Modeling Carbon Fiber Composite Microstructures Using Optical Microscopy

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- Dr. Ray Fertig III – Faculty Advisor
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Presentation Overview

- Background
- Project Overview
- MATLAB Analysis
- Abaqus Analysis
- Conclusions
- Future Work

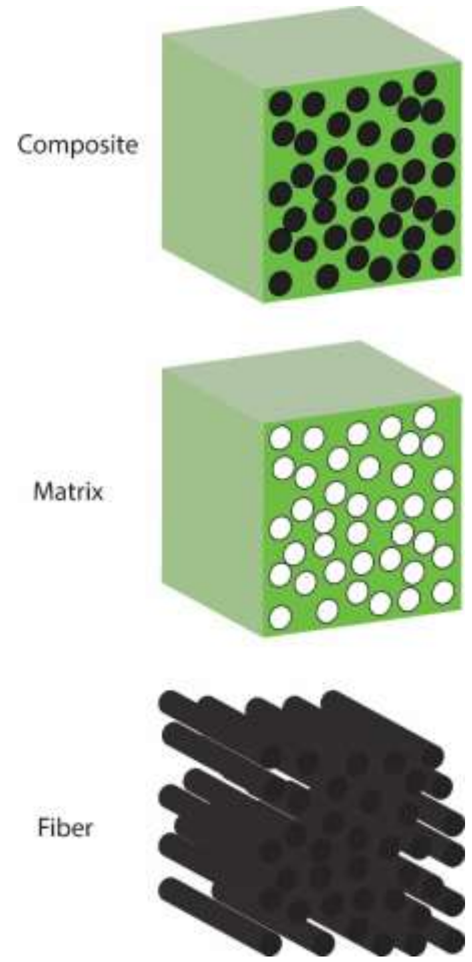
Background - Motivation

- Composites desirable for use in aerospace, wind energy, and sporting goods
- Clear understanding of material properties critical to safety
- Ability to model 3D microstructures for comparison with actual broken specimens is desirable

Steve Georgiadis , Andrew J. Gunnion , Rodney S. Thomson , Bruce K. Cartwright
Bird-strike simulation for certification of the Boeing 787 composite moveable trailing edge
Composite Structures Volume 86, Issues 1–3 2008 258 - 268
http://dx.doi.org/10.1016/j.compstruct.2008.03.025

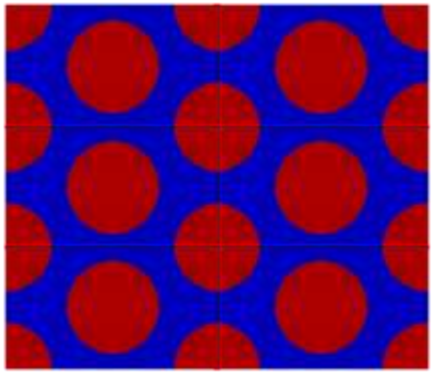
Background - Composites

- Usually consist of high stiffness fibers in low stiffness matrix
- Primary focus on carbon fibers in epoxy matrix
- Fiber-volume fraction common characterization

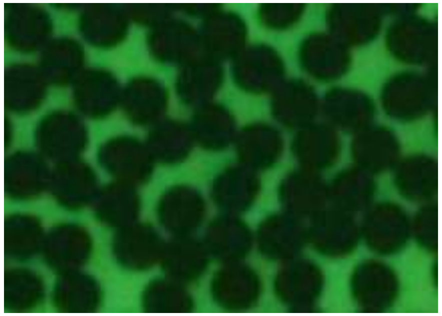


Background – Ideal vs Actual

- Ideal Microstructure
  - Hexagonal packing
  - Uniform FVF
- Actual Microstructure
  - Semi-random packing
  - Varied FVF
  - Defects
    - Voids
    - Alignment Fibers



