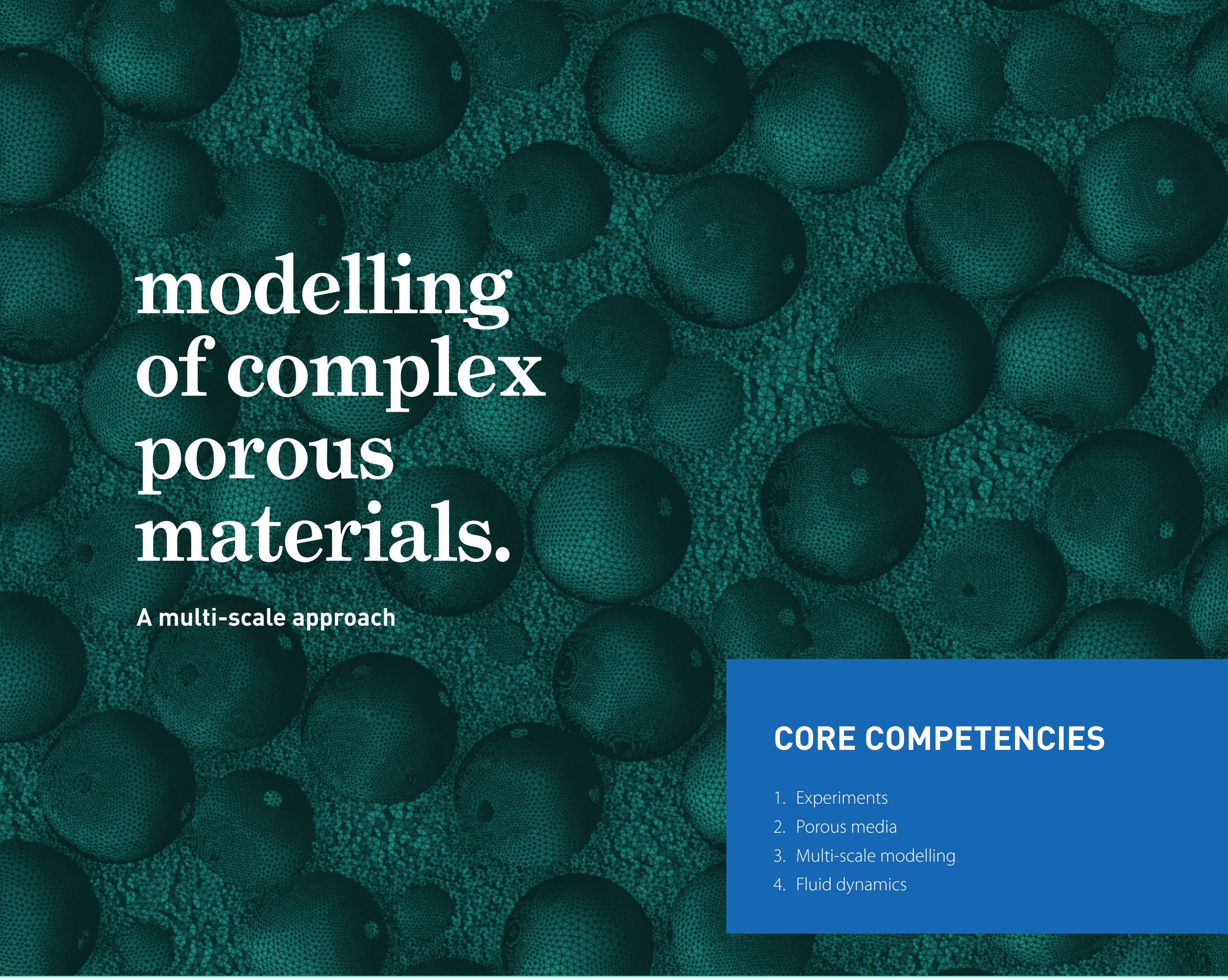

modelling of complex porous materials.

A multi-scale approach

CORE COMPETENCIES

1. Experiments
2. Porous media
3. Multi-scale modelling
4. Fluid dynamics

Goal

Fluid flow through porous media is an interesting but also complex field of study. This kind of flow consists of an interpenetrating liquid or gas through a labyrinth of solid material. This solid labyrinth could for example be a randomly packed bed of beads, rocks, sand or straws. It could also be one solid material with holes or canals (like a sponge). The figure in the header shows the microstructure of a certain porous material.

The concept of porous media is widely used in the industry: filtration, ventilation, heat transfer, bio-engineering, drainage, oil extraction, drying processes and many more. Porous media are often components in larger fluid flow systems. If flow through the entire system needs to be analyzed or predicted, you are dealing with two very different scales of flow. The macro-scale flow that runs through pipes, chambers and machinery. And the micro-scale flow that occurs at the complex structure of porous components. Simulating this micro-scale flow entirely, in full detail and accurately, is very difficult and time consuming. Instead, flow through the porous component can be modelled as a 'black box', in which the main characteristics of the micro-scale flow is represented. These characteristics are the pressure drop over the porous medium and corresponding flow rate or flow velocity.

