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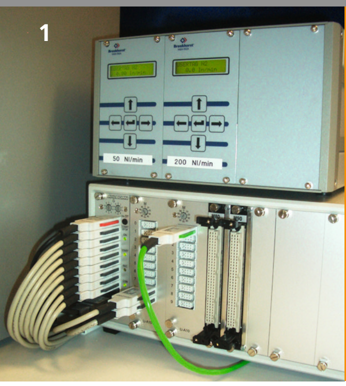
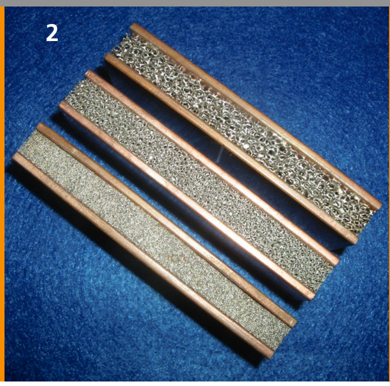
FRAUNHOFER INSTITUTE FOR MANUFACTURING TECHNOLOGY AND ADVANCED MATERIALS IFAM, BRANCH LAB DRESDEN





1 Multifunctional data receiver for variable input signals
2 Metal foam samples prepared as sandwiches for flow investigation
3 Thermostat with adjustable circulating pump
4 Accurate adjusting and measuring device for gas volume flow rates

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THERMAL AND FLOW CHARACTERISATION OF CELLULAR MATERIALS

Problem

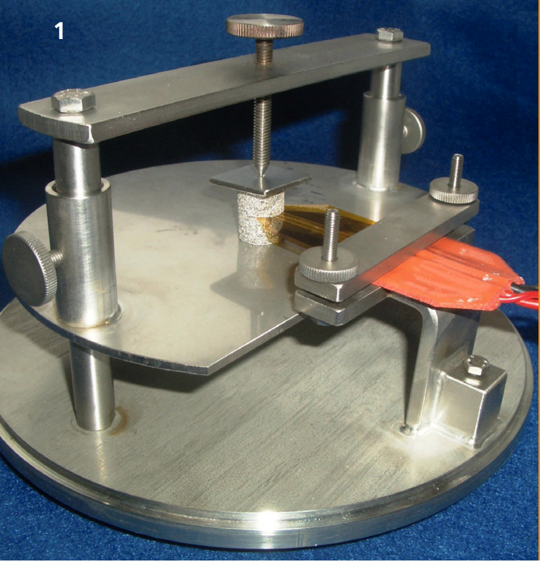
Cellular materials offer a large number of applications in the field of power engineering. This includes the use in heat exchangers, evaporators, thermal energy storages, thermally insulating devices and filters, respectively. The most important advantage with respect to heat transfer is the possibility of a flow passing the structure in connection with the extremely large inner surface.

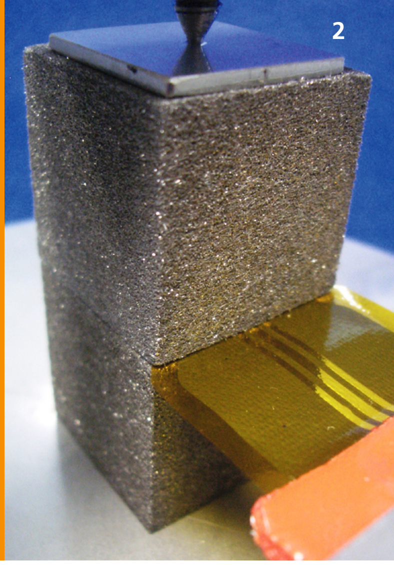
Typical representatives of cellular materials are foam, fiber, wire, hollow sphere and honeycomb structures, which can be manufactured either of metals – as done at Fraunhofer IFAM Dresden – or of other materials (ceramics, plastics). In order to design a technical device using such types of cellular structures, qualified information about the heat transfer and flow coefficients are needed.

