Title:

Modelisation of the thermal degradation of composites in order to predict their fire reaction when they are exposed to flames

(proposed by Pr A. Coppalle, CORIA Laboratory, INSA Rouen, coppalle@coia.fr)

Composite materials are increasingly used in transportation (aeronautical, automotive, rail and sea). The main advantage is their low weight. A composite material is an assembly of carbon or glass fibers embedded in resin. This latter is combustible and therefore presents a risk of ignition. It is therefore necessary to understand the effects of flames on the thermal properties and structural integrity of composites during their use. The widespread use of composite implies to consider more finely their thermal degradation when they are exposed to damaging and severe heat stresses (beyond conventional thermal stresses during normal operation). The project aims to develop a modelisation tool in order to predict their behavior under flame exposure.

There exist standard tests, recognized by the Federal Aviation Agency and in Europe, they are used for assaulting a sample with high-powered propane or kerosene flames (for kerosene, the NexGen burner). However, they are developed at large scales, they need large samples, and their operations are expensive. So they are difficult to use for research and development purposes. At the CORIA laboratory of the INSA Rouen, it has been developed a propane burner which allows to test small samples under the same thermal fluxes as in standard test cases, i.e. from 116 to 200 kW/m2. Its utilization is easy and flexible and it allows to apply screening methods to characterize and optimize efficiently the composite materials. Now a kerosene burner is being developed also at the laboratory scale for aeronautical applications. It will make it possible to compare the influence of the two kinds of flames (propane or kerosene) on the fire reaction and thermal behavior of the composites.

The modelisation tool will help to understand the physical and chemical processes that occur at the material surface exposed to the flame, and also inside the material.

However in order to avoid a large number of experimental tests, both at large and small scales, it is now recognized that it is interesting to use simulation tools. It is well known that the use of predictive simulations in the processes of development and implementation of materials has an impact on industrial productions. The increase in development costs of a product requires now design procedures that are optimized and reliable in order to achieve the expected features. In the case of fire reaction analysis, such a tool must predict the flame and their thermal stresses on the materials. ***With this tool it will be possible in future to optimize the process of material design***.

The modelisation tools will be developed from the fireFoam/OpenFoam free softwares:

#OpenFOAM (for "Open source Field Operation And Manipulation") is a toolbox for the development of customized numerical solvers, and pre-/post-processing utilities for the solution of continuum mechanics problems, including computational fluid dynamics (CFD). The code is released as free and open source software under the GNU General Public License.

FireFOAM is a software package developed from OpenFOAM toolbox and composed of physical models related to fluid mechanics, heat transfer and combustion. FireFOAM has also the capacity to simulate the thermal degradation inside solids taking into account heat transfer and pyrolysis.

Scheduling of the PhD

First year:

- Bibliography on propane and kerosene flames, and on thermal degradation of composites
- getting started the fireFoam software with:- a simulation of a free propane jet flame - a simulation of the thermal degradation inside a composite exposed to an imposed thermal flux (no CFD calculation)

Second year:

- Simulation of a propane flame on a sample of composite, test and validation on the experimental results obtained with the propane burner at CORIA laboratory.
-Simulation of a spray combustion of kerosene

Third year:

- Simulation of a kerosene flame on a sample of composite, validation on the experimental results obtained with the kerosene burner at CORIA laboratory.
- Application to the simulation of standard tests using the large scale burners
- PhD report writing

This PhD will be done in the framework of existing collaborations with the main institutes and industrial partners involving in aeronautic (AIRBUS, ONERA, ZODIAC, SAFRAN, …)

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summary

Composite materials are increasingly used in transportation (aeronautical, automotive, rail and sea). The main advantage is their low weight. The resins of the composites are combustible and therefore present a risk of ignition. It is therefore necessary to understand the effects of flames on the thermal properties and structural integrity of composites during their use. The project aims to develop a modelisation tool in order to predict their behavior under flame exposure. At the CORIA laboratory of the INSA Rouen, it has been developed a propane burner which allows to test small samples under the same thermal fluxes as in the case of standard tests, i.e. from 116 to 200 kW/m2. It is more flexible than standard tests, and it is adapted to characterize and optimize efficiently the composite materials. Now a new kerosene burner is being developed also at CORIA laboratory for aeronautical applications. Compared to propane, the kerosene flame is more representative of the thermal stress in the case of aircraft crash. The aim of the project is to make the simulations of these tests, for both propane or kerosene flames cases. The modelisation tools will be developed from the fireFoam/OpenFoam free softwares. This PhD will be done in the framework of existing collaborations with the main institutes and industrial partners involving in aeronautic (AIRBUS, ONERA, ZODIAC, SAFRAN, …)