Project title: Burning material behaviour in hypoxic environments: An experimental study examining fire dynamics of composite materials in vitiated conditions

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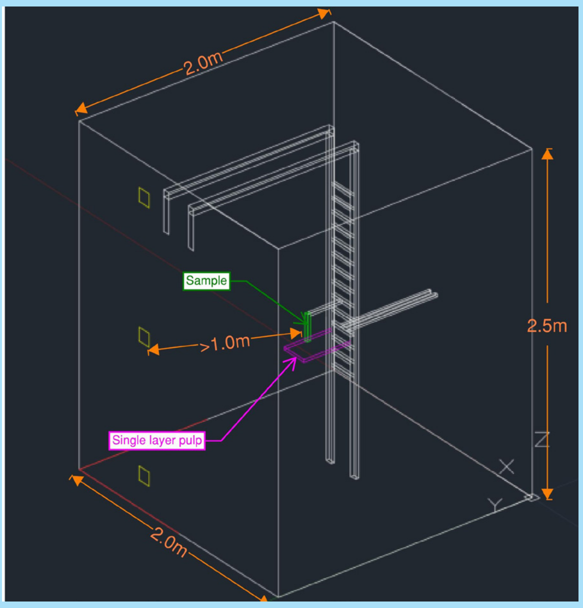
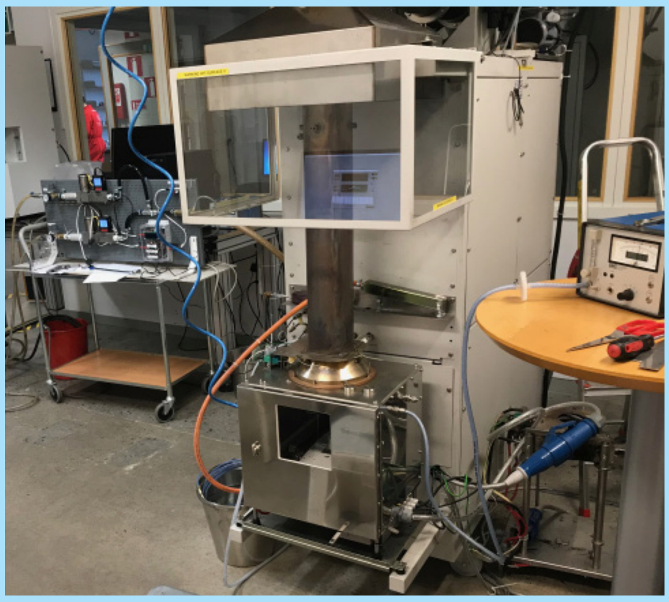
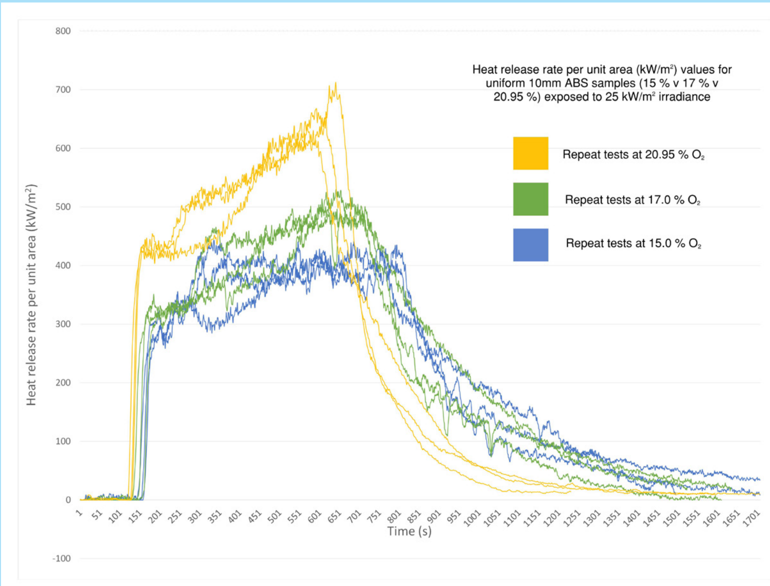


Introduction

The ignition threshold is a target oxygen concentration that applies an approximate limiting oxygen concentration (LOC) of the materials contained within a 'protection zone' and an additional safety margin (typically 0.75-1.0 % O_2 concentration). The application of the ignition threshold is in order to ensure the lowest concentration of oxygen necessary to prevent the ignition of stored materials within an oxygen reduction system (ORS). The test used to define the ignition threshold (test rig shown on the left) has been noted as being very material dependant and primarily for the testing of generic materials. Such limitations are of concern because of the likelihood that composite materials are contained within the protection zone.

Cone calorimeter and controlled atmosphere cone calorimeter experiments were conducted on various samples with the test setup shown on the right. The intent of the tests was to examine the behaviour of uniform and composite samples in a range of thicknesses, irradiances and oxygen concentrations. A uniform layer of acrylonitrile butadiene styrene (ABS) samples were compared to a composite mix, comprising of ABS with a surface layer of cardboard and a secondary layer of polyethylene bubble wrap (intended to represent a potential storage arrangement).



