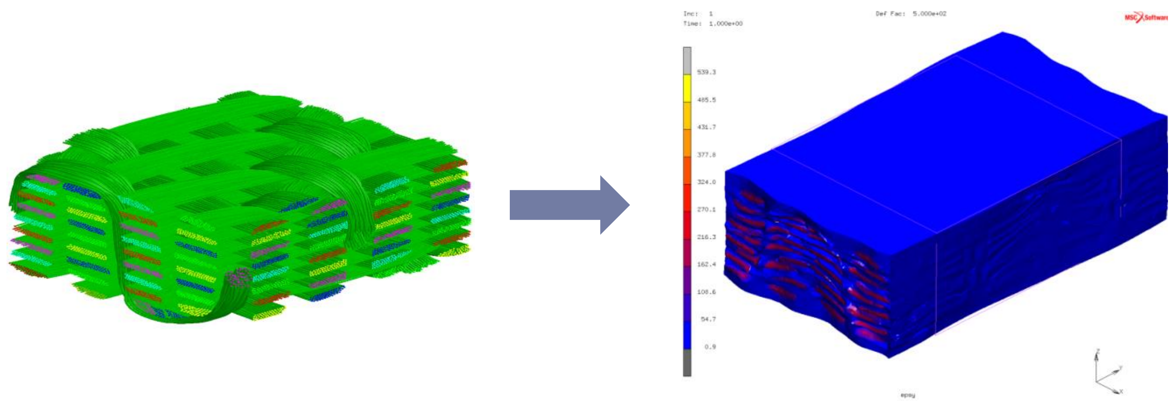
Modeling of 3D woven composites



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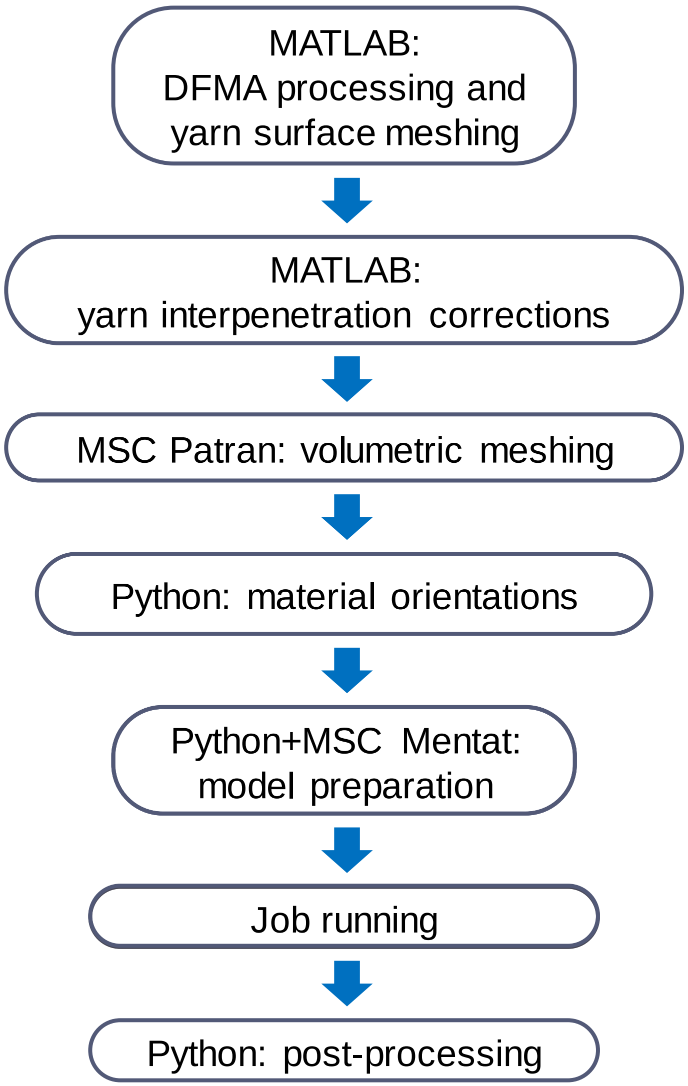
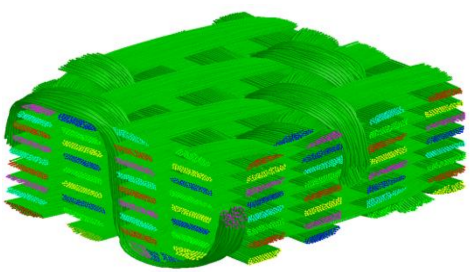
Model preparation steps

- Simulations in DFMA
- Export from DFMA and surface meshing
- Yarn interpenetration correction
- Volumetric meshing of a unit cell
- Assignment of material properties and orientations
- Assignment of boundary conditions
- Creation of loadcases
- Running the jobs
- Post-processing

