Penetration Model in the NETZSCH LFA Software – Porous Materials Finally Handled Properly!

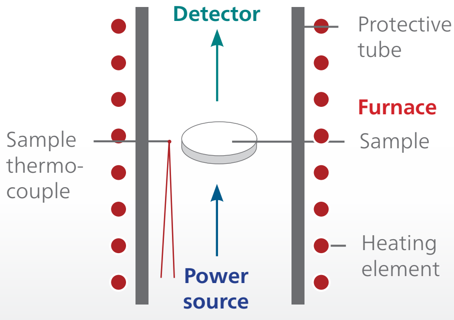
Filled Polymer with/without Boreholes

Dr. André Lindemann

Introduction

Software models that consider the influence of the shape and surface of specimens are becoming more and more important for the precise determination of thermophysical properties (TPP) such as thermal diffusivity (a), thermal conductivity (λ) and specific heat capacity (c_p). For this reason, in recent years NETZSCH has been committed to continually improving existing LFA (laser flash analysis) models and to developing new calculation models, corrections and mathematical operations considering heat loss in combination with pulse correction, radiation, multilayer systems, in-plane tests, baseline corrections, etc.

This application note presents the *Penetration* model based on McMasters [1]. It is suitable for measurements on materials with rough surfaces and on extremely porous materials.



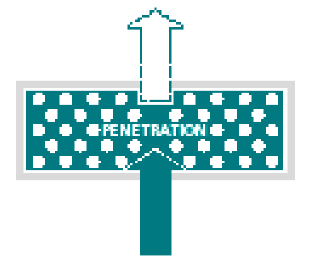
1 Schematic of LFA method

Porous Materials Are a Challenge – But Not for the *Penetration* Model

In standard flash measurements, the front face of the specimen absorbs the total energy. A thermal wave will then travel through the specimen's thickness before reaching the rear face (figure 1). For porous materials, NETZSCH has now introduced the *Penetration* model (figure 2) that includes the following considerations:

- Absorption of the pulse energy is no longer limited to the front face
- Absorption is extended over a thin layer into the specimen's thickness
- Absorption layers can be handled as the mean free path in the material

Consideration of these aspects results in an exponentially decaying initial temperature distribution within the specimen. Application of this approach, which accounts for the porosity of the material, results in improved accuracy and precision for the thermal diffusivity, thermal conductivity and specific heat capacity values determined.



2 *Penetration* model implemented in the NETZSCH *Proteus*® LFA software

NGB · Application Note 111 · EN · 1017 · Technical specifications are subject to change.

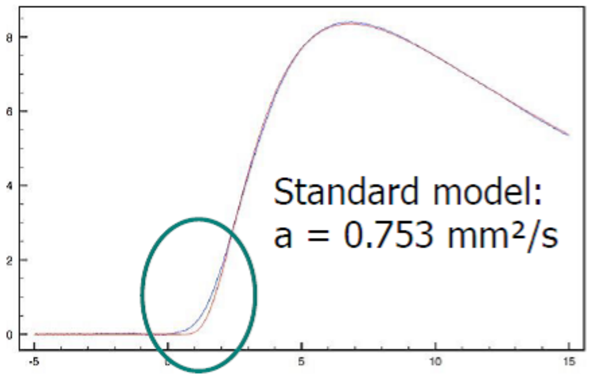
Measurement Conditions

For testing the suitability of the *Penetration* model, two filled polymers made of the same type but of different shapes were measured. One measurement was carried out on a specimen with a surface, which was covered with boreholes of 0.5 mm in diameter. For comparison reasons, a second measurement was carried out on the original specimen with a smooth surface (figure 3). The thermal diffusivity was determined on specimen dimensions of 12.7 mm in thickness and 1.96 mm in diameter at room temperature.