In order to replace a porous component with this 'black box', the flow characteristics through the porous medium need to be determined first. Depending on the information available of the porous medium two approaches can be chosen to determine the flow characterisitics.

DEMCON | MULTIPHYSICS

Experimental approach

If the material of the porous component to be analyzed is already produced and easily available, an experimental setup is a fast and realiable way to obtain flow characteristics.

A modular setup (as shown in Figure 1) was designed to experimentally meassure the pressure loss through a porous medium. From the experimental data, the relation between pressure drop, flow rate and material length is derived.

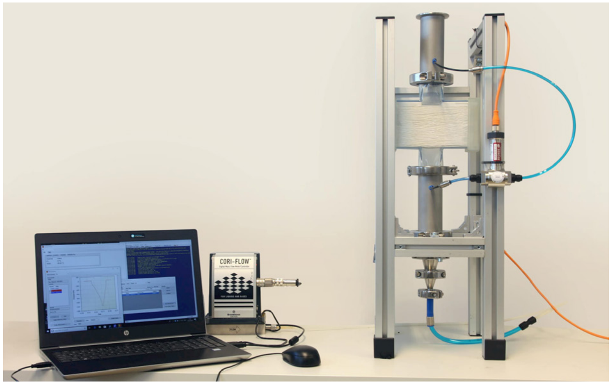

Figure 1 Experimental setup to meassure pressure loss for given flow rate over a porous medium.

Numerical approach

If the porous material is not physically available or is still conceptual, a micro-scale simulation of the porous material can be used. However, some knowledge of the material structure is needed.

In this case the detailed micro-scale flow through only a small part of the total material is modelled. Incorporating a suitable void fraction and grain or pore size. Such a micro-scale simulation model can be seen in Figure 2, where the colours represent flow velocity in between the solid labyrinth. Again, the relation between pressure drop, flow rate and length of the material is determined and scaled to match the total porous component.

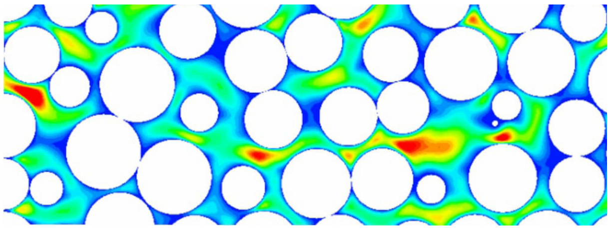

Figure 2 Flow velocity in a micro-scale flow simulation.

Results

The relations found through the experiments are compared to analytical relations for porous flow (such as Darcy's law or the Ergun equation). For this specific case we were able to find a good match between the experiments and the Ergun equation (Figure 3). This validates that the experiment is a fast and reliable way to determine flow characteristics of a porous medium and it can be used for various types of porous structures.

Additionally, the micro-scale simulation results matched the experimental data as well. This is, therefore, a good approach when experiments are not possible and sufficient information on the material structure is available.

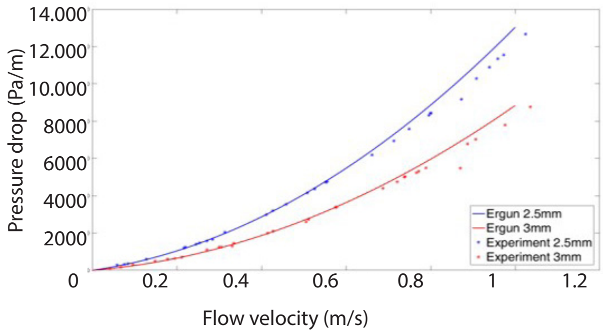

Figure 3 Measured pressure drop for two grain sizes compared to Ergun equation.

Replacing the porous component by a 'black box' with the obtained flow characteristics, saves extensive simulation effort in the analysis of the larger system. This can be implemented either in a system analysis as demonstrated in Figure 4 or in a macro-scale CFD simulation..

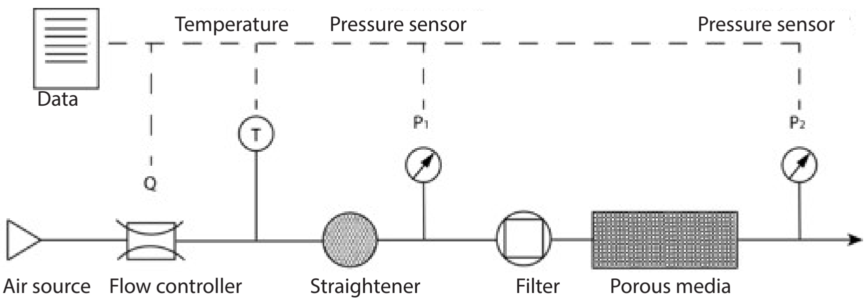

Figure 4 Flow circuit of the experiment to simulate pressure loss over the porous medium.