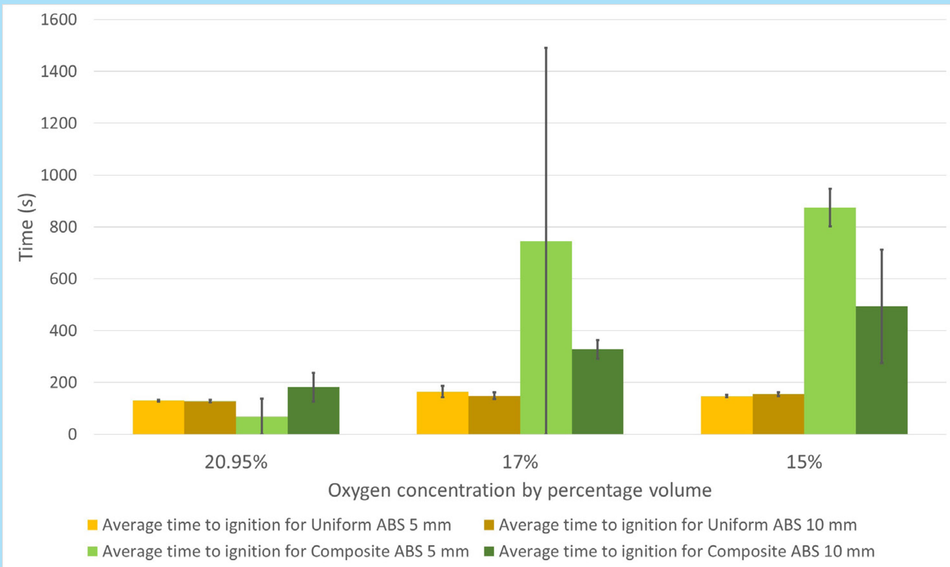


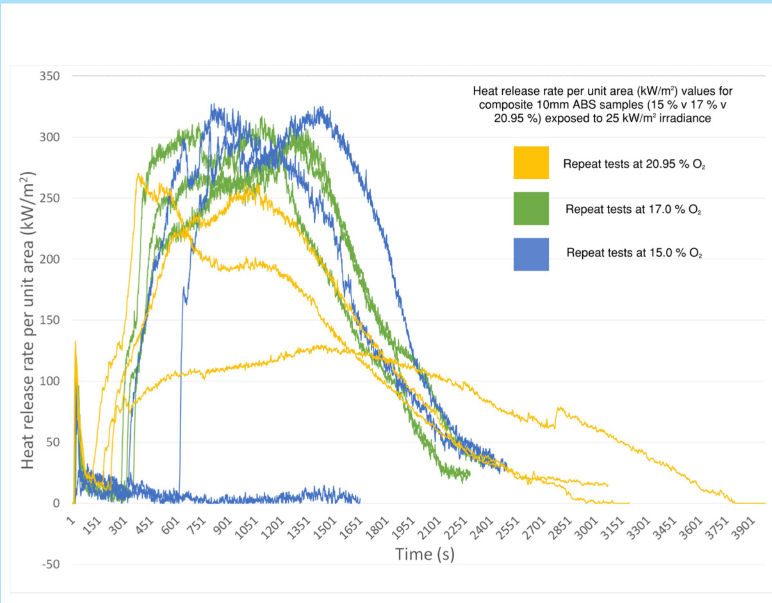
Ignition

Observations from the tests undertaken indicated a negligible increase in time to ignition between ambient and hypoxic conditions for uniform samples. The most notable cases where oxygen concentration influences ignition time are all cases where there is a composite arrangement.

The figure below shows the average time at which flaming was observed to occur in uniform and composite samples at an irradience of 25 kW/m² over three repeat tests in uniform (yellow) and composite (green) tests.

Research into flame ignition times have shown that this output variable is very sensitive to experimental conditions. The findings from experiments conducted showed that while ignition time was relatively insensitive to hypoxic conditions in isolation the combination of both composite layers and hypoxic conditions changed material ignition times considerably. This finding suggests that key variables for determining true ignitability are being discounted when testing materials in isolation.





HRRPUA

An interesting finding from the experiments conducted was that, in some instances, HRRPUA was found to be higher in hypoxic conditions than was found for ambient tests with other variables remaining the same. This can be seen in figures on the left with the upper figure showing unform samples and the lower figure showing composite samples. It was hypothesised that this unexpected effect occured due to two contributory material effects;

1. The initial burning of the cardboard layer, its combustion efficiency during this stage and the coverage of the subsequent soot and char residual layer created once the cardboard layer has ignited.
2. The time between self-extinguishment of the initial flaming cardboard, caused by the development of the protective soot and char residual layer, and the reignition of the ABS due to the reintroduction of the spark igniter. Over this time preheating occurs due to the application of an external heat flux.

A diagram describing this effect on composites, and how it differs in ambient and hypoxic conditions, is included below.

Conclusion

The experiments carried out aimed to provisionally identify characteristic behaviours that differentiate material performance of uniform/generic materials and those stored in composite arrangements when exposed to an ignition source.

Observations have identified a number of examples where the influence of composite layers have resulted in significantly different outcomes for material behaviour. This was demonstrated to even produce instances where the HRR was greater in hypoxic conditions than in ambient conditions for some composite samples. The interaction between hypoxic conditions and material layers demonstrates that testing materials in isolation cannot be assumed to yield results that correspond to materials where placed in series.

The results highlight important, interacting factors that should be considered where designing testing methodologies for fire prevention or protection systems.

It is concluded that sufficiently capturing a wider range of variable conditions in burning material behaviour under hypoxic conditions will introduce further design resilience and help optimise fire protection/ prevention methods.