Modelling Sintered Aluminum Fibers for Simulation of Heat Transfer

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Introduction

Using micro computed tomography we analyzed the microstructure of sintered aluminum fibers. The fiber sample is modelled by a Boolean model that is fitted to the original fiber structure by means of geometric characteristics estimated from the μCT image. Simulations in models with altered microstructure then allow to study the dependence of heat conductivity on the geometric structure of (zeolite-)coated fiber systems.

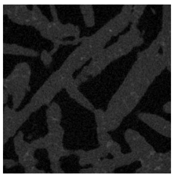

Figure 1: xy-slice of the uncoated structure.

Figure 2: xy-slice of binarization of the uncoated structure.

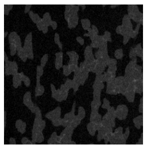

Figure 3: xz-slice of the uncoated structure.

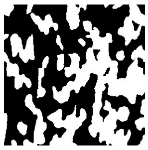

Figure 4: xz-slice of the binarization of the uncoated structure.

We analyzed a μCT image of an uncoated sintered fiber system with an image size of 300^3 voxel and a voxel size of 12.1μm.

The estimation of geometric characteristics of the fibers and the calculation of the granulometries were performed using the MAVI software package.

Model Description and Modelling

The fiber system is modelled by a Boolean model. Grains, here segments of hollow cylinder, are placed in centers generated by a Poisson point process. We gained kidney-like cross-sections (as observed in the real structure) by an adaptable morphological dilation. The coating is done via morphological dilation.

Model Parameters The free model parameters are the following:

- λ – the intensity of the point field
- α – cut out angle
- b – anisotropy parameter
- R_1, R_2 – bounds of radii of cylinder shells
- t – size of the structuring element for the coating

Model Fit The deviation of the model realizations from the fiber sample are measured by

$$D(s,m) = \sqrt{\sum_{i=1}^{n} \left(\frac{s-m}{s} \right)^2},$$

where s represents the vector of values derived from the sample and m represents the vector of the model. The length and the thickness of the fibers were fix as observed in the μCT image. The fitting of the model was done in two steps. We first fitted the volume fraction of the realizations, i.e. we gained 12 % of the 960 realizations that were suitable for the model w.r.t the volume fraction. In the second step we examined the specific surface area and the directional distribution of the surface normals of the realizations in the three main directions x, y, z.

The best model obtains the following parameters:

- $\lambda = 20.89mm^{-3}$ (intensity of the Poisson point process)
- $\alpha = 0.8$ (cut out angle)
- $R_1 = 12, R_2 = 15$ (radius uniformly distributed in $[R_1, R_2]$)
- $b = 5$ (anisotropy parameter)

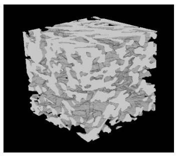

Figure 5: Visualization of the uncoated sintered fiber sample, porosity 50.3 %.

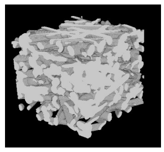

Figure 6: Visualization of a realization of a model for the uncoated structure, porosity 50.4%.

Estimation of Geom. Characteristics Derived from μCT Image and Model The following table gives an overview of certain geometric characteristics:

	uncoated fibers	model
specific surface	5107 mm^{-1}	4676.7 mm^{-1}
surface normals (x-direction)	3.5 %	5.5 %
surface normals (y-direction)	2.7 %	5.0 %
surface normals (z-direction)	16.8 %	19.4 %

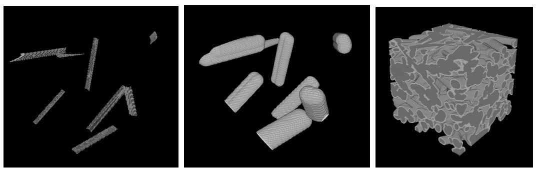

Figure 7: The initial fiber skeletons (left), the same fibers dilated by adaptable morphology (middle) and a coated, virtual sintered fiber system (right).

Conclusions

The model described here is useful to do first simulations on e. g. heat conductivity in sintered fiber systems. For doing more precise simulations it is necessary to consider more geometric characteristics of the sample like the roughness of the surface of the metal or the zeolite coating that consumes a volume share of the fibers.

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