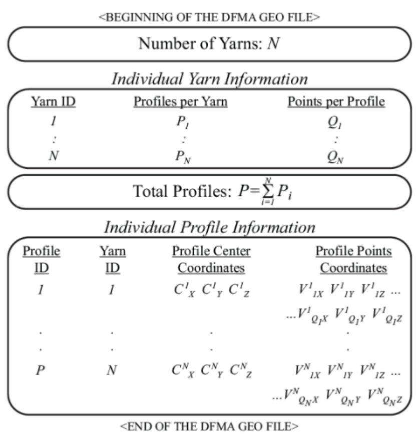


Processing of DFMA GEO file

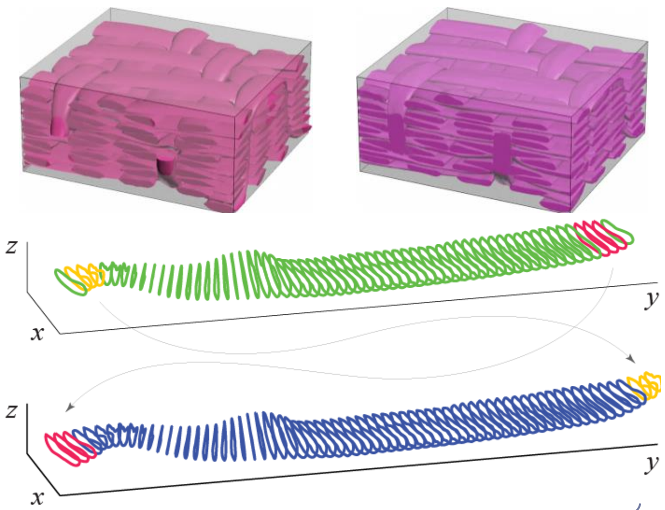


DFMA

GEO File



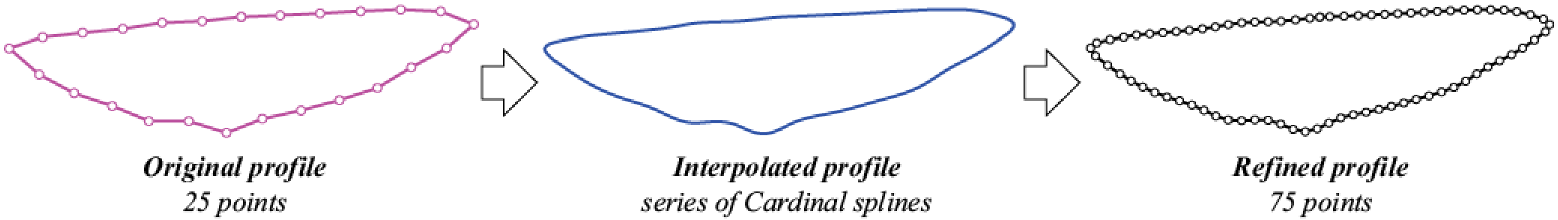
Yarn extension

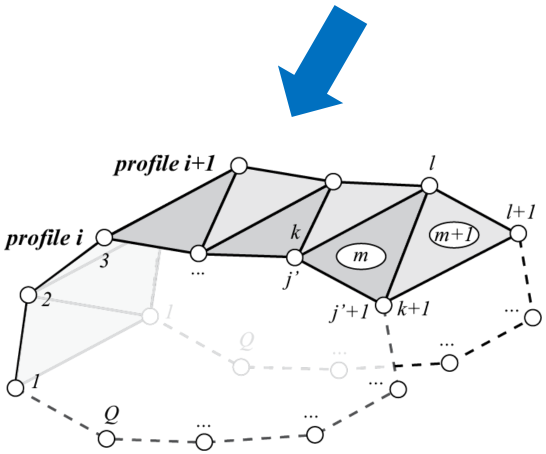


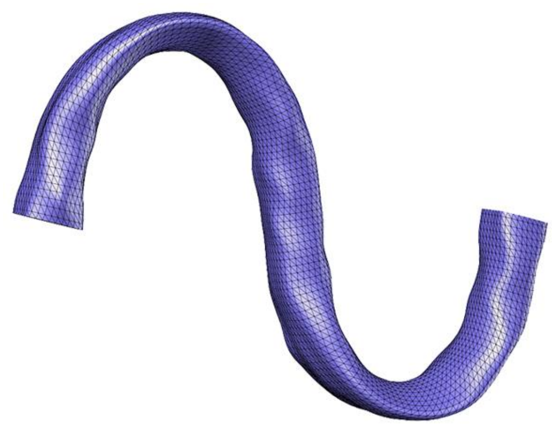
Matlab

Processing of DFMA GEO file

Profile re-discretization (for mesh sensitivity studies)





