minimize the effect of properties' temporal variation. The heat source (infrared bulb), the sample of the foam and the detector (heat flux gauge) are all arranged collinearly. Foam samples of different thicknesses are used to determine the amount of heat transmitted through the foam. Care must be taken to ensure that the source of radiation is as diffuse as possible. Also, the distances between the samples, the source and the detector should be accurately measured in order to correctly evaluate the effect of the view factor between the source and the foam sample and also between the foam sample and the detector. This is achieved by using an optical track. Since the intensity of radiation is very low, care must be taken to ensure that extraneous radiation sources are eliminated and convective effects are minimized.

For the thermal diffusivity measurement, the foam sample is placed on a cylindrical aluminum block which is heated gradually. The sides are insulated to ensure a one-dimensional heat flow pattern. Temperatures are measured at three axial locations. To determine the thermal diffusivity, the constant property conduction equation is solved with the measured temperatures at two end thermocouple locations as boundary conditions. For a given value of the thermal diffusivity, the numerical solution is used to generate the temperature history at the central thermocouple location. The value of the thermal diffusivity is determined by minimizing the error between the measured and calculated temperature rise at the center thermocouple location.

Conclusions

In order to correctly evaluate the performance of fire protection foams, the thermal and physical properties of the foam must be accurately determined. Unlike other materials, there are several challenges in determining the properties of these foams since these are water-based and their structure changes fast with time. The current experimental set up is designed to ensure that the errors associated with property measurement are reduced and/or could be exactly determined.

References

1. C. Boyd and M. di Marzo, 'Fire Protection Foam in Radiative Environment,' Presented at the National Heat Transfer Conference, Houston, June 1996.
2. C. Boyd, 'Fire Protection Foam in Radiative Environment,' Ph.D. Dissertation, University of Maryland, 1996.
3. S. Wang, 'Generation and Characterization of Fire Protection Foam,' M. S. Thesis, University of Maryland, in preparation.