Transient Heat Transfer in Rotating Cylinder – Thermography Measurement to Analyse Intense Heat Flux Distribution

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The analysis of spatial distribution of intensive heat flux on curved surfaces is a crucial aspect of atmospheric re-entry characterization. This issue can be studied with ground testing facilities. This work is devoted to exploring several possibilities offered by experiments where a rotating cylinder is exposed to an intense heat flux. The principle of the experiment consists in analysing the temperature response measured by IR thermography on the outer face of the cylinder (*Fig. 1*). The main advantage is to avoid exposing the IR camera to the intensive flux environment and to allow indirectly a front face analysis (with very short characteristic response time).

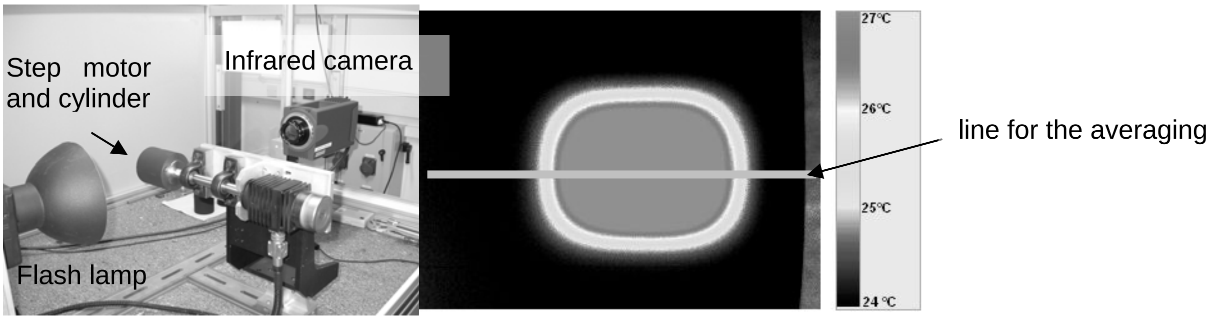

Fig. 1: Experimental device and results (temperature field 1.5 laps after the flash)

The signal processing is implemented with a suitable analytical solution of the transient temperature response to an impulse heat excitation. One example of the one dimensional response (average of a column of pixels) to a theoretical two dimensional impulse excitation is shown in *Fig. 2*. Such a temperature response contains information related to the radial heat diffusion, the rotation rate of the system (occurrence of the slots) and the angular diffusion (erosion of the slots).

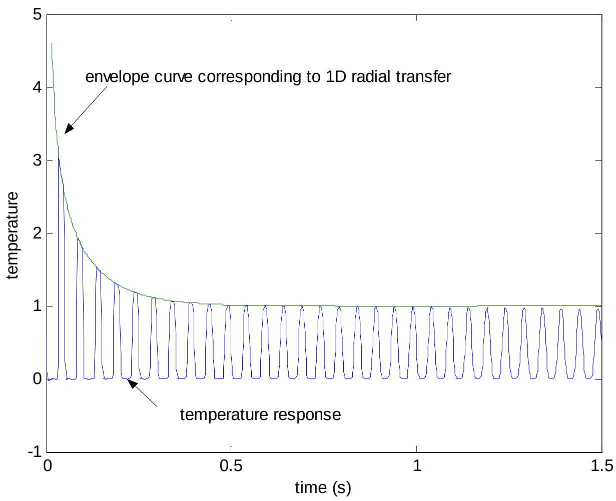

Fig. 2: Example of the theoretical response to an impulse heat excitation

The analytical model of this experimental situation will be first examined especially in the case of the impulse response. The main point is then related to the separability of heat transfer, which allows us to simply explore various possibilities of parameter estimation (velocity, thermal diffusivity, initial temperature related to the heat flux).

We first determine the rotation velocity of the cylinder using a Fourier analysis of the signal, which enables us to superpose the angular temperature field for the different periods (*Fig. 3*). Fort this first step, the zone parallel to the focal plane will only be taken into account: one column of pixels, parallel to the cylinder rotation axis as shown in *Fig. 1*. The increase of the signal base line versus time comes from parasitic heating sources. We resolve it by both using protective panels and implementing a numerical process which consists in estimating the base line level at each time step.

Then the Fourier transform of the temperature at two successive times allows us to estimate the thermal diffusivity of the material. For of a stainless steel cylinder, the estimated diffusivity by such a method is about 5% of the value obtained with the standard flash method.

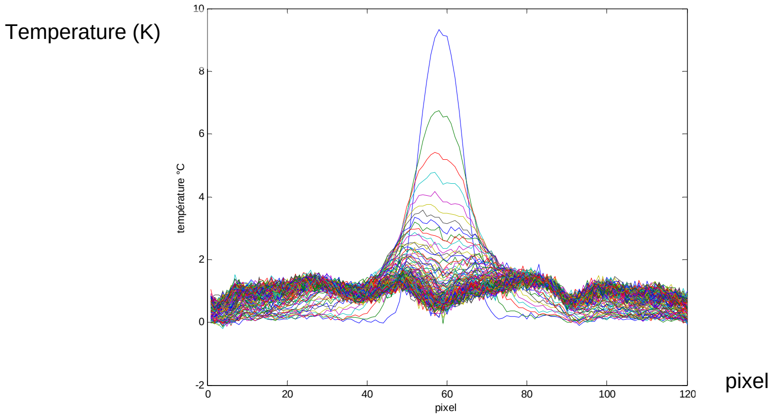

Fig. 3: Superposition of the angular temperature fields issued of the rough data

The cylinder rotation velocity and the material thermal diffusivity being known, it is then possible to process such temperature response in order to estimate the initial temperature distribution directly related to the shape of the heat flux applied to the cylinder. The method we use consists in separating the three dimensional heat transfer in three one dimensional transient problems.

I. Philippi, J.-C. Batsale, D. Maillet, A. Degiovanni, Mesure de diffusivité thermique par méthode flash-Application à la caractérisation de plaque en mouvement, *Proc. 1994 Congrès SFT,* Editions Européennes Thermiques et Industrie, 493 – 498

I. Philippi, J.-C. Batsale, D. Maillet, A. Degiovanni, Measurement of thermal diffusivity through processing of infrared images, *Rev. Sci. Instrum.*, 66-1 (1995), 182-192