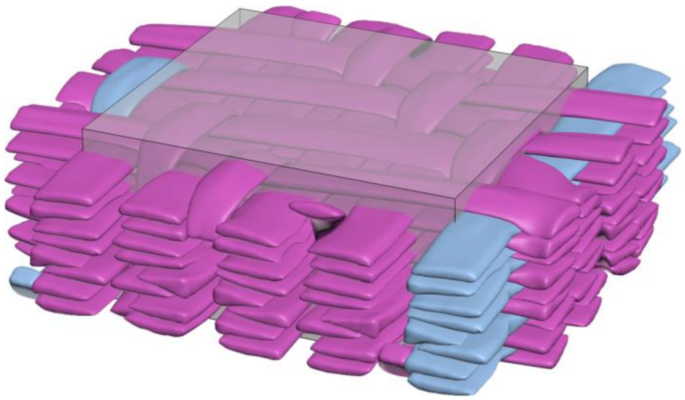


Meshing

Final yarn surface mesh

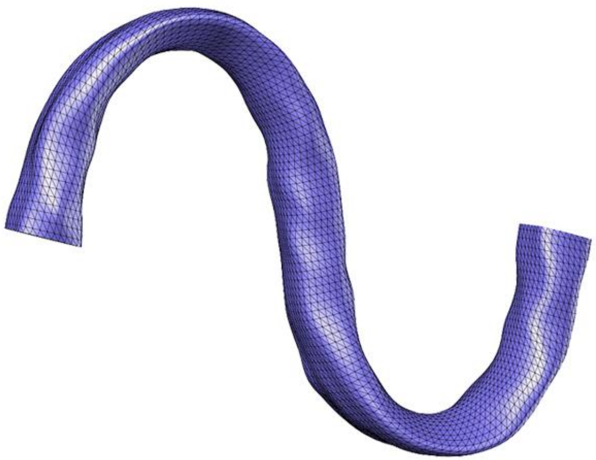
Matlab

Yarn duplication

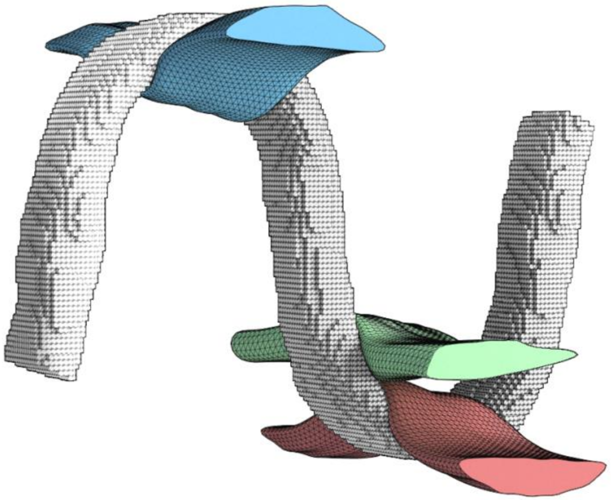


Unit cell with additional yarns to ensure that opposite faces have the same geometry