Ideal microstructure



Actual microstructure

Project Overview

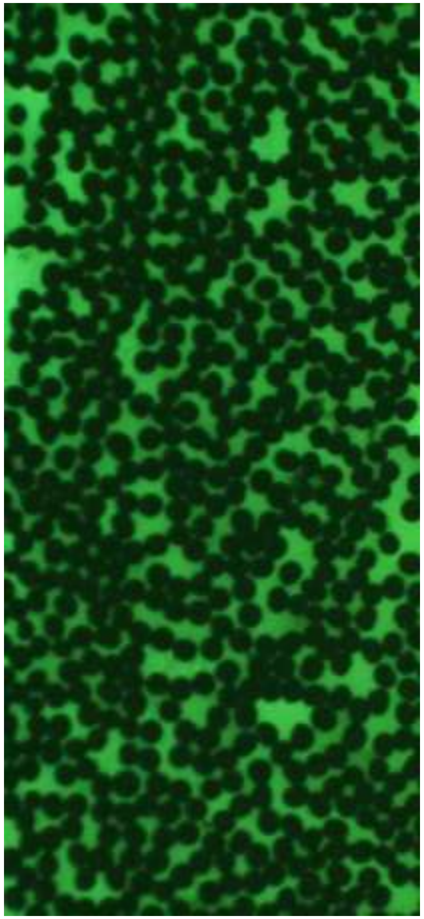
Toolbox construction

- MATLAB image analysis
  - Fiber volume fraction
  - Abaqus™ input files
- Abaqus™ modeling
  - 3D model from 2D images
  - Actual microstructures

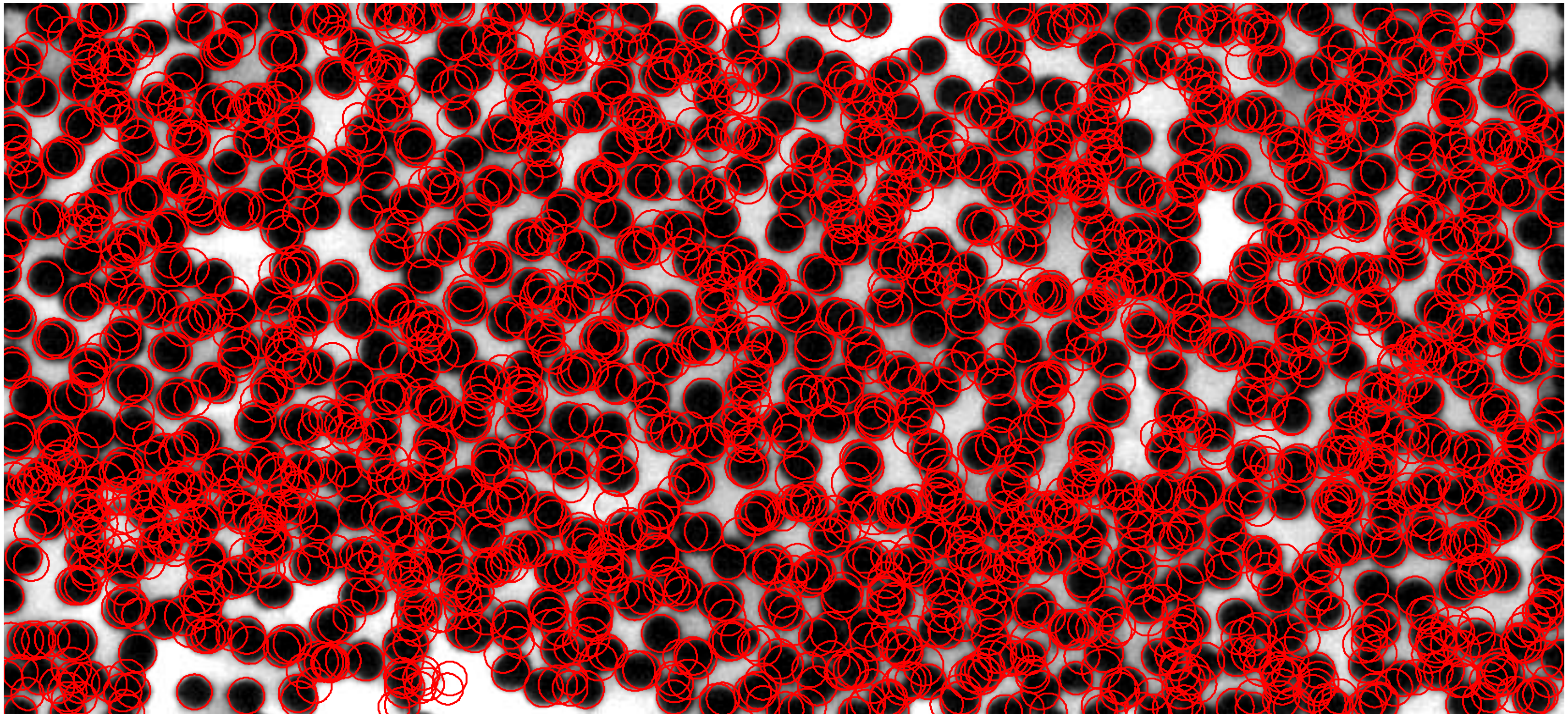
http://commons.wikimedia.org/wiki/File%3AMatlab_Logo.png
http://commons.wikimedia.org/wiki/File%3ALogo_Dassault_Systemes.jpg

