Characterisation Of The Thermal And Chemical Effects Of Energetic Materials Not Likely To Detonate

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Introduction

Energetic materials encompass a wide range of chemical compounds all associated with a significant risk of fire and explosion. They include explosives, pyrotechnic materials, powders, fertilizers and other unsteady chemicals. These materials store a high level of chemical energy and are able to release it rapidly without external contribution of oxygen or other oxidizer.

The aim of this work is the analysis of thermal and chemical characteristics of energetic materials, powders, fertilizers and other unsteady chemicals. These materials store a high level of chemical energy and are able to release it rapidly without external supply of oxidizer. This peculiarity precludes the use of established techniques as oxygen consumption calorimetry to study its fire performance.

Methodology

In order to develop a robust methodology to predict the Heat Release Rate during the decomposition of energetic material, the applicability of Oxygen Consumption Calorimetry [Babrauskas and Janssens] has been first evaluated. This procedure assumes several simplifications, which could lead to uncertainties in the results [Brohez]. A comparison of HRR measurement using different methods has been carried out for an energetic fuel (heptane) and a solid fuel (PMMA).

Experimental Work

The experimental work is being conducted using the FM Global Fire Propagation Apparatus FPA [ASTM E2058-03], also called Tewarson Calorimeter. One of the benefits of using this device rather than the Cone Calorimeter is that it allows the decomposition of energetic material, the applicability of Oxygen Consumption Calorimetry with average values for E and α, for (a) PMMA, (b) Heptane, (c) Heptane (Under-ventilated fire).

Results (continued)

- The variation induced by using average value instead of actual value for E, the energy released per unit mass of O₂ consumed is between 1 and 5%.
- The variation induced by using an average value instead of actual values for the expansion factor α is between 1 and 2%.

When the chemical composition of the burning fuel is known, actual values for calorimetric coefficients should be used. The results found with Oxygen Consumption Calorimetry tend to be close to those found by means of the material’s Heat of Combustion for well-ventilated fires. For under-ventilated combustion, corrections have been applied in the calculations for CO generation. Discrepancies increase compared to well-ventilated combustion.

Results

The results have shown:
- In the case of well-ventilated combustion, the Heat Release Rate calculated by means of Oxygen Consumption Calorimetry differs between 8 and 15% from the HRR calculated by using the material’s Heat of Combustion (Fig. 2.a, 2.b);
- In the case of under-ventilated combustion, the difference between the 2 procedures is more important (30% in average for the heptane test with an incoming flow of 60 l/min). The calculations include a correction for CO generation.
- These differences on the HRR measurement increase when average values for the energy released per unit mass of O₂ consumed, E and the expansion factor, α (a number of moles in the fraction of air fully depleted of its oxygen is replaced by a equal or larger number of moles of combustion products in the exhaust flow) are used.

Future Work

- Series of tests will be carried out with 2 different smoke powders consisting in ternary mixtures containing starch and lactose as fuel components and potassium nitrate as an oxidizer in order to study their fire behaviour;
- Oxygen Consumption procedure will be applied to the 2 powders. The objective being to evaluate the calculation uncertainties to burning conditions where the oxidizer is also provided internally;
- Assessment of the ability of the FPA to study fast burning rate reactions.

References