Penetration **identification** and **correction**



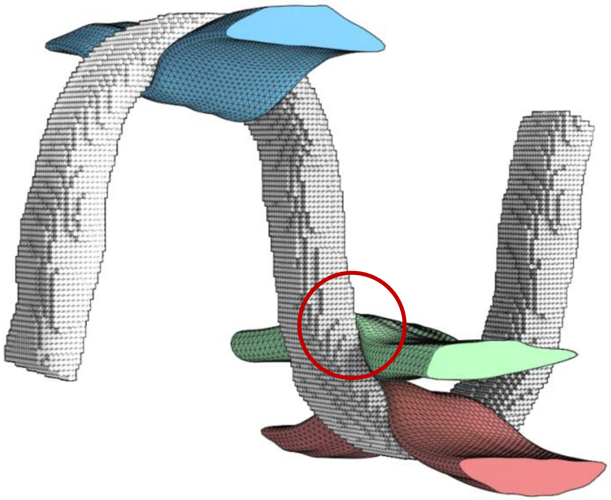
Surface mesh of the “host” yarn

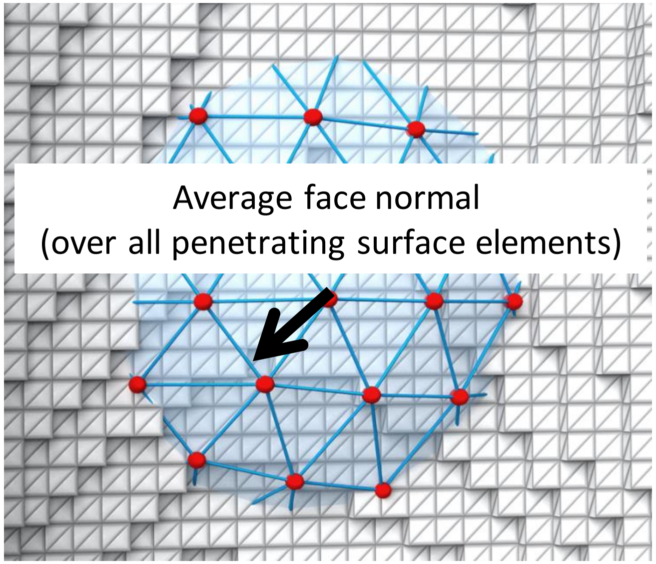


Voxel representation of the “host” yarn

Matlab

Penetration **identification** and **correction**



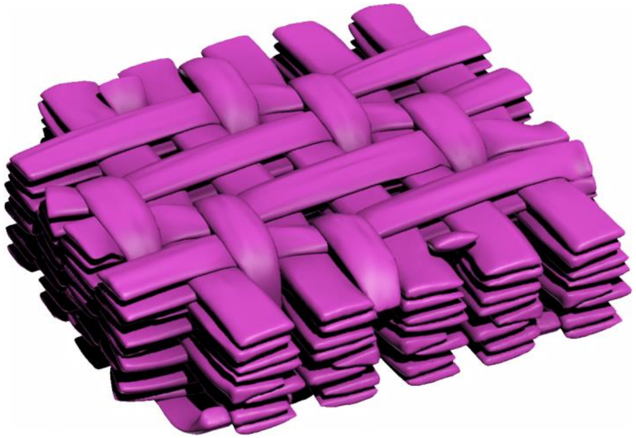


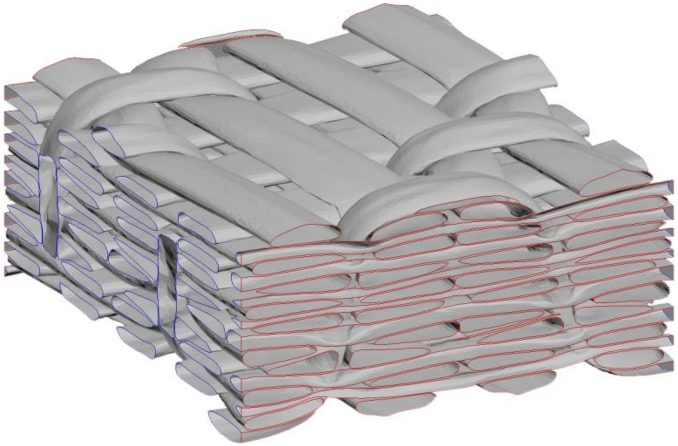
Voxel representation of the “host” yarn