MATLAB – Circle Detection

- Pre-processing:
  - Greyscale
  - Intensity adjustment
- Processing:
  - Circular Hough Transform
  - Cleanup algorithms
  - Manual adjustment

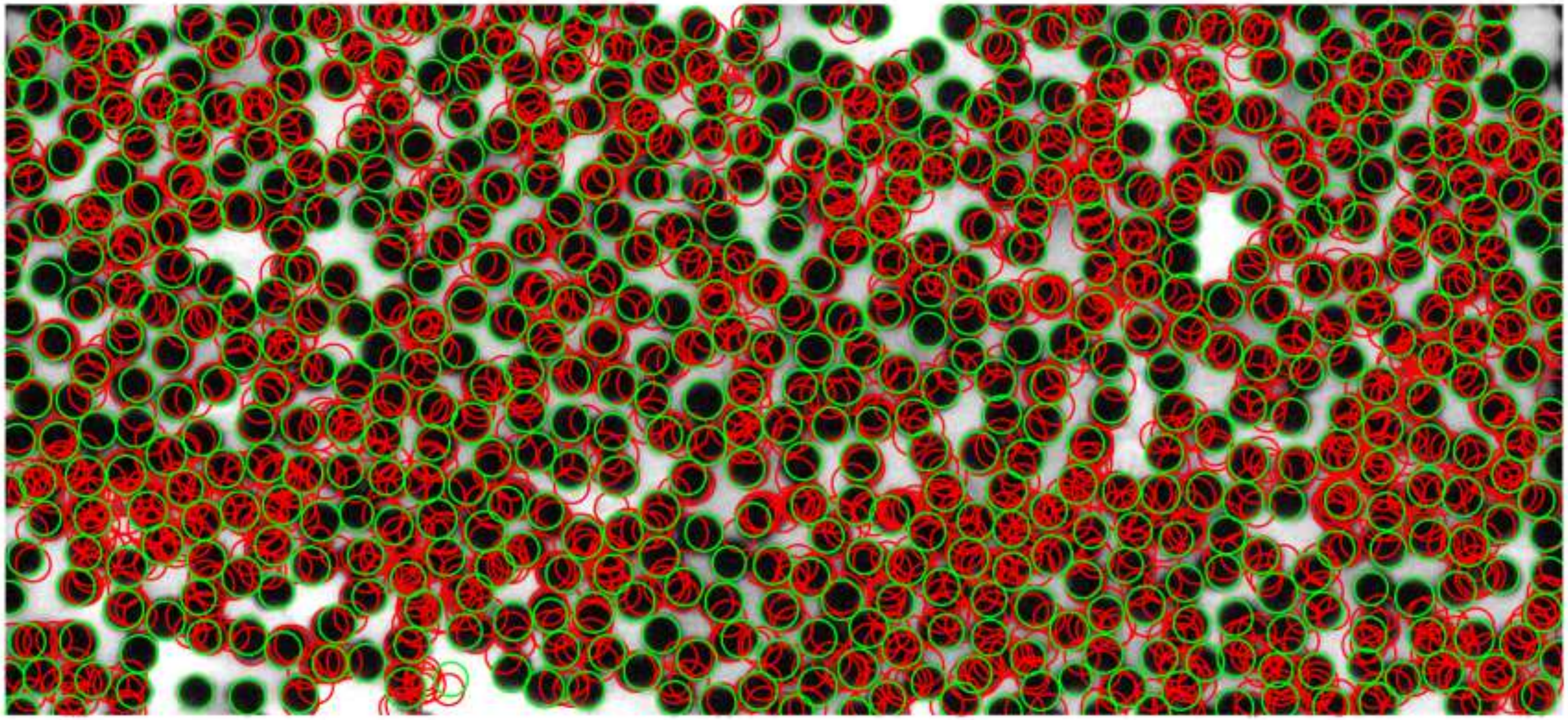


MATLAB – Hough Transform



