Material Models and Property Prediction based on CT-Scans

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Introduction

1. General approach to computer aided material engineering

2. Examples
   - Knitted wire meshes
   - Woven metal wire meshes
Aim: Computer Aided Material Engineering

Lab

Porous Media
Composite
Material
Aim: Computer Aided Material Engineering

Lab

Porous Media Composite Material

measure

Properties

Properties are:
- pore size distribution
- permeability
- diffusivity
- capillary pressure curve
- ...

[Diagram of porous media composite material]

[Image of porous media composite material]
Aim: Computer Aided Material Engineering

Properties are:
- pore size distribution
- permeability
- diffusivity
- capillary pressure curve
- ...

Lab

Porous Media Composite Material

manufacture
next material

measure

Properties
Aim: Computer Aided Material Engineering

Properties are:
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- permeability
- diffusivity
- capillary pressure curve
- ...

Lab

Porous Media Composite Material

measure

Properties

 manufacture
next material

Computer

Model

<Object1>
  Color 2
  NumberOfSegments 1
  <Point1>
    Coordinates 0,0,1
    Radius 0.25
  </Point1>
  <Point2>
    Coordinates -1,0,0
    Radius 0.25
  </Point2>
  RoundedEnd 0
  Type CircularFiber
</Object1>
Aim: Computer Aided Material Engineering

Properties are:
- pore size distribution
- permeability
- diffusivity
- capillary pressure curve
- ...

Lab

- Porous Media
- Composite
- Material

measure

Properties

Computer

- Model
- generate
- Voxel
- Mesh

manufacture
next material
Aim: Computer Aided Material Engineering

Properties are:
- pore size distribution
- permeability
- diffusivity
- capillary pressure curve
- ...

Lab

Porous Media Composite Material

measure

Properties

manufacture next material

Computer

Model

generate

Voxel Mesh

compute

Properties
Aim: Computer Aided Material Engineering

Properties
- pore size distribution
- permeability
- diffusivity
- capillary pressure curve
- ...

Lab
- manufacture
- next material
- measure
- Properties

Computer
- Model
- generate
- Voxel Mesh
- compute
- Properties
- try next set of parameters
Aim: Computer Aided Material Engineering

Properties

Model

Voxel Mesh

compute

properties

Model

generate

Voxel Mesh

Properties

Computer

Lab

Porous Media Composite Material

measure

Properties

manufacture

next material

Properties are:
• pore size distribution
• permeability
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• capillary pressure curve
• ...

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Validation - Step 1: Property Computations

Porous Media Composite Material

measure

Properties
Validation - Step 1: Property Computations

- Porous Media Composite Material
- CT Image
- Properties

Diagram:
- Porous Media Composite Material
  - image
  - measure
  - Properties

流程图说明了从多孔复合材料到CT图像和最终属性的计算过程。
Validation - Step 1: Property Computations

- **Porous Media Composite Material**
  - Measured properties

  - CT Image
    - Filter & segment
      - Voxel Mesh

  - Properties
Validation - Step 1: Property Computations

- Porous Media Composite Material
- CT Image
  - filter & segment
  - Voxel Mesh
    - compute
      - Properties

- measure
- image
- Properties
Validation - Step 1: Property Computations

Porous Media Composite Material → CT Image → Voxel Mesh

measure → [image] → filter & segment → compute → compare

Properties → Properties
Validation - Step 1:

Property Computations
... and image acquisition
... and image processing
... and measurements

Porous Media
Composite Material

measure

CT Image

filter & segment

Voxel Mesh

compute

Properties

image

Properties

... and image acquisition
... and image processing
... and measurements
Validation - Step 2: Material Models

CT Image

filter & segment

Voxel Mesh

compute

Properties

Model
Validation - Step 2:

Material Models

- CT Image
  - filter & segment
  - Voxel Mesh
    - compute
    - Properties

- Model
  - generate
  - Voxel Mesh
Validation - Step 2:

Material Models

CT Image
- filter & segment
- Voxels Mesh
- compute
- Properties

Model
- generate
- Voxels Mesh
- compute
- Properties
Validation - Step 2: Material Models

CT Image
  filter & segment
  Voxel Mesh
  compute
  Properties

Model
  generate
  Voxel Mesh
  compute
  Properties

compare
Computer Aided Material Engineering with GeoDict

Porous Media Composite Material

image

CT Image

model

Voxel Mesh

filter & segment
generate

compute

Properties

Properties
Computer Aided Material Engineering with GeoDict

Lab

Porous Media Composite Material

image

CT Image

filter & segment

Voxel Mesh

generate

Model

compute

Properties

Properties
Computer Aided Material Engineering with GeoDict

Lab

Porous Media Composite Material

image

CT Image

filter & segment

generate

Voxel Mesh

compute

Properties

Model

Properties

Tomograph
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Lab

Porous Media Composite Material

image

CT Image

filter & segment

generate

Model

Voxel Mesh

compute

Properties

Properties

Tomograph

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Computer Aided Material Engineering with GeoDict

Lab

Tomograph

GEO

DICT

Porous Media Composite Material

CT Image

Model

Voxel Mesh

Properties

Properties

manufacture next material

measure

image

filter & segment

generate

compute

try next set of parameters
Computer Aided Material Engineering with GeoDict

Lab

Porous Media Composite Material

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Properties

Tomograph

CT Image

image

filter & segment

generate

Model

Voxel Mesh

compute

Properties

GEO DICT

engineer

next material

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The GeoDict Software

**GEOmetry**
- CT Image
- Nonwoven Model
- Sintered Structures Model

**preDICTions**
- Permeability
- Diffusivity
- Capillary Pressure

...
Knitted Wire Meshes: Geometry-Based Property Analyses

(a): CT-scan of a knitted wire mesh.
(b): Largest through pore.
(c): Bubble point pressure in dependency of the contact angle.
(d): Pore size distribution.
Knitted Wire Meshes: Partial-Differential-Equation-Based Property Analyses

(a): Visualisation of the flow field in a CT-scan of a knitted wire mesh.
(b): Velocity dependent pressure drop of three knitted wire meshes.
Woven Metal Wire Meshes: Geometric Validation

Woven Metal Wire Meshes: Measurement and Simulation

Comparison: GeoDict and Measurement

Velocity dependent pressure drop: Comparison between measurements and simulations on corresponding geometry models.
Woven Metal Wire Meshes: Complex weave models

Left: Model of a two-layer weave based on a CT-scan.
Right: Model of a complex one-layer twill Dutch-weave.
Summary Part I

Models:
- CT Images
- Fibrous nonwovens
- Woven structures
- Sintered structures
- Sphere packings
- Layered structures

Properties:
- Pore size distribution
- Surface area
- (Knudsen) Diffusivity
- Permeability
- Electric conductivity
- Heat conductivity
- Capillary pressure curve
- Bubble point
- Relative (= saturation dependent) permeability
- Relative (= saturation dependent) diffusivity
- Filter efficiency and life time
Summary Part II

Knitted Wire Meshes:
- property analyses on CT-scans

Woven Metal Meshes:
- model validation based on CT-scans
Thank You!

Geometry generator, property predictor and virtual material designer

www.geodict.com