EFFECT OF THERMAL GRADIENT ON THE DENSITY DISTRIBUTION OF MACROPOROUS CERAMICS OBTAINED BY SPARK PLASMA SINTERING

G. Jean[1], T. Vanherck[2], V. Sciamanna[1], M. Demuynck[3], F. Cambier[3] , M. Gonon[1]

[1]UMONS, Faculté Polytechnique, Service de Science des Matériaux, 56, rue de l'Epargne, 7000 Mons (Belgium)

[2]UMONS, Faculté Polytechnique, Service de Génie Electrique, 31, Bd Dolez, 7000 Mons (Belgium)

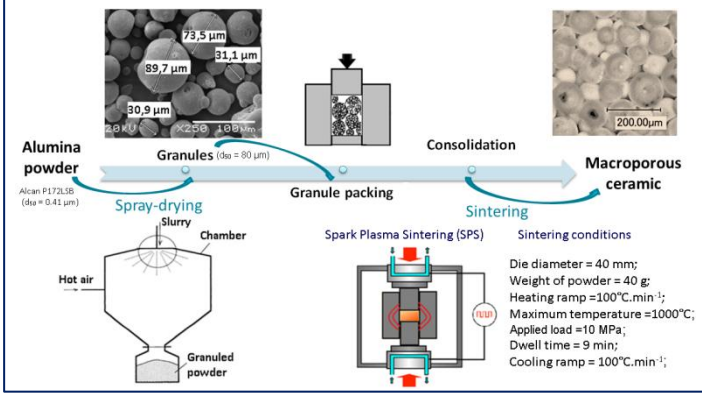
[3]Belgian Ceramic Research Centre, 4, avenue du gouverneur Cornez, 7000 Mons (Belgium)

Purpose

This work aims at correlating density heterogeneities observed in macroporous alumina ceramics made by Spark Plasma Sintering (SPS) with thermal field heterogeneities during the sintering cycles.

Specimens of average relative density of about 45 % are obtained by partial sintering of alumina spray-dried granules. 2D X-ray radiography highlights significant density gradients.

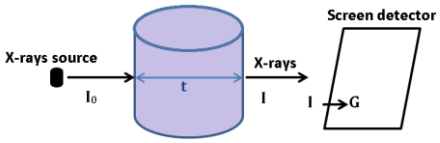
Elaboration of macroporous ceramics



Density gradient characterization

Radiography and 3D-CT are techniques based on X-ray absorption contrast, which follow the Beer-Lambert's law :

$$I = I_0 \exp(-\mu^* \rho t)$$



Intensities *I* are converted into proportional grey levels *G*.

2D-Radiography : Along a diameter, thickness *t* and the mass absorption coefficient μ^* are constant, the grey level is linked to the average density ρ along the diameter.

3D-CT : The grey level associated to a voxel is proportional to the linear absorption coefficient $\mu = \mu^* . \rho$.

In both cases μ^* was experimentally determined on a homogenous reference specimen of known density.

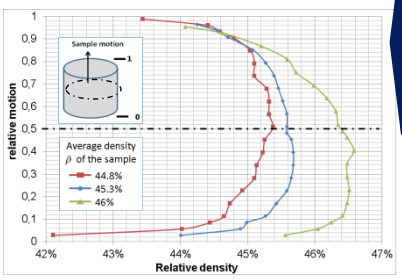
Densities are calculated with reference to the average grey level $\bar{G}$ to which the average density $\bar{\rho}$ of the sample is associated .

$$(\rho - \bar{\rho}) = \ln\left(\frac{\bar{G}}{G}\right) / (\mu^* t)$$

Experimental results

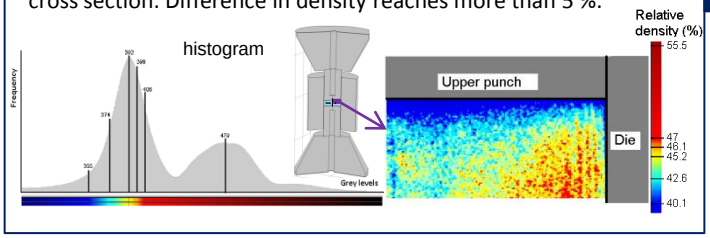
2D-Radiography

3 samples were tested.
Average densities were measured along diameter at different heights.
→ maximum for the median plane of the specimen.



3D-CT

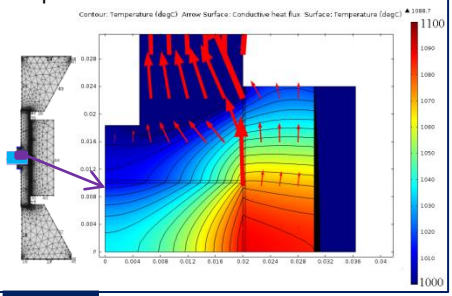
According to the symmetry of the specimen, the full characterization of density distribution can be obtained by an axial cross section. Difference in density reaches more than 5 %.



Temperature field evaluation

Knowing the electrical and thermal characteristics of materials and the limit conditions, a coupled thermo-electric numerical model of the SPS (by finite-element method) evaluates the temperature field inside the tools and the sample.

The results given by the numerical model agree with the experimental results. Indeed, high temperature areas predicted by the model correspond to the high density areas measured inside the sample.



Conclusion

- 2D X-ray radiography and 3D X-ray computed tomography highlight the presence of a density gradient in the porous alumina ceramics obtained by SPS. 2D radiography indicates a maximum average density in the median plane of the specimens. 3D-CT allows a full characterization of the density distribution that can be compared to the temperature field given by a numerical model.
- The temperature field and the density distributions are in a good agreement. This confirms the hypothesis according to which the density gradient mainly results from the sintering device and parameters.

Université de Mons | guillaume.jean@umons.ac.be | FPMs - Service de Science des Matériaux