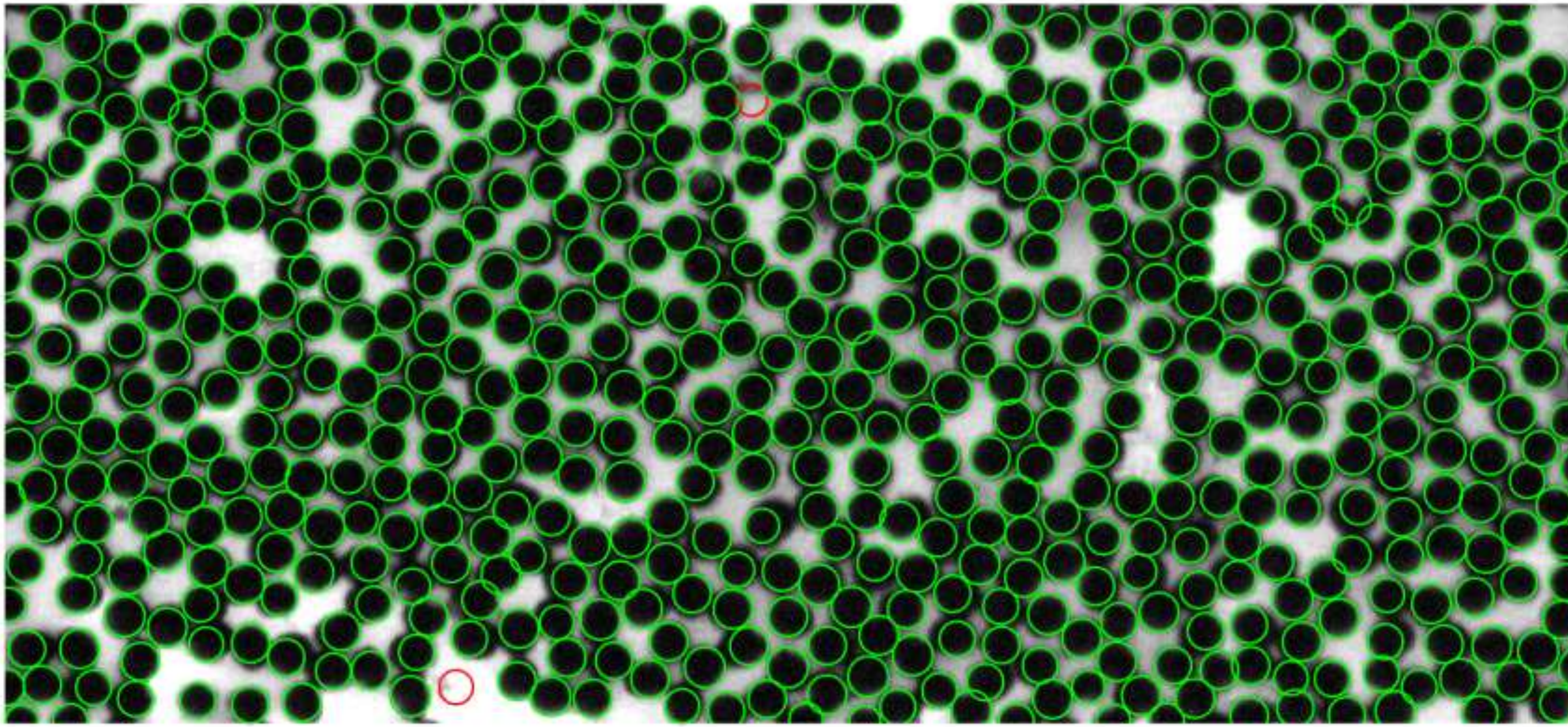
Raw *imfindcircles* results

MATLAB – Algorithm 1



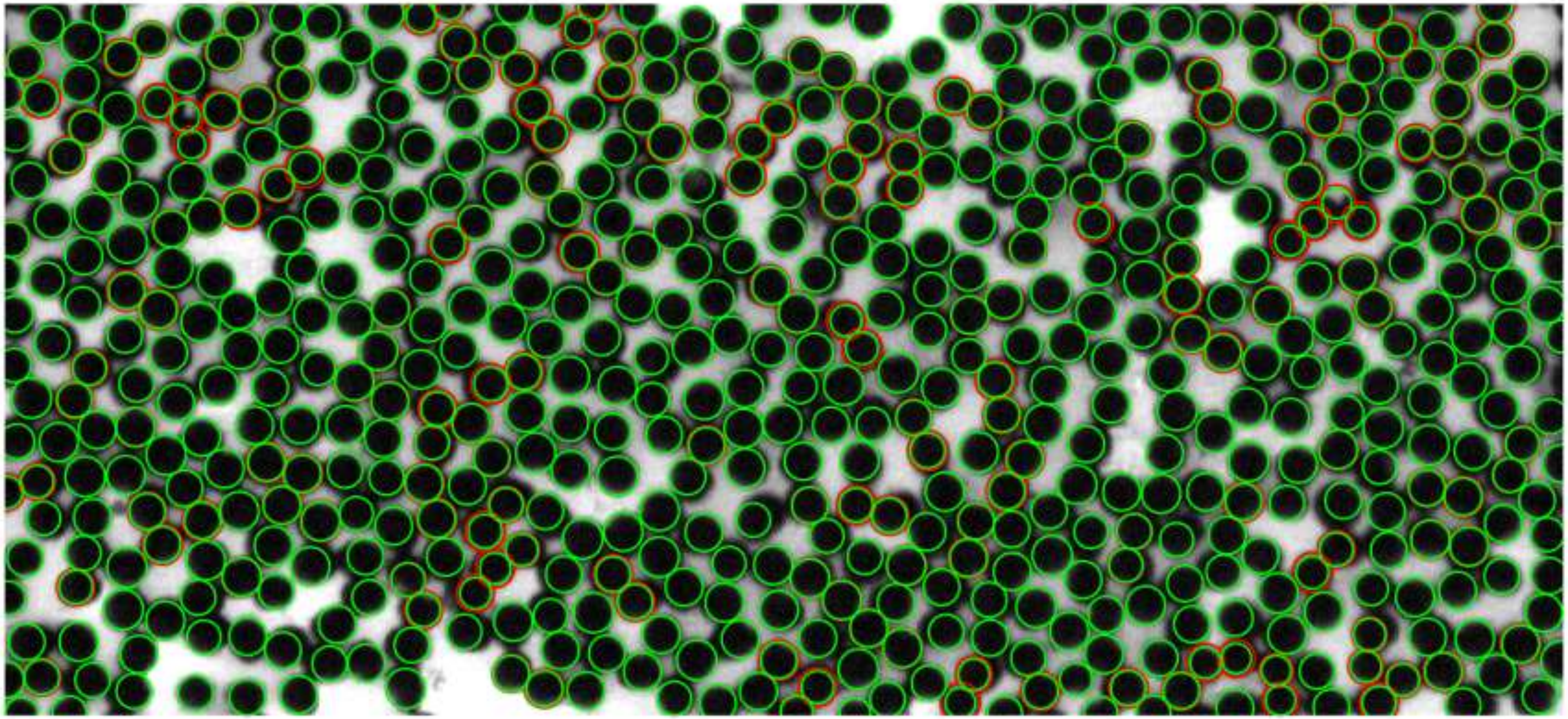
Remove concentric circles

MATLAB – Algorithm 2



Remove matrix circles

MATLAB – Algorithm 3

