Simulation for Additive Manufacturing
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From 3D images to 3D printed optimized materials for high temperature thermal insulation

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Since a few years, a small revolution is happening in material science through the development of experimental techniques leading to get the 3D representation of significant volume of material at a representative scale (TEM, FIB/SEM, X-Ray micro-tomography). Thus, using more and more powerful image processing techniques, new microstructural analysis approaches arise to study materials from nanometers to millimeters scales. Moreover, recent computer abilities (especially high performance computing solutions) allow achieving numerical experiences to estimate some physical properties of materials through the use of their 3D numerical description. Nevertheless, these computations can only be done if the properties of each component of the material are known at the appropriate scale. Beyond the estimation of properties of a given material, these simulations enable the development of optimized materials. In fact, the 3D microstructure can be numerically transformed or can be entirely designed by computer. Also, in numerical simulations, the base component properties can be easily changed. Then, according to thermal and/or mechanical specifications, an optimized material can be designed by changing either the microstructure and/or the base component properties. The Figure 1 shows different steps of the process; from 3D numerical design to real test through numerical simulations.

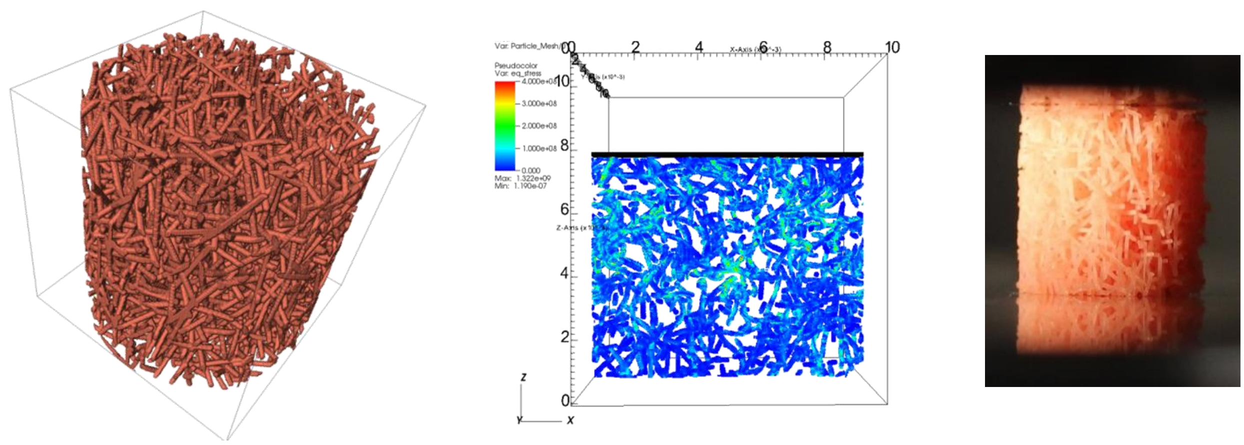

Figure 1: 3D voxel representation of a fibrous numerically created sample (left). Extraction of constraint field during a dynamic compression simulation (center). Same sample (made by additive manufacturing) before a quasi-static compression test (right).

In this study, the reasoning described above is applied to develop new thermal insulating materials. Super-insulating materials (material with better thermal properties than air) are usually mechanically very fragile. To improve mechanical performances of such media without degrading its thermal properties, the addition of solid skeleton, made by additive manufacturing, is studied. Then, we present the simulation leading to the best compromise between thermal and mechanical behaviors. All the simulations are fed by local characterizations. Thus, the influences of the printing parameters are taken into account in the calculations.

Another specificity of this work is the need for this material to work at high temperatures (>1000 °C). Then, the 3D structures are made by stereolithography using inorganic loaded resins. Finally, comparisons between simulations and experiences are made for thermal properties as well as mechanical ones.