Penetrating vertices inside the “host” yarn

Matlab

Yarn cutting to unit cell dimensions

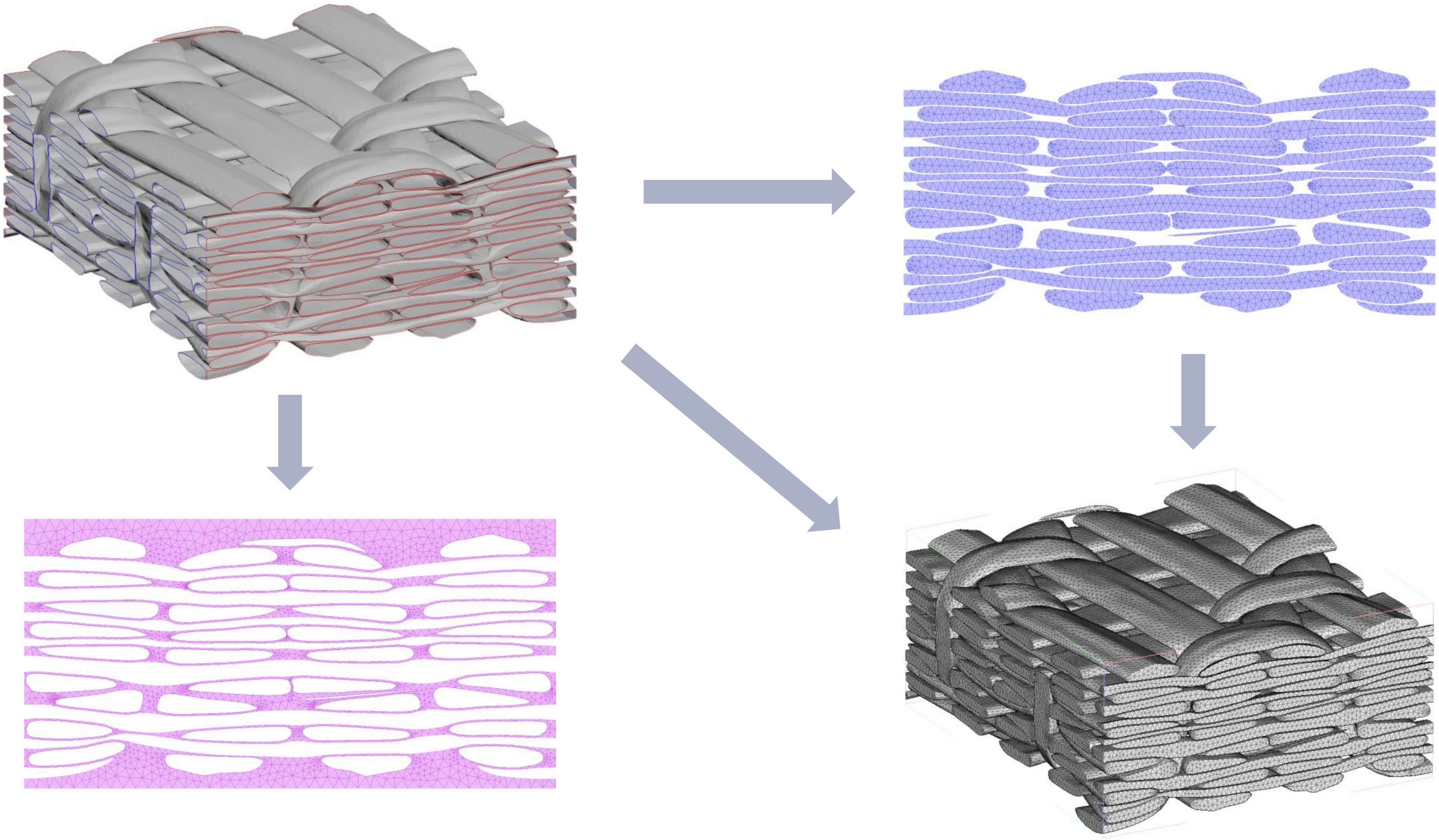




Matlab

Unit Cell Side Mesh

Meshing of yarn end caps and unit cell sides was done in MSC Mentat

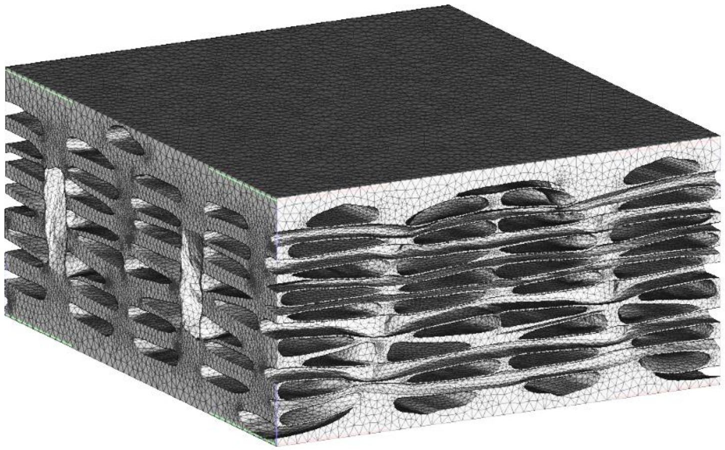


Final Mesh

3D mesh based on surface meshes was created in MSC Patran. Yarn and matrix mesh were combined and assigned material properties in MSC Mentat