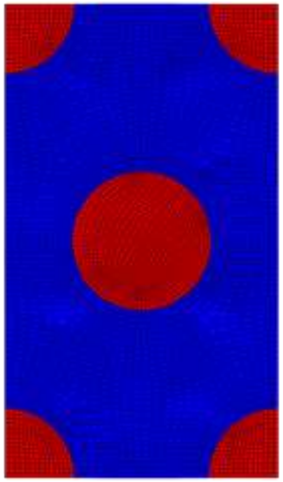


Shrink touching circles

MATLAB – Fiber Volume Fraction

- Areal Method
  - Actual circle diameters
  - Requires high resolution
- Fiber Count
  - Based on nominal fiber diameter
  - More accurate
  - Works with lower magnification

30%



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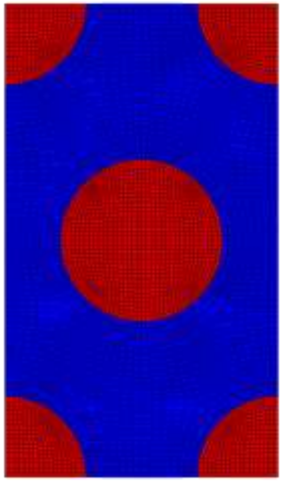
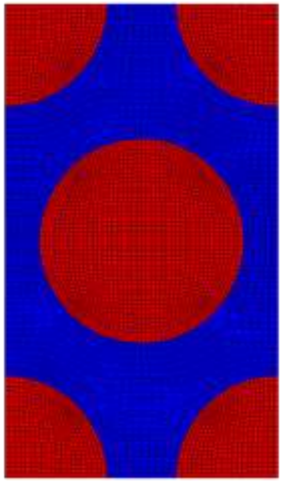
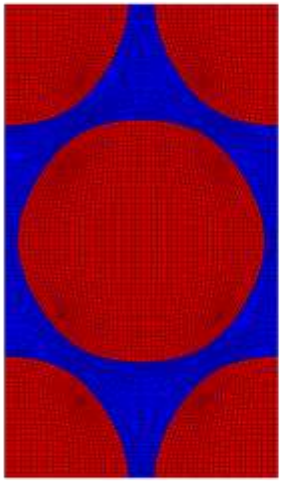