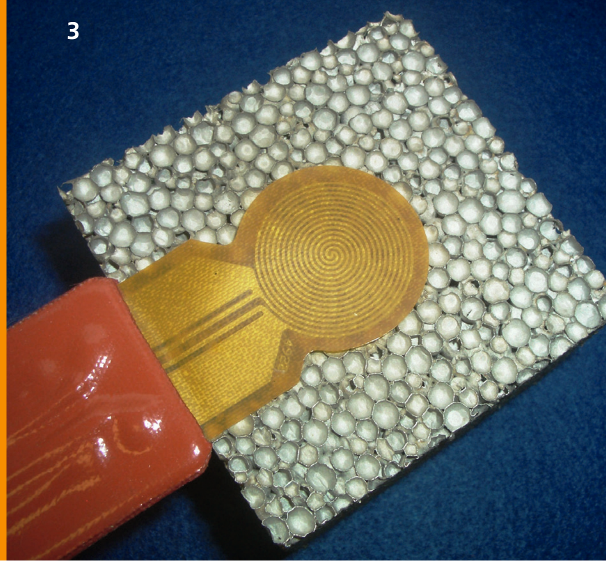
Procedure

Transport coefficients have to be determined from experimental investigations – not only in the case of cellular materials. To ensure an optimal transferability of the measurements, defined flow conditions are generated in the laboratory and the measuring results are plotted in a generalised – mostly dimensionless – way. At IFAM Dresden, the required experimental equipment as well as the scientific know-how for an optimal data evaluation are available.

Measuring results can be presented depending on the special requirements as simple graphical plots extended to the use of mathematical, primarily empirical methods. These correlations are at least qualified for calculations of pressure losses and temperature distributions as well as for the implementation into numerical algorithms (boundary conditions, transport coefficients).







Effective heat conductivity

For many applications of cellular materials firstly detailed information about the effective heat conductivity are required. For cellular materials especially, the so-called Hot Disc method is used, a transient measuring procedure. A flat, heated sensor (hot disc) is positioned between two identical samples with surfaces as plane as possible. The following options are available using a Hot Disc device:

- Measurement of isotropic as well as anisotropic materials (e.g. fiber structures),
- Investigation of flat samples down to very thin layers,
- Measurement of heat capacity (volumetric or specific).

Measuring results are optionally generalised using thermal resistance models depending on structural data of the cellular material. Additionally, a so-called sandwich-sample can be used to investigate heat transfer resistances between a cellular material and a solid wall by means of a steady-state measuring procedure – e.g. for thermal characterisation of soldered or glued connections.

Flow coefficients

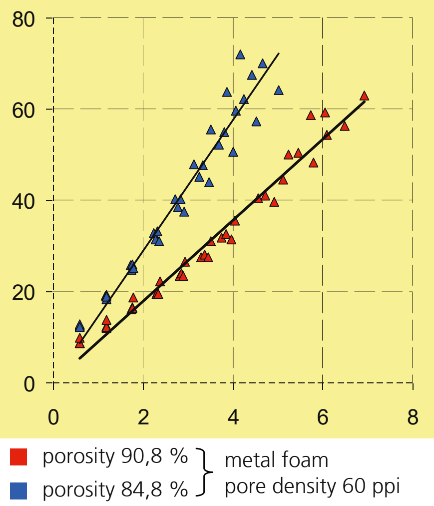
In the case of open cellular materials which allow a flow through their structure the additional flow characterisation has an important relevance. Keeping characteristic numbers with respect to the flow conditions constant the results determined in the laboratory can be extrapolated to several practical applications with high accuracy.

The thermo technical laboratory at IFAM Dresden provides comfortable basic equipment to generate defined flow conditions:

- Gas flows up to 250 litres/min (mass flow controllers), also heatable,
- Liquid flows up to 30 litres/min (turbine-type meter), temperature range -40 °C to 200 °C.

The used flow channel is adapted in each case to the special sample geometry.

Normalised pressure loss measurements in a foam plotted against superficial velocity



Pressure losses are measured by means of pressure transducers available for gases and liquids with different measuring ranges. To evaluate and process the results, various options are possible:

- Pressure loss per unit length depending on the superficial velocity,
- Dimensionless pressure loss coefficients depending on the Reynolds number,
- Friction and inertia coefficients with respect to the Darcy Forchheimer equation.

In the field of mathematical modelling of measuring results depending on structural parameters multiple competencies are existing including the implementation of numerical simulations (COMSOL Multiphysics©).

Heat transfer coefficients

Heat transfer coefficients quantify the heat transfer by means of convection between a fluid flow and a solid surface. Its determination is mostly realised by indirect methods using an energy balance. For this reason the above mentioned equipment is completed by variable heating options and thermocouples.

Depending on the special aim of the investigation, the measuring results are processed as temperatures, heat transfer coefficients or resistances and dimensionless Nusselt or Stanton numbers, respectively. Additionally, temperature distributions are detectable with very high local resolution (micrometer scale) by means of a capable thermal imaging system.

1 *Sample-holder with hot disc sensor and samples for measurement of heat conductivity*
2 *Measurement of anisotropic heat conductivity of cubic fiber samples*
3 *Hot disc sensor positioned on a hollow sphere structure*