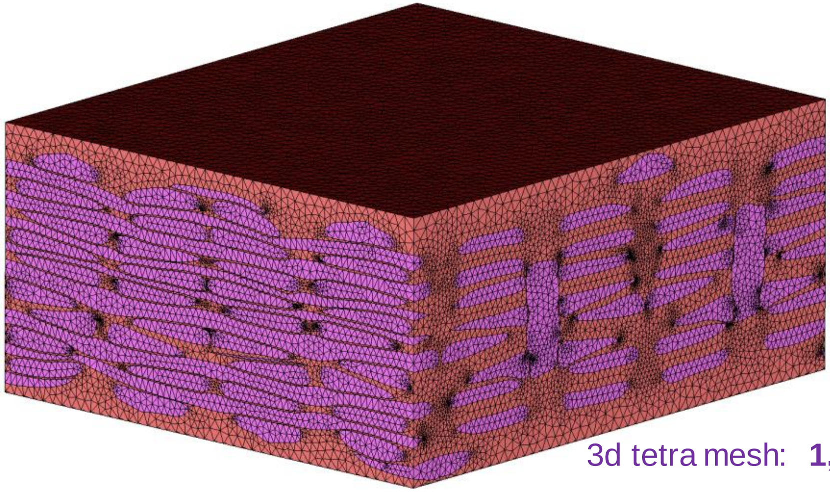
Tri surface mesh: **373,702** elms

3d tetra mesh: **1,034,283** elms



Tri surface mesh: **388,068** elms

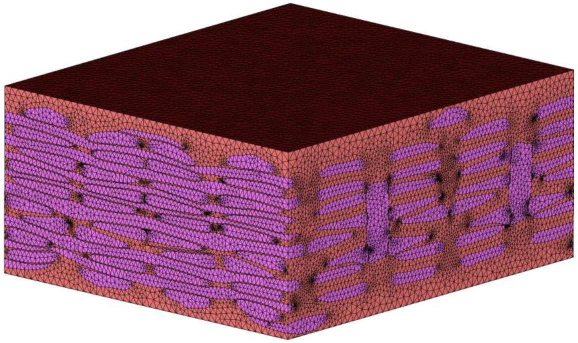
3d tetra mesh: **843,040** elms



3d tetra mesh: **1,877,323** elms

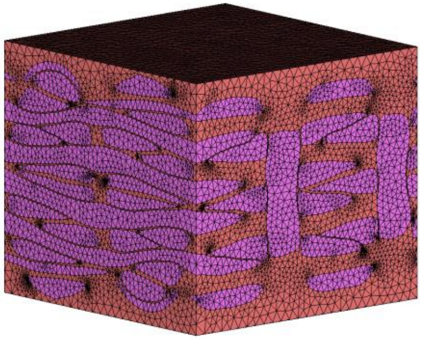
Several Configurations Meshed and Ready

2x2 Orthogonal



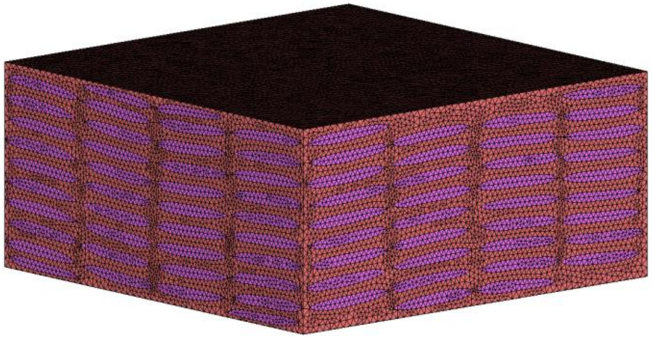
3d tetra mesh: **1,877,323** elms

1x1 Orthogonal



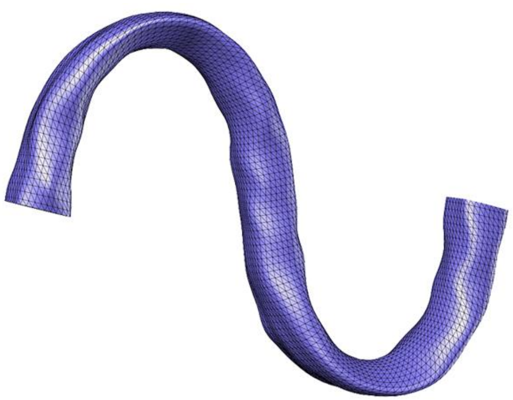
3d tetra mesh: **629,156** elms

Ply to Ply

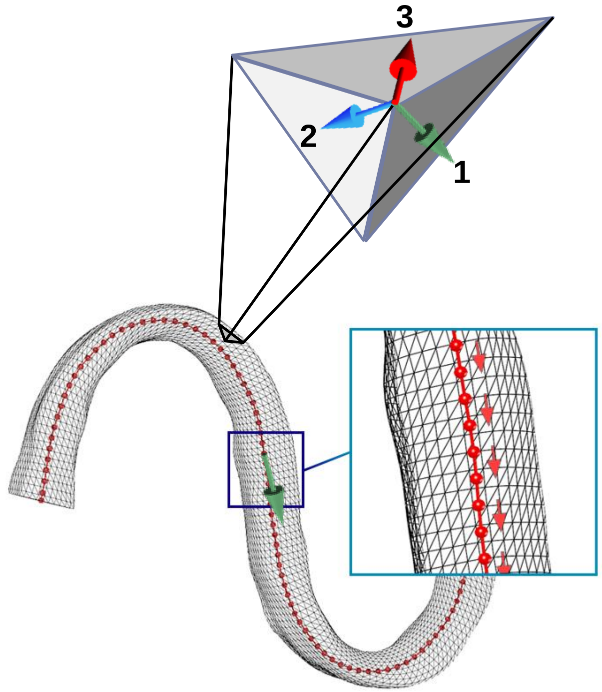


3d tetra mesh: **1,725,788** elms