60%

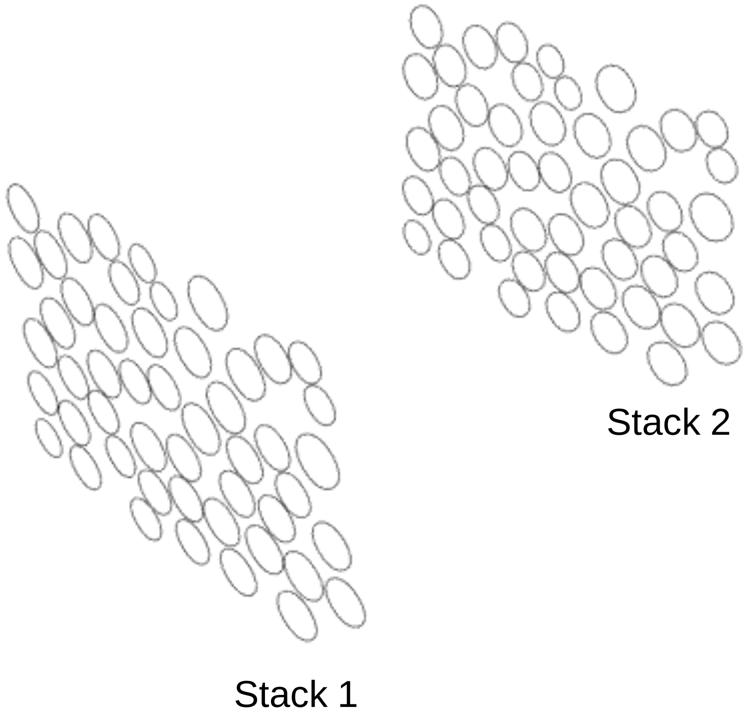


80%



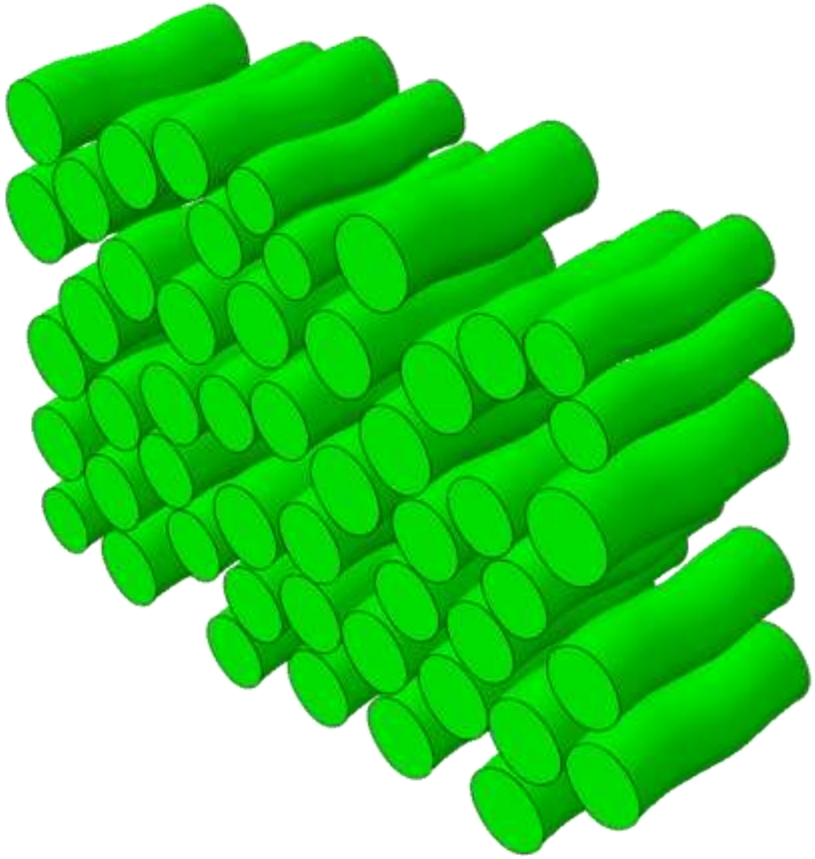
MATLAB – Abaqus Input Data

- Append to text file
  - Center location
  - Radii
- Multiple stacks written to same file
- Ordered by nearest neighbor comparison

