Synthesis of Virtual Nonwoven, Cellulose Material and Patterned Structures

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GeoDict User Meeting 2012
Computer Aided Material Engineering

Lab

Porous Media
measure

Properties

CT Image

image

filter & segment

Voxel Mesh

Model

generate

compute

Properties

Tomograph

GEO DICT
Computer Aided Material Engineering

1. Validation:
   Model should mimic existing material

2. Virtual Lab:
   Create new materials
Cellulose Material (3D Tomography)

**Difficulties:**
- Curved fibers
- Non-circular profile and torsion
- Inhomogenous distribution

**Needed for?**
- Permeability
- Capillary pressure curve

*Annual Report ITWM, 2011*
Paper (SEM Images)

- Grammage: 60 g/m²
- Paper height: 200 μm

Difficulties:
- Non-circular profile
- Packed fibers

Needed for?
- Permeability
- Stability
Occam's Razor

What is an acceptable structure model, which simplifications are allowed?

- Accept overlapping fibers in the model?
  Permeability, Diffusivity: Yes
  Elastic properties, Conductivity: No

- Fill hollow fibers?
- Use mean value for fiber diameter or size distribution?
- Ignore inhomogeneities?
Cellulose Material (3D Tomography)

Simplifications:
- Ellipsoidal fiber profile
- Allow overlapping fibers

Need:
- Curved fibers
- Torsion
- Inhomogenous distribution

Annual Report ITWM, 2011
Resulting 3D Model

Annual Report ITWM, 2011
Curved Fibers

Idea: create curved fibres out of straight segments

Algorithm:
1. start with one segment
2. add segments until desired fibre length is reached
Curved Fibers

How to determine the direction of the next segment?
Many possibilities:
- keep previous direction + random deviation
- keep previous curvature + random deviation
- keep main fiber direction + random deviation
- anisotropy
Curved Fibers

Determine fiber direction $d_{n+1}$:

$$(d_{n+1} - d_n) - (d_n - d_{n-1}) = G_\sigma(0) - \alpha(d_n - d_{n-1}) - \beta(d_{n} - d)$$

$\alpha = 0, \beta=0$ : keep previous curvature
$\alpha = 1, \beta=0$ : keep direction

$\alpha=1, \beta=1$: keep main direction:  
$$d_{n+1} = G_\sigma(0) + d$$

(then normalize $d_{n+1}$)

Full 3D anisotropy would be:  
$\alpha, \beta, \sigma \in R^{3\times3}$  
Used in GeoDict:  
$\alpha, \beta, \sigma \in R^3$ (~diagonal matrices)

$\alpha$: straightness
$\beta$: force
$\sigma$: randomness
Curved Fibers

Inhomogeneous distribution?
Inhomogeneities

1. Create mask with SinterGeo
2. Use 'On current structure' in FiberGeo
3. Use LayerGeo:Add

(For realistic structure: mask should contain more than one object)
Paper (SEM Images)

- Grammage: 60 g/m²
- Paper height: 200 mm

Need additionally:
- Non-overlapping fibers, but dense packing
PaperGeo Model (with Overlap)

- Realistic cellulose fibers (dark gray)
- Fines attached to the fibers (light gray)
- Grammage: 50 g/m²
- Paper height: 160 mm
- Fiber Overlap
Paper Lay-Down (without Overlap)

Fiber lay-down on a forming fabric (modeled with WeaveGeo).
(a): 10 g/m². (b): 20 g/m². (c): 60 g/m². (d): The resulting paper-layer.
Summary

Presented features:
- Curved fibers
- Inhomogeneous structures
- Lay-down of fibers (PaperGeo)

Upcoming features (2012R2):
- FiberGeo: fiber bundles
- FiberGeo: arbitrary fiber cross sections
- PaperGeo: faster lay-down algorithm
- PaperGeo: improved user interface
... and Patterned Structures

GridGeo:
- Perforated foils
- Parallel cylinders
- Predefined grid of spheres

New in upcoming 2012 R2:
- User defined grid
Thank you!