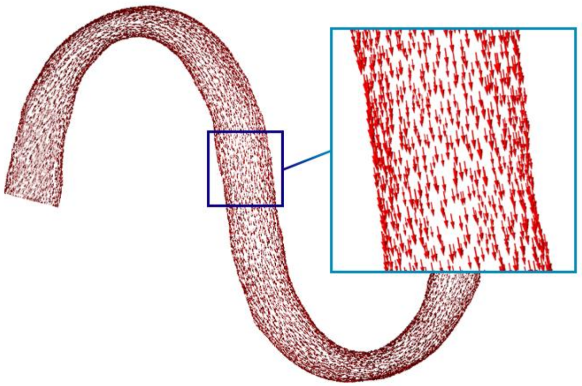
Material orientations



Yarn meshed with
3d elements

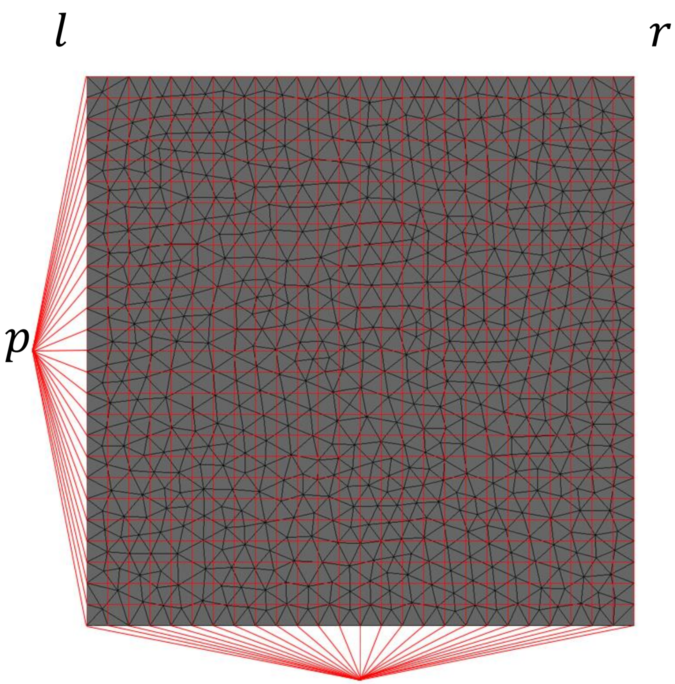


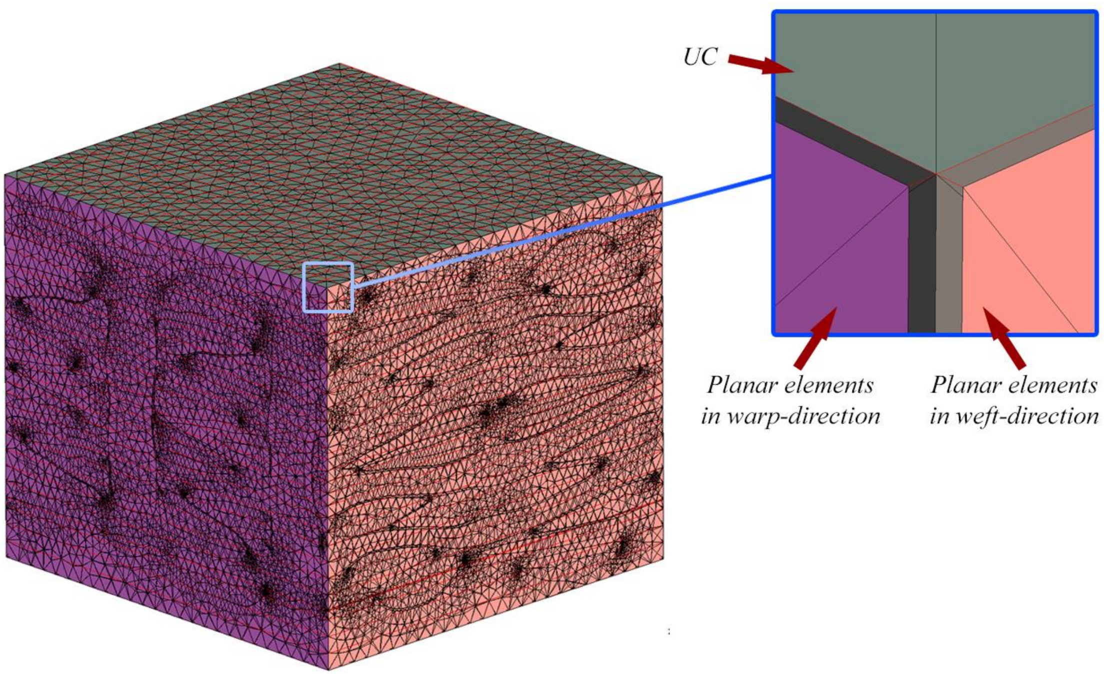
Center line of the yarn
(from point cloud processing)



Major orientations (1st direction)
for all elements of the yarn

FEA Simulations. Boundary conditions





$$\underline{u}_r - \underline{u}_l = u_p \underline{1}$$
$$\underline{v}_r - \underline{v}_l = v_p \underline{1}$$
$$\underline{w}_r - \underline{w}_l = w_p \underline{1}$$

- van der Sluis et al. (2000), Mechanics of Materials
- Trias et al. (2006), Computational Materials Science

