IDENTIFICATION OF TEMPERATURE AND RADIATIVE PROPERTIES IN SEMITRANSPARENT MEDIA USING HIGH TEMPERATURE SPECTRAL DIRECTIONAL EMISSION: APPLICATION TO CARBON FELT.

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Space modules encounter harsh thermal conditions during atmosphere reentries. To protect their content, thermal shield are required. Since the launching cost of such modules is closely related to their weight, low density materials, such as carbon fiber felt, are often chosen as thermal protections. These materials are usually highly porous and radiative heat transfer through them plays a key role on their global heat balance. Evaluating the performances of such barriers thus requires a detailed knowledge of their radiative properties which are still fairly unknown.

An identification technique has been developed to determine simultaneously the radiative properties of low density fibrous media like carbon felt together with their inner temperature field (under high temperature conditions). This method uses the spectral directional emission of isothermal or non isothermal samples at high temperatures measured by a Fourier Transform-Infrared (FT-IR) spectrometer, *see figure 1*.

Figure 1. Picture of the spectral directional emission measurement setup

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Samples are heated using a CO_2 laser beam which wavelength is centered on 10.6 µm. Temperatures up to 2,000 K can be achieved depending on the nature of the samples. In order to obtain a homogeneous temperature, samples must me heated by the laser from both sides uniformly. To do so, a zinc-selenium beam splitter provides two equally powerful beams. On each path golden-coated-plane mirrors and zinc-selenium lenses dispatch the laser beam to the sample through a kaleidoscope. It will homogenize the intensity of the beams morphing the spherical Gaussian-shaped beam into a square top-hat-shaped one. Each beam is then redirected to a side of the sample by plane mirrors. Since the samples are carbon based they are heated in a vacuum vessel to protect them from oxidation. A golden mirror in this vessel allows for pyrometric measurement of the temperature on both sides of the sample. For measurement purpose a calcium fluoride viewport, which transmittance is higher than 90% from 0.5 to 8 µm, is present to maximize the measurement scope. Moreover its transmittance falls under 10% at 10 µm effectively shutting down any parasite reflection of the laser at 10.6 µm on the sample. The emission is measure by the FT-IR spectrometer in a direction shifted by 30° from the normal to the sample side.

A numerical inversion process, based on an evolutionary technique (Genetic Algorithm), enables to identify the temperature field inside the medium as well as its radiative properties as described by *figure 2*. The model developed to estimate the emission factor uses a Backward Monte Carlo ray tracing method.

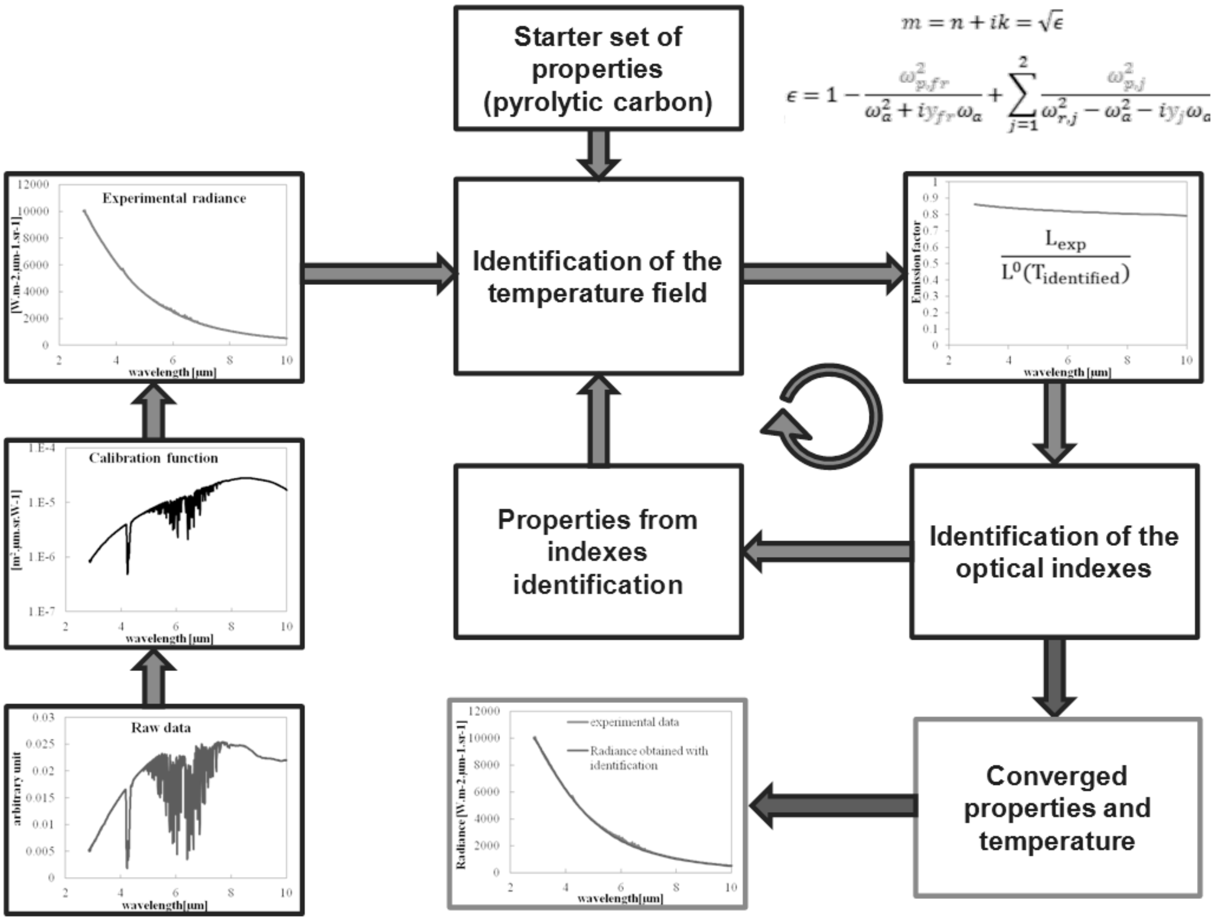

Figure 2. Flow chart of the identification procedure

The derivation of the radiative properties works as follows. In a first step, a Drude-Lorentz Model (DLM) of the dielectric function of carbon provides the complex refractive index of carbon. The parameters from this DLM model will be the properties to identify reducing the number of unknown from two per wavenumber (the real and imaginary parts of the complex refractive index) to a total of six. From the computed refractive index, radiative properties are calculated via Mie theory for infinite cylinders. Fibers used for carbon felt usually are chipped rayon pieces several mm long with a diameter usually around 10 µm thus enabling the use of the infinite hypothesis. The computation is made for several incident angles and gives the extinction and scattering coefficient as well as the scattering phase function of a fiber depending on the wavenumber and the incident angle. The properties of a fiber are then homogenized to the whole medium using a homogenization technique. Those homogenized properties are then used by the Backward Monte Carlo method to estimate the emission factor. DLM parameters as well as the temperature field are finally identified from emission measurements.

Preliminary results, such as temperatures of samples and radiative properties, are given for various heating powers in non isothermal configurations for felt of density of 0.18 $g.cm^{-3}$. We show that the identified properties do no vary with laser heating powers, since the carbon properties do not dependent significantly on temperature. However, as the carbon type of the sample is modified during the heating process, the optical and radiative properties of the material are strongly affected. Temperatures derived from the inversion technique are consistent with pyrometric measurements performed on both surfaces of the sample. Further tests, using materials having a Christiansen frequency (such as ceramics), will be conducted in a close future to validate both the experimental and numerical methods.