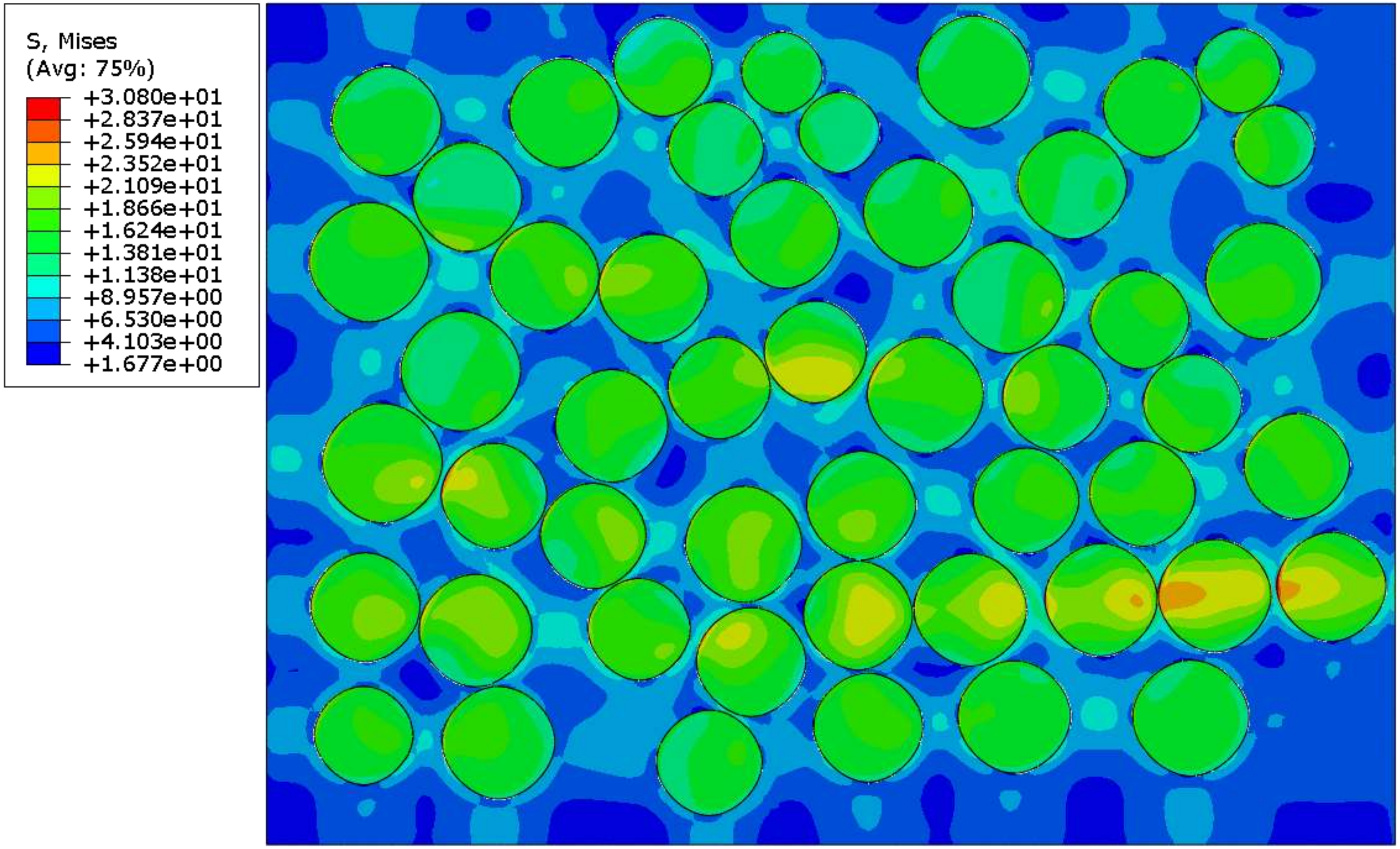


Abaqus – Model Generation

- Read text file
- Create wireframe
- Loft sections
- Generate mesh
- Create constraints



Abaqus – Results



Conclusions

- Toolbox creation successful
  - Working framework for future expansion
  - Accurate measurement of FVF achieved
- Interesting observations
  - Non-uniform stresses
  - Stress concentrations due to fiber arrangement

Future Work

- Code
  - Change shrinking algorithm
    - Change criterion
    - Add shifting
  - Improve edge handling
  - More robust circle ordering mechanism
  - Efficiency improvements
  - Implement interface
- Lab Work
  - Actual Specimen

Questions?