Effective properties of different architectures

all three are shown without matrix

2x2 Orthogonal

3d tetra mesh: **1,877,323** elms

1x1 Orthogonal

3d tetra mesh: **1,701,378** elms

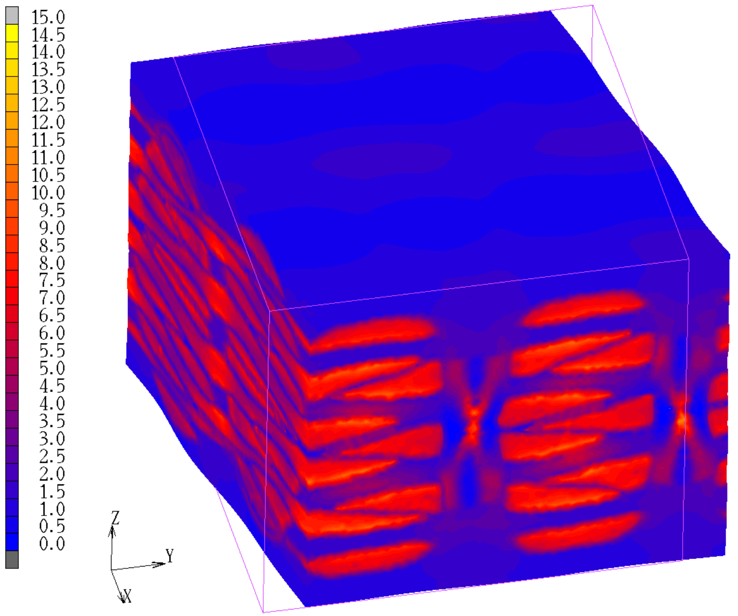
Ply to Ply

3d tetra mesh: **1,725,788** elms

Model	E_1, GPa	E_2, GPa	E_3, GPa	ν_{12}	ν_{13}	ν_{23}
2x2 (V_F = 0.62)	54.0	69.2	7.5	0.047	0.526	0.468
1x1 (V_F = 0.67)	60.5	56.1	8.7	0.061	0.469	0.558
P2P (V_F = 0.64)	63.2	69.4	7.0	0.084	0.499	0.495

Mesh sensitivity study. 1x1 orthogonal

	Base	Quadratic	Refined	Reduced
Elements, $x10^6$	2.39	2.39	19.1	2.31
Nodes, $x10^6$	0.41	3.23	3.23	0.39
Mesh type	4-node linear tetrahedron	10-node quadratic tetrahedron	4-node linear tetrahedron	4-node linear tetrahedron
Domains	1+3	1+3	1+7	1+3
Memory, GB	12.0	40.4	85.5	11.6
CPU time, s	128	937	745	129
Actual time, s	208	1,242	2,220	199
% CPU	62	75	33	65



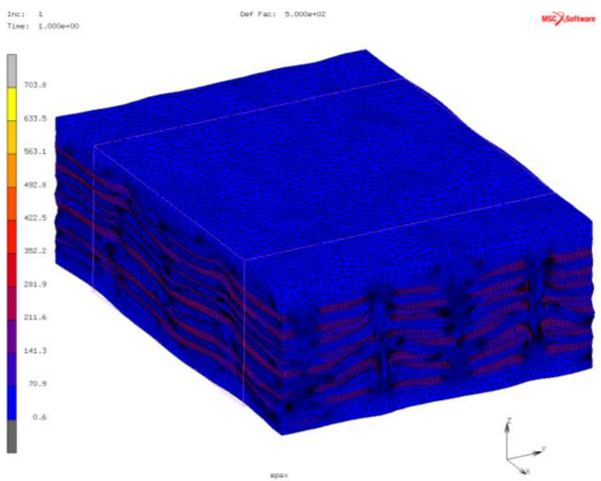
Elastic constant	Model			
	Base (0.66)	Quadratic	Refined	Reduced (0.58)
E_x	58.3	56	55.7	52.0 (-10.8%)
E_y	54	50.8	50.2	47.5 (-12.0%)
E_z	8.42	7.96	8.5	7.74 (-8.1%)
ν_{yz}	0.578	0.601	0.569	0.557 (-3.6%)
ν_{zx}	0.070	0.072	0.075	0.071 (1.4%)
ν_{xy}	0.062	0.060	0.063	0.065 (4.8%)
G_{yz}	1.61	1.41	1.52	1.51 (-6.2%)
G_{zx}	1.95	1.72	1.87	1.83 (-6.2%)
G_{xy}	4.01	3.85	3.79	3.50 (-12.7%)

Deformed Mesh

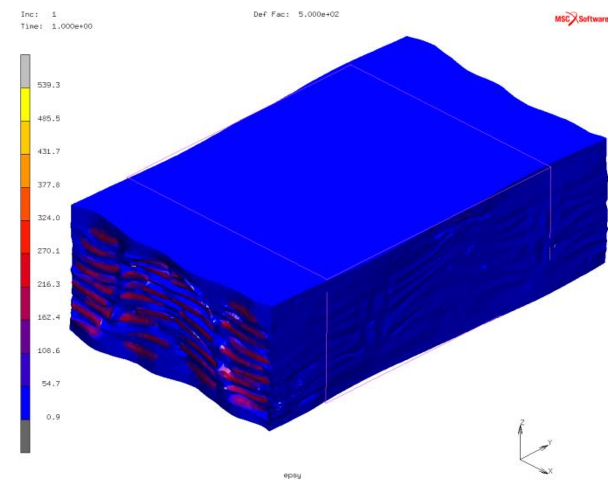
2x2 Orthogonal

X-,Y-,Z- strains of 0.001, def. factor 500, units MPa. Autoscale Von-Mises

X:



Y:



Z: