ICAM2009

11th International Conference
on Advanced Materials

Rio de Janeiro Brazil
September 20 - 25

Tailoring Microcellular Biomorphic Ceramic Composites: a Computational Fluid Dynamic Approach

C. Soares(1)*, L. M. Porto(1), D. Hotza(2) and C. R. Rambo(1)

(1) Integrated Technologies Laboratory (InteLAB), Federal University of Santa Catarina (UFSC) – Chemical and Food Engineering Department, Florianópolis – Brazil. E-mail: {cintia, luismar, rambo}@intelab.ufsc.br
(2) Group of Ceramic and Glass Materials (CERMAT), UFSC (E-mail: dhotza@gmail.com)
* Corresponding author.

Abstract – Computational fluid dynamics (CFD) was used to evaluate the pressure drop and permeability constants of microcellular biomorphic Al_2O_3. Rattan-derived Al_2O_3 was produced by biotemplating through Al-vapor infiltration reaction and oxidation into a pyrolysed rattan template. Vector plots and pressure drop curves as a function of the fluid velocity allowed a complete evaluation of the fluid dynamics phenomena inside the rattan channels. Microcellular Al_2O_3 can be used as template for molten metal infiltration under thermodynamic considerations. Our results suggest that CFD analysis can be applied to the characterization of composite materials.

A recently developed method to produce ceramic materials with microcellular structure is based on the replication of the microcellular anatomy of wood into ceramic materials [1,2]. Highly porous ceramics with microcellular morphology, such as biomorphic microcellular Al_2O_3, can be used for pressureless molten active or inert metal infiltration to produce multiphase composites or functional graded materials. The demand for new technologies in molten metal infiltration requires the knowledge of the infiltration flow regimes. In order to predict the pressure drop and the flow regimes during molten metal infiltration into microcellular ceramics, a morphological characterization of the porous structure and the determination of the permeability are required. This work reports on a computational fluid dynamic evaluation taking into account Darcyan (viscous) and non-Darcyan (inertial) effects for molten metal infiltration into microcellular biomorphic Al_2O_3 ceramics produced from rattan. Rattan-derived Al_2O_3 was produced by biotemplating through Al-vapor infiltration reaction and oxidation into a pyrolysed rattan template [2]. Computational fluid dynamics (CFD) techniques were used to evaluate the pressure drop and permeability constants of the microcellular biomorphic Al_2O_3. All calculations were performed using the software CFX 11.0 of ANSYS®. The numerical method used to solve the model is based on the finite volume method with a structured multi-block grid, generated by the body fitted on a generalized coordinate and collocated system. The pressure-velocity coupling used was the SIMPLEC algorithm with a first order interpolation scheme. Pre-processing was used to generate the geometry and numerical grid representing rattan in the computational domain (Figure 1); post-processing comprised analysis and visualization of major flow features. Simulations were carried out at different values of air velocity inside the channels (shown as triangle points in Figure 2) and the pressure drop as a function of the fluid velocity was calculated. Permeability is an exclusive property of the porous media [3]. The calculated permeability constants were in good agreement with experimental data [4] and were then applied to molten Al infiltration. In experimental conditions of infiltration into the biomorphic ceramics, the fluid flows in a combination of laminar and turbulent regimes, characterized by the parabolic behavior of the curve (Figure 2). Vector plots allowed the evaluation of fluid dynamics phenomena of Al infiltration inside the rattan channels (Figure 3). We propose that CFD may be used as a valuable tool for the processing of new composite materials.

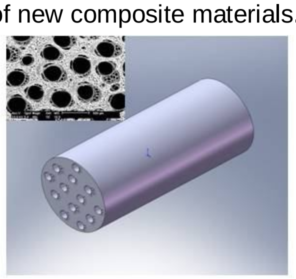

Figure 1: Geometry used in the numerical simulation based on a rattan microstructure (insert).

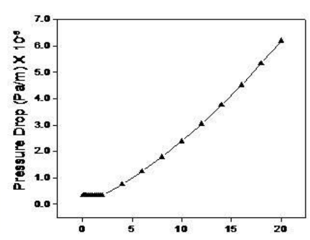

Figure 2: Pressure drop curve for air in rattan derived Al_2O_3 (▲ calculated points).

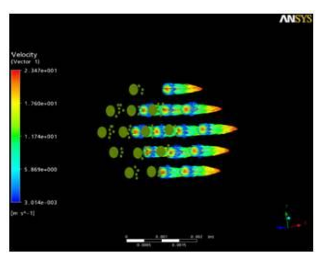

Figure 3: Vector plot of the velocities along the vessels during Al infiltration.

References

[1] P. Greil, Biomorphous ceramics from lignocellulosics, J. Eur. Ceram. Soc. 21 (2001) 105–118.
[2] C.R. Rambo, H. Sieber, Adv. Mater. 17 (2005) 1088.
[3] P. Colombo, M. Scheffler, Cellular Ceramics: Structure, Manufacturing, Properties and Applications, New York: Wiley, 2005.
[4] C.R. Rambo, T. Andrade, T. Fey, H. Sieber, A.E. Martinelli, and P. Greil, J. Am. Ceram. Soc., 91 [3] (2008) 852–859.