Natural and mixed convection in mono- and bidisperse porous media

The Data Center (DC) serves as facility for storing and managing numerous types of electronic equipment, such as computing clusters or servers. Thanks to them, it is easier to organize, store, process, and share digital data. One of the DC main parts is the cooling system which has to provide sufficient cooling capacity to prevent the electronic equipment from overheating and thus destroying data. Due to the continuous development of digital technologies such as artificial intelligence, computational engineering, and cloud computing to name a few, the electrical energy consumption of cooling systems accounts for up to 45% of the total DC electricity consumption. Moreover, the increasing heat fluxes dissipated from the electronic equipment force engineers and scientists to develop novel cooling technologies to meet high requirements. The air-cooling is not sufficient to maintain the temperature at the desired level. Thus, liquid cooling technology, especially immersion cooling is getting heightened attention.

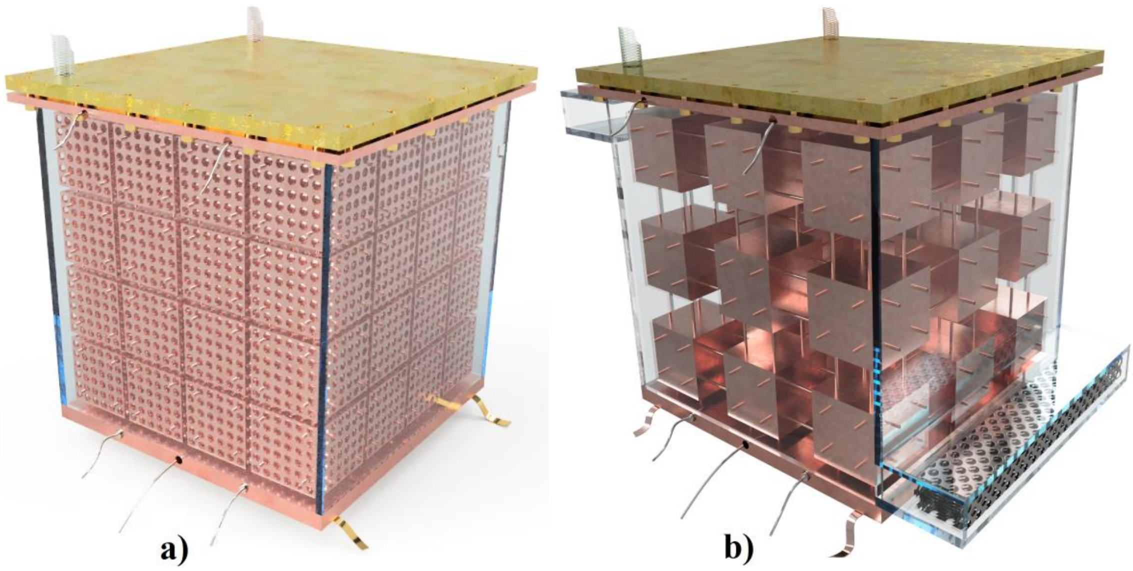
The immersion cooling in DC involves direct immersion of IT racks in a liquid. Heat is dissipated from the electronic equipment and transferred to the surrounding coolant. Due to the substantial height of the DC, the natural convection of the cooling liquid cannot be neglected during calculations. Moreover, the liquid can also be pumped through the DC to improve the heat transfer. As a result, the mixed convection condition has to be taken into account during the cooling analysis. Another aspect that complicates the analysis of electronics cooling in DC is the fact that electronic equipment is not a homogeneous, solid body made of one material. It must therefore be treated as a porous media. Additionally, the distribution of many electronic components in the DC space causes the entire system to be treated as Bidisperse Porous Media (BDPM).

The term BDPM was introduced in 2000 and is defined as a composition of large particle clusters that are agglomerations of small particles, so BDPM can be considered as a Mono Disperse Porous Media (MDPM) in which each solid particle is replaced by a medium with microporosity. Since the definition, BDPM has attracted many heat and fluid flow researchers.

The research questions arise:

- How do the macro volume fraction, micro porosity, and solid-to-fluid thermal conductivity ratio influence the effective thermal conductivity in BDPM?
- How do the macro volume fraction and micro porosity influence the permeability in BDPM?
- How does the solid-to-fluid thermal conductivity ratio influence the heat transfer process in the MDPM and BDPM during natural and mixed convection?
- How different are the attached and detached configurations in MDPM and BDPM during natural and mixed convection?
- Which geometrical or thermal-hydraulic parameter is the most influential on the natural and mixed convection heat transfer characteristics of MDPM and BDPM?

The project aims to provide experimental data that help to understand a heat transfer and fluid flow for MDPM and BDPM during natural and mixed convection. Various parameters are tested to create heat transfer characteristics in terms of Nusselt number in a function of Rayleigh number for various macro volume fraction, micro porosity, thermal conductivity ratio, and Richardson number. Moreover, the differences between attached and detached geometries will be researched and described.



Schematics of the test stand: a) natural convection with 64 BDPM; b) mixed convection with 27 MDPM