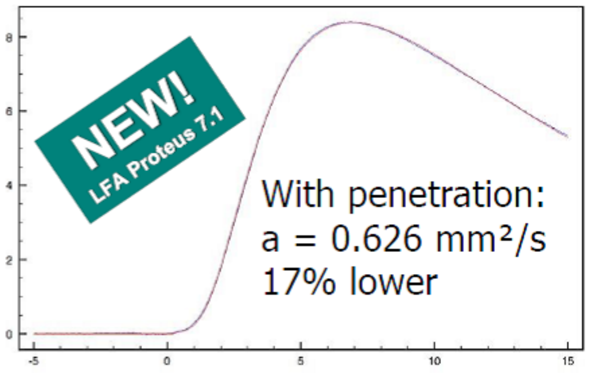
Measurement Results

Figures 4 and 5 depict the measurement on the sample with boreholes. In figure 4, the model fit of the detector rise signal (red curve) is obtained by using the standard model by Cowan [2]. The green circle indicates the area of deviations between the fit and the measurement curve (blue). With this – obviously insufficient – model fit, the thermal diffusivity is calculated at 0.753 mm^2/s. The calculation based on the *Penetration* model yields a thermal diffusivity of 0.626 mm^2/s, which is nearly 17% lower in value (figure 5).

3 Filled polymer disc on the left, polymer disc with boreholes on the right

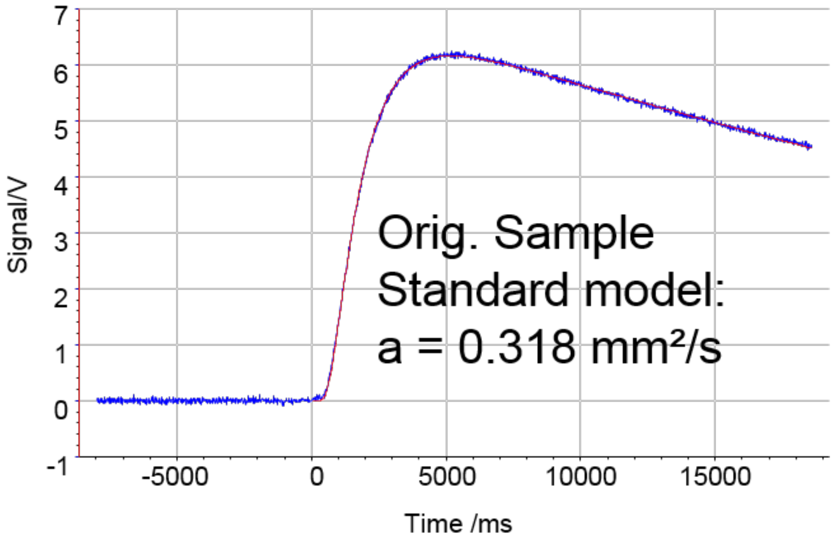


4 Specimen with boreholes, fit of the signal rise curve determination using the standard model



5 Specimen with boreholes, fit of the signal rise curve determination using the *Penetration* model

NETZSCH-Gerätebau GmbH
Wittelsbacherstraße 42 · 95100 Selb · Germany
Phone: +49 9287/881-0 · Fax: +49 9287/881505
at@netzsch.com · www.netzsch.com



6 Measurement on the original specimen without boreholes, fit of the detector rise curve obtained using the standard Cowan model.

Figure 6 shows the rise of the detector signal from the measurement on the original filled polymer disc with smooth surface. Using the standard Cowan model here for determination of the thermal diffusivity yields nearly the same measurement results as were obtained with the *Penetration* model for the specimen with boreholes (figure 5). The deviation amounts to approximately 3%. This proves that the calculation of the thermal diffusivity based on the *Penetration* model yields correct results.

Conclusion

Along with the various classical models (e.g., Cowan 5/10, Parker, improved Cape-Lehman, etc.), the NETZSCH LFA *Proteus*® software includes many different calculation models, corrections and mathematical operations. The *Penetration* model is specifically suitable for porous materials and materials with a rough surface. This special feature of the LFA *Proteus*® software involves the penetration of the light flash into the specimen beyond the actual heated surface. It accounts for the specimen's porosity, which causes much of the light flash energy to be deposited inside the specimen. This means the *Penetration* model considers for absorption of the pulse energy over a thin layer into the specimen thickness.

Measurements on samples of the same specimen but with very different surface structures (smooth vs. porous), confirm the correctness of the *Penetration* model.

Literature

[1] McMasters, Beck, Dinwiddie, Wang (1999): "Accounting for Penetration of Laser Heating in Flash Thermal Diffusivity Experiments", Journal of Heat Transfer, 121, 15-21
[2] Cowan, Robert D.; Journal of Applied Physics, Vol. 34, Number 4 (Part 1), April 1963

NETZSCH-Gerätebau GmbH
Wittelsbacherstraße 42 · 95100 Selb · Germany
Phone: +49 9287/881-0 · Fax: +49 9287/881505
at@netzsch.com · www.netzsch.com