ESTIMATION OF THERMAL EFFUSIVITY OF POLYMERS USING THE THERMAL IMPEDANCE METHOD

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***Abstract*— Thermal impedance is a way of defining the characteristics of thermal systems. It is a function that represents the relation between the frequency components of temperature and heat flux. From the experimental point of view, it is determined simply by measuring the heat flux and the temperature, simultaneously. In this work, these signals are measured only on the frontal surface of the sample. The experimental technique proposed here can be well adapted for making in situ measurements. A one-dimensional semi-infinite thermal model is used. For the semi-infinite model, just the thermal effusivity, *b*, can be estimated. The thermal effusivity is estimated for three polymers. An objective function representing the difference between experimental and theoretical values of the modulus of the thermal impedance function is minimized. For all cases studied in this work the thermal effusivity is in good agreement with literature. In addition an uncertainty analysis is also presented.**

***Keywords*— Thermal properties estimation, Heat conduction, Optimization, Experimental methods, Thermal impedance.**

I. INTRODUCTION

Information on thermal transport properties (thermal effusivity, b, thermal conductivity, λ and thermal diffusivity, α) has become increasingly important in a wide range of engineering fields, especially in the evaluation of insulation material performance. In this sense a lot of experimental techniques have been developed for the determination of these properties. These experimental techniques that allow determining the thermal properties values are based upon an identical principle: a signal is produced on the entrance face of a studied material sample, and the thermal response is then recorded at the same face or at another point on the material. This signal is generally an impulse, a periodic function or a step function. Some experimental methods have been used for determining these properties such as the hot wire, flash and photoacoustic methods.

Blackwell (1954) presented the hot wire technique for the measurement of the thermal conductivity. This technique requires inserting a probe inside the sample, and this appears to be the main difficulty of the method when applied to solid materials (it is a destructive method). Another restriction is the use of this method in metallic materials, due to the problems of the contact resistance. Moreover, their high thermal conductivity would greatly reduce the maximum time of measurement. Variations of this method have been used in recent works for the thermal conductivity determination. For example, the λ determination of liquid gallium in Miyamura and Susa (2002) and in Luo *et al.* (2003) by solving inverse heat conduction problems (IHCP) in an infinite region. Parker *et al.* (1961) have developed one of the most employed methods for measuring α of solid materials. This method involves exposing a thin slab of the material to a very short pulse of radiant (or other form) energy. The thermal diffusivity is determined through the identification of the time when the rear surface of the sample reaches half of the maximum temperature rise. The use of the flash method to measure α has been employed in countless papers, for instance, in Mardolcar (2002) for rocks at high temperature, in Eriksson *et al.* (2002) for liquid silicate melts and in Santos *et al.* (2005) for polymers. However, it should be observed that in the flash method the costs with the experimental apparatus are very expensive. The Photoacoustic method for measuring the thermal effusivity of solids samples based on the theory of layered samples was proposed by Benedetto and Spagnolo (1988). The method consists of the measurement of the phase of the sound pressure generated with a front-surface illumination, as a function of frequency. The sample surface is pained by a black spray whose thermal properties have been previously determined. This allows moreover to eliminate the stray light contribution, which may be important in the case of reflecting samples, as metals with polished surface, and to improve the signal-to-noise ratio, also with low exciting power. Moreover the technique has the advantage of requiring neither laborious sample preparation nor specific ad hoc manufacturing. A possible limit is that the method can not be applied to samples for which the deposition of a surface layer may change the sample properties.

In this work, impulse signals are used in an experimental technique based on the concept of the thermal impedance. The thermal impedance method requires simultaneous measurements of the variations in heat flux and temperature of the measured surface. The sensor, placed on the system to be characterized, induces a disturbance. For a slow change in thermal characteristics and for low frequencies, the disturbance due the sensor is negligible (Defer *et al.*, 1998). The thermal impedance concept has been used in several works (De-