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INTERMEDIATE SCALE COMPOSITE MATERIAL FIRE TESTING

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ABSTRACT

Composite materials are increasingly being used in aviation applications. As the quantity of composite material increases, there is a corresponding need to develop a better understanding of composite material response in fire environments. We have recently developed a program to examine this problem experimentally and computationally. Although Sandia National Laboratories and Air Force Research Laboratories at Tyndall have slightly different focuses, we are collaborating to focus on understanding duration, intensity, and the underlying physics during composite fires, as well as the technology and procedures to safely manage composite fire events. In the past year, we have been performing both small and intermediate scale testing to understand the behavior of composite materials used in aviation applications. The current focus is on a set of intermediate scale tests to generate data useful for understanding the behavior of carbon fiber epoxy composites in adverse thermal environments. Intermediate scale testing will help bridge the gap of understanding between smaller scale experimental efforts and help improve the understanding of the performance of practical scale problems.

Our intermediate scale testing is expected to result in a thermally extreme environment that may be representative of an intense fire scenario. The test set-up involves a 90 cm cubic enclosure, instrumented to measure heat flux, gas species, velocity, and temperature. Features of the enclosure include controlled air aspiration, insulated walls, and gas burners to ignite the enclosed composite materials. The floor of the enclosure is loaded with 50 to 100 lbs of material. Propane burners are used to ignite the solid materials during the first few minutes of the test. The remainder of the test involves sustained combustion of the composite materials. Preliminary results of these tests will be reported to provide data on the severity of the environment in terms of thermal intensity, duration, and chemical products.

DETAILS

The increased amounts of composites used in aircraft results in an increasing likelihood of a fire where the composites burn in the fire environment. Thus we are motivated by a need to understand the composite fire environment. To better understand the dynamics of aircraft fire events, we are developing models and conducting experimental programs. The modeling is aimed at developing a simulation tool that can reproduce with accuracy accident environments. The testing is intended to provide input to the model, as well as provide useful data in understanding the types of environments that can result from composite fires [1,2].

Composite thermal decomposition is not trivial. Composites are heterogeneous. Fiber lay-up is important to the behavior, as is morphology and thickness. There are a myriad of binders and fibers that are used, each material exhibiting behavior that is potentially dramatically different from one another in a fire. As the material decomposes, there are multi-phase interactions, and pyrolysis products evacuate leaving behind porous-like materials as they evolve. Chars may form. Under severe conditions, the char and fibers may burn through oxidative reactions.

Experimental testing will help elucidate the mechanisms and regimes of physical importance. A test program has been designed to evaluate a range of relevant composite materials under a range of conditions. The intent of the experimental program is to develop data that will help meet the goals of understanding duration, intensity, and underlying physics during composite fires. A salient feature of the testing is that it encompasses a range of scales. This is important because

(a) certain decomposition physics are dependent on the length scale, and (b) the limiting fire rate dynamics may transition between thermal, kinetic, and mass transfer control through the duration of a fire. Table 1 lists testing planned as part of this project.

The small and very small scale testing is used to generate fundamental data for physical modeling. Intermediate and large scale experiments can be used for scoping, validation and confirmatory testing. Smaller scale testing may not reveal the complex dynamics that occur at larger scales. Large-scale testing is the most relevant to aircraft fires, but is prohibitively difficult to perform due to the cost of the materials and the scale of the tests. The intermediate scale testing provides opportunity to explore fire dynamics in a scale regime that is close to the full-scale.

A series of tests has been performed in an insulated test enclosure with 25-40 kg of composite materials to attempt to generate a severe fire environment fueled mostly by the composites. Partial documentation of the tests has been previously presented [3]. Wood fires were also performed for comparative purposes. The composite materials are distinctive from the wood in several ways. The composites do not ignite as readily, suggestive of a lower propensity for volatile release. Also, the composite fires burn for a much longer time, in some cases in these tests up to 8 hours, compared to less than 2 hours for the wood. Composite material flaming combustion normally takes place over a short time frame, 5-30 minutes. It is followed by glowing surface oxidation of the mostly carbon residual material. Heat fluxes were extracted from Medtherm gauges and also interpreted from calorimeter temperatures. Figure 1 summarizes some of the results in this regard, illustrating the duration and magnitude of the thermal environment created by the burning of the composite materials.

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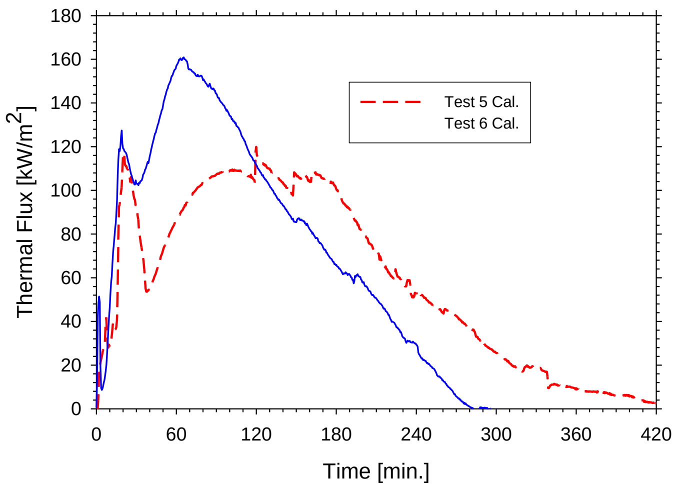

Figure 1. Thermal flux deduced from calorimeter temperatures in the composite fire bed.

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Table 1. A list of the test scales planned for the composite fire programs.

	Characteristic Length Scales	*Characteristic Mass*	*Experiments*	*Purpose of Testing*
Very small	0.1 mm to 1 mm	Milligrams (initial mass)	TGA, DSC	Fundamental kinetic, chemistry, decomposition behavior, and property measurements
Small	mm to 10 cm	Hundreds of grams	Cone calorimetry, radiant heat	Burn rate and scaled dynamics determination, simple validation testing
Intermediate	10-100 cm	0.1-100 kg	Radiant heat and environmental chamber tests	Bridge the gap between small and very small scale and large scale testing to discover dynamics not exposed at the smaller scales that will be present at larger scales
Large	Meters and above	Hundreds of kg and above	Full-scale fire testing	Full-scale with all physics represented in appropriate scale range