Passive heat dissipation system using phase change materials (PCM) embedded inside open cell metal foams

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To avoid damage of electronic devices the heat generated by these equipments has to be dissipated by adequate cooling systems. In aeronautic for instance, some electronic parts work during short periods of flight (takeoff, landing, breaking, ...) but they must be cooled because the heat produced by devices could destroy themselves. Various solutions have been proposed to avoid such damages. The most used is the water cooling using forced convection. This type of cooling has good performances but requires a lot of equipments like pumps, filters, networks, etc... So this is not the best choice for aircrafts when the weight, the price and the reliability are critical, the aim is to get a passive system which works without any energy supply. The basic solution to get a passive system of heat dissipation is to place on the electronic device a bloc made of aluminium or copper to dissipate the heat. But such a system can become heavy so it is not the best solutions for aircrafts because of the additional weight. An other consists in using the latent heat of phase change materials (PCMs). The controlled mass of PCM can dissipate the quantity of heat generated by the device. The PCM used in this study is a polymer and the major disadvantageof this material is its low thermal conductivity. This is why it is necessary to find a system to conduct the heat flux inside the PCM to obtain its homogeneous temperature inside the PCM [2]. After comparing the different thermal conduction system, it was decided to test have been done with an open cell metal foam of aluminium because of the low density of the foam and the thermal conductivity of this material. Experimental tests have been performed in this study to measure the performances of such systems of heat dissipation and compared to performances of pure PCM system.

In order to optimize the heat dissipation system without additionnal experimental test, numerical analysis by finite elements and finite volume have beenperofrmed to simulate the phase change of the PCM and the thermal evolution of the system. The complex geometry of the aluminium foam is a problem for the simulation because to mesh the PCM embedded in open cell foams, a huge number of elements is necessary. To circumvent this difficulty, it has been decided to replace the PCM inside the open cell foam by an homogeneous material having the equivalent thermal properties of the mixture. Several thermo-physical properties are needed for thermal transient analyses, namely : the density, the thermal conductivity, the specific heat and the latent heat ofthe PCM. Scalar quantities such as density, specific heat and the latent heat of PCM/foam mixture are determined in function of the mass fraction or concentration of each component. For the tensors quantities such as thermal conductivity, it is necessary to take into account the specific geometry of the open cell metal foam. A model using the geometry of an open cell metal foam has been proposed by Boomsma et al. [1]. This model is based on an ideal geometry of the foam : the tetrakaidecahedron. This polyhedron has been chosen as a result of statistical observations on the open cell foams and because the tetrakaidecahedron is the space filling arrangement of cells of equal size with the minimal surface energy [1].

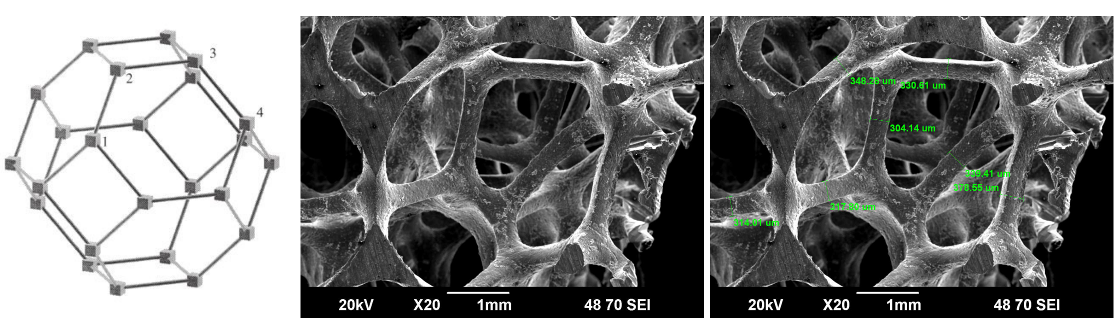
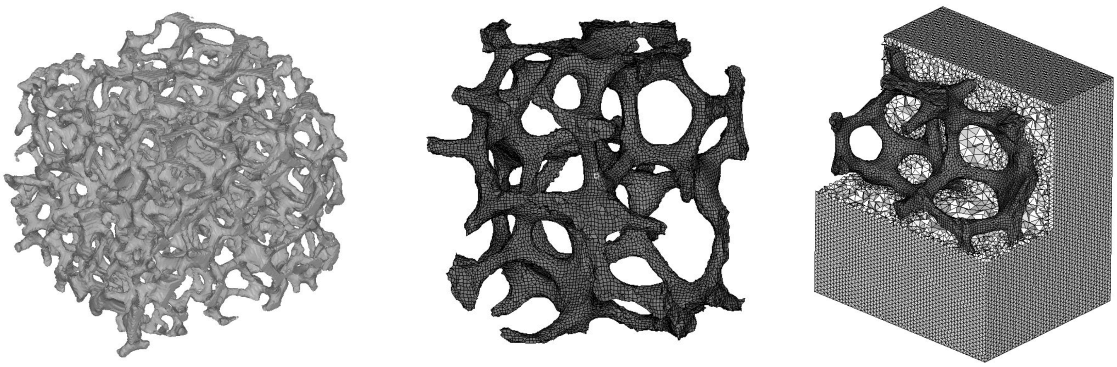


