APPLICATION **NOTE**

Metals – Laser Flash Analysis

Precise Heat Transfer Data for Pure Iron: The Key to Simulating Industrial Processes

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Introduction

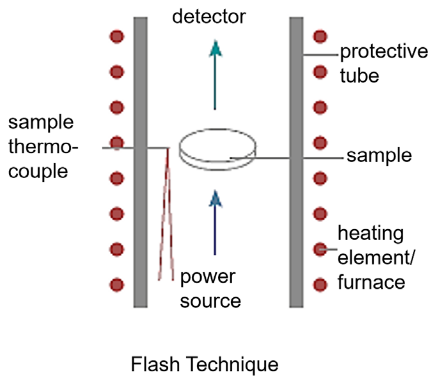
Due to its excellent magnetic and thermophysical properties, pure iron is frequently used in electromagnetic components where efficient heat transfer is essential. Examples include transformer cores, electric motors, induction coils, and components in power electronics, where both magnetic and thermal stresses occur. Precise understanding of the thermal properties over a wide temperature range is therefore essential for reliably designing components and accurately simulating their operational behavior under real-world conditions.

Knowledge of thermal conductivity is crucial, as it significantly determines how efficiently heat is transported within a material. In applications involving pure iron, particularly in electromagnetic components, it directly influences temperature distribution, heat dissipation, and thus the operational safety and service life of the components. Insufficient heat dissipation can lead to local overheating, reduced efficiency, or even failure. Therefore, precise understanding of the thermal conductivity is essential for the thermal design, optimization, and simulation of industrial systems.

Method and Measurement Conditions

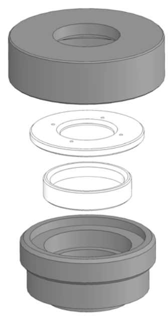
Laser flash analysis (LFA, see figure 1) is primarily used to determine the thermal diffusivity (a) of a material. When combined with density (ρ) and specific heat capacity (c_p), the thermal conductivity (λ) can be calculated ($\lambda = a \cdot c_p \cdot \rho$).

During the measurement, the bottom of the sample is heated by a short laser pulse. The resulting temperature increase on the opposite side is detected using an infrared detector. The thermal diffusivity of the material can then be determined based on this temperature profile over time and corresponding mathematical models.



1 LFA measuring principle

Using a special sapphire sample holder for molten metals (see figure 2), the thermal diffusivity of a pure iron sample was continuously measured with the LFA 707 *StratoFlash® Classic* as it transitioned from the solid to the liquid state.



2 Sapphire sample holder for molten metals

NGB · Application Note 429 · EN · 0326 · Technical specifications are subject to change.

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The specific heat capacity (c_p) was determined in the temperature range from room temperature to 1600°C using the DSC 500 *Pegasus*®, equipped with a rhodium furnace. The measurement conditions are detailed in table 1.

Table 1 LFA measurement conditions

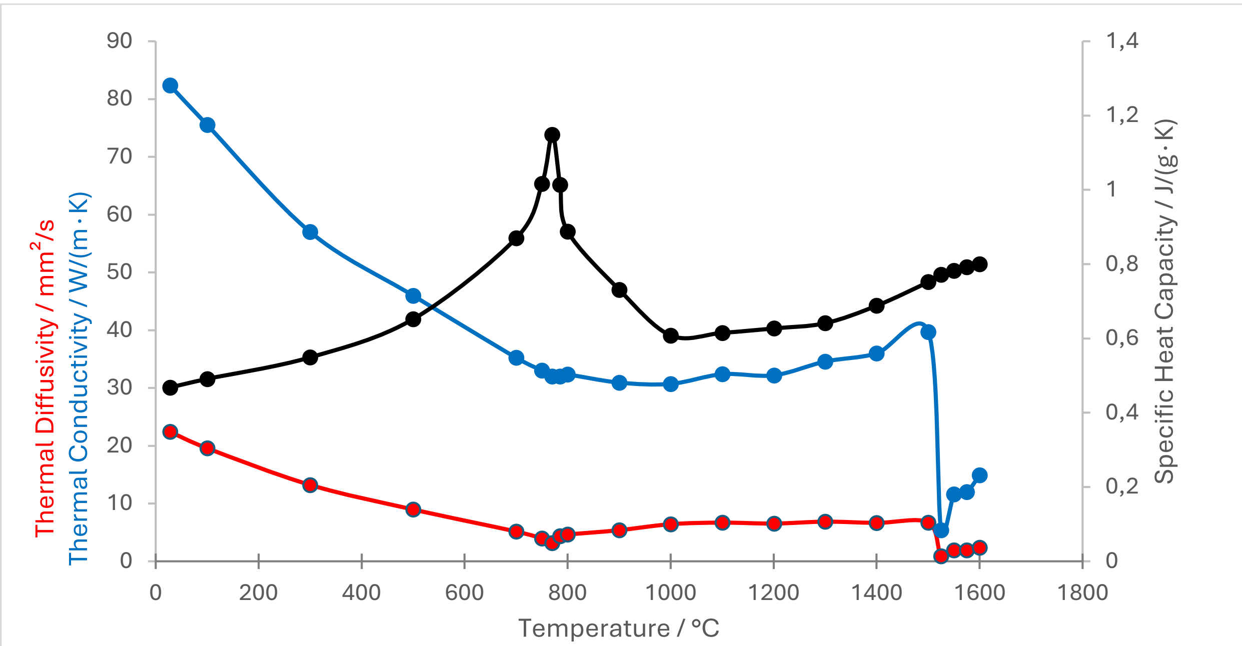
Temperature range	RT - 1600°C
Sample holder	Sapphire for molten metals
Sample size	Ø 1.39 mm; thickness ~ 1,4 mm; planparallel surfaces
Coating	Graphite
Specific heat capacity	By means of DSC 500 *Pegasus*®
Atmosphere	Ar
Heating rate	Variable 10 to 20 K/min
Energy	650 V; 600 µs

Results and Discussion

Figure 3 depicts the typical behavior of pure iron, including the Curie transition (≈770°C). Both the thermal diffusivity (red curve) and the specific heat capacity (black curve) exhibit distinct changes at this point, with a local minimum and maximum, respectively. Thus, the Curie transition can clearly bee seen in the thermal diffusivity and specific heat capacity, whereas the thermal conductivity (blue curve) shows no effect in this region. In the melting range above 1525°C, the thermal diffusivity and thermal conductivity significantly decrease as the lattice structure breaks down and heat transport via phonons no longer occurs.

Summary

From solid to liquid: Using the LFA 707 *StratoFlash*® *Classic*, equipped with a special sapphire sample holder, metals can continuously be characterized all the way down to the melt. The resulting data provides valuable insights into the temperature-dependent thermal conductivity behavior, forming a reliable basis for simulation, material selection and component optimization, even under extreme operating conditions.



3 Thermophysical properties of pure iron

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