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Experimental and Numerical Analyses of Pressure Drops In A 3D Printed Foam

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Extended Abstract

Open-cell foams have many interesting combinations of physical, thermal, and mechanical properties. They are currently adopted in many technological applications in the automotive and aerospace industry, energy storage, medical and biomedical fields. However, each application requires a custom design that involves optimization of many geometric parameters, such as porosity, pore density, etc.

The use of numerical simulations is recommended to improve the design process reducing time and cost. Unfortunately, performing simulations of stochastic foams is difficult because the exact geometry is unknown.

Additive manufacturing could overcome this limit, as it allows to faithfully reproduce a CAD-drawn geometry. So, it is possible to calibrate the numerical simulation on the very-same geometry.

In this work an open-cell stochastic foam was designed based the Voronoi and Catmull-Clark algorithm, fabricated from Polyamide 12 (PA12) using Multi Jet Fusion technology, and experimentally tested at different temperatures (20 to 40°C) and at different sample orientations. Pressure drop data were collected when water flowed through it. No effects of temperature or orientation were observed.

Data were compared against two literature models developed for conventional foams: the MRE is 1.7 % and 2 % and the MAE is 6.1 % and 6.3 % for the models of Mancin et al. [1] and Tadrist et al. [2], respectively.

These steps demonstrated that 3D printing process did not affect the foam quality and fluid dynamics and that it produced foams having very similar performance to the traditional ones.

Next, a numerical simulation was developed in Ansys Fluent 18.2 to evaluate the pressure drop as a function of water flow rate through foams having 5, 10, 20, and 40 PPI and 0.935 porosity. The numerical model was validated against experimental pressure drop data collected on the very-same geometry.

It was stated that the increase in pressure drops is not linear to the increase in PPI. For instance, the difference in pressure drop between 10 PPI and 5 PPI is much lower (+3.7%) than the difference between 40 PPI and 20 PPI (+25.5%), although in both cases there is a PPI value doubling.

Then, the local water velocity in the 5 PPI and 20 PPI foams at the same flow rate were compared. The 20 PPI foam had higher local velocity values but also some stagnation zones where the local velocity is even lower than in the 5 PPI. This issue can compromise the heat transfer performance, so it is not certain that there is a linear increase in heat transfer performance as pressure drops increase.

So, in the future it will be necessary to perform a detailed thermal analysis aiming at selecting the optimal geometry as a compromise which can ensure low pressure drops and contemporary high heat transfer coefficients

References

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[2] Tadrist L, Miscevic M, Rahli O, and Topin F, 2004. About the use of fibrous materials in compact heat exchangers. Exp. Therm. and Fluid Sci., 28 193-199.