Figure 1: Tetrakaidecahedron and measurement of the foam pore size

In order to calculate the effective thermal conductivity according to Boomsa et al. [1] various geometric characteristics of the foam pores are necessary as well as the thermal conductivities of the mixture components. To validate the thermal conductivity of the homogeneous material, a heat transfer problem analyses has been compared for the homogeneous material and a volume of PCM containing open cell foam have been performed. The geometry of the foam has been obtained by X tomography, in order to reproduce the realistic 3D object. A representative part of the foam has been selected to limit the number of elements for the meshing of foam and PCM.



(a) Reconstruction of the foam geometry (b) Representative part of the foam (c) Creation of the PCM around the foam

Figure 2: Meshing of the PCM embedded inside open cell foam

After validation of the homogenization model, the thermal properties has been applied to the model representing the experimental investigations and compared the evolution of the temperature at the heater contact and the top PCM surface.

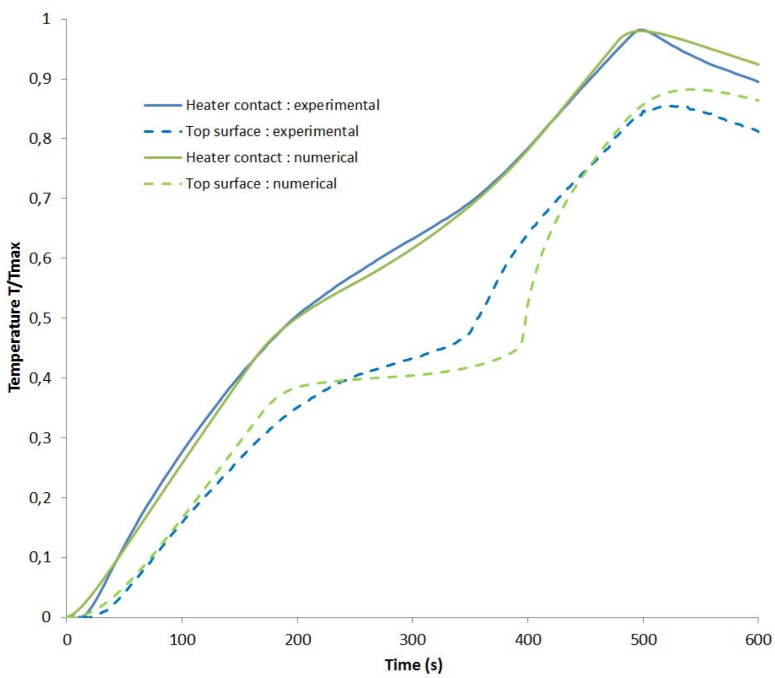


Figure 3: Experimental and numerical comparison for PCM embedded inside open cell metal foam

[1] K. Boomsma and D. Poulikakos. On the effective thermal conductivity of a three-dimensionally structured fluid-saturated metal foam. *International Journal of Heat and Mass Transfer*, 44(4):827–836, February 2001. 1

[2] C.Y. Zhao, W. Lu, and Y. Tian. Heat transfer enhancement for thermal energy storage using metal foams embedded within phase change materials (pcms). *Solar Energy*, 84(8):1402 – 1412, 2010. 1