Identification of Radiative Properties of Fibrous Insulation for High Temperature Applications

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Keywords : fibrous media, identification, radiative properties

1 Introduction

To increase performances of high temperature thermal insulation, low phonic conductivity materials with porous structure resulting from the manufacturing process (sintering, plasma spraying, or fiber materials) are elaborated. However because of their structure and/or composition, most of them are semi-transparent materials (STM) regarding radiation, leading to a decrease in the thermal insulation performances of the barrier. To develop new materials, it is relevant to determine whether radiation is a significant part of the overall heat transfer, or if it may be neglected in computer codes developed for industrial applications.

In recent years the impact of radiative heat transfer within these heterogeneous media became an active research area. Among the community focusing on these topics the CETHIL laboratory works on experimental and numerical characterization of radiative properties of thermal protection systems for high temperature applications [1-2].

The present work is a contribution to the modelling of radiative heat transfer through low density fibrous ceramic material. The identification approach for the determination of radiative properties is based on emission spectroscopic measurements associated to an Inverse Monte Carlo Method (IMCM) widely described by Howell [3] or Modest [4]. We focus here on the global approach and the high temperature metrology for the determination of radiative properties.

2 Identification method

2.1 The global approach

The identification method includes seven steps. The sample spectral emission power is measured (1). A calibration for the whole measurement chain from source (sample) to detector (spectrometer) leads to the spectral radiative heat flux (2). The sample surface temperature is obtained using Christiansen pyrometry (3). In the meantime, the IMCM (4) is used to analyze the sensitivity of the emission factor to the radiative properties. Sensitivity analyses are carried out in order to derive a simplified model (5). Emission power and temperature are used together with this simplified model in a Genetic Algorithm (GA) (6) to identify the radiative properties of the tested material (7).

2.2 The experimental set up

An experimental bench was designed and built to measure spectral radiative intensity from porous samples at high temperatures from 800K to 2000K. The experimental set up is depicted in Fig. 1 and Fig. 2. Square samples (11x11x3 mm^3) are placed in a *vacuum chamber*. A *CO_2 laser* beam, is split (*beam splitter*) in two identical beams that reach both faces of the sample. Two squared-aperture *kaleidoscopes* using the breaking up integrating principle are located on the optical path to homogenize the original laser beam energy distribution. The emitted spectral radiative heat flux is measured by a BRUKER *FTIR spectrometer* in the wavelength range lying from 2μm to 10 μm.

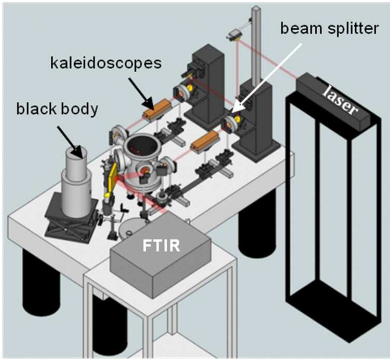

Figure 1: Schematic of the experimental set up

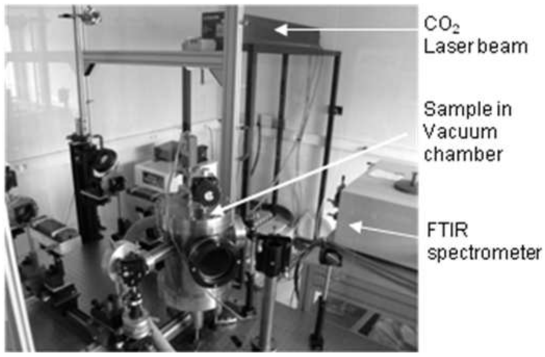

Figure 2: Picture of the pilot bench

3 Example of results on silica fibrous ceramic

To test the identification method previously introduced, measurements were carried out on a silica ceramic used for high temperature insulation applications. Samples were provided by CREE Saint – Gobain with various fiber volume fractions. In Figure 3 predicted and measured spectral radiative intensity are compare showing a very good agreement. The new identification method previously introduced and performed on SiO_2 sample provided the radiative properties necessary for modeling radiative heat transfer in participating media. Absorption and scattering coefficients are presented in Figure 4 for two values of the laser power.

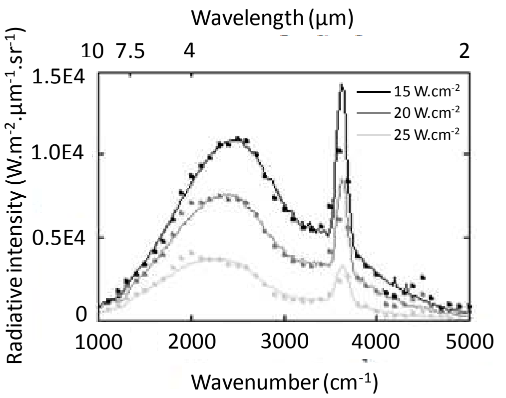

Figure 3 : Predicted (solid line) and measured (dotted line) radiative intensity
Laser power: 15, 20, and 25 W.cm^{-2}

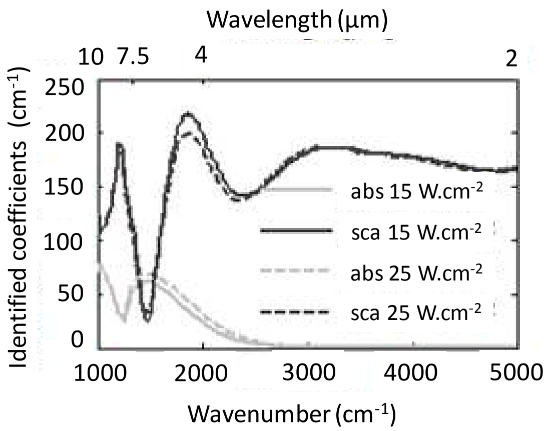

Figure 4: Identified absorption and scattering Coefficients. Laser power: 15 and 25 W.cm^{-2}

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