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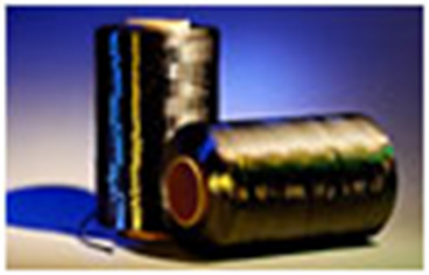
Application of High Performance Computing for Numerical Simulation of Fracture of Fiber Reinforced Composite Materials

Takeaki Nadabe

University of Tokyo

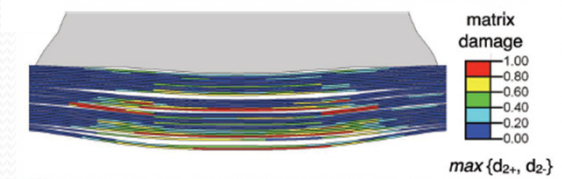
Background

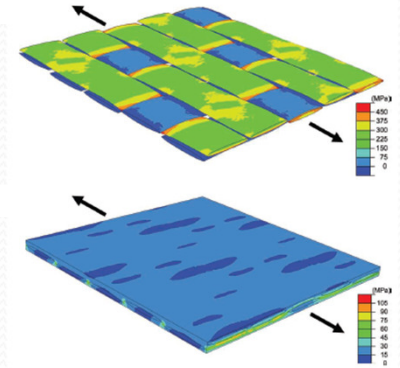
- Application of composite materials in several industrial fields.



Necessity of analysis for mechanical response of materials increases.

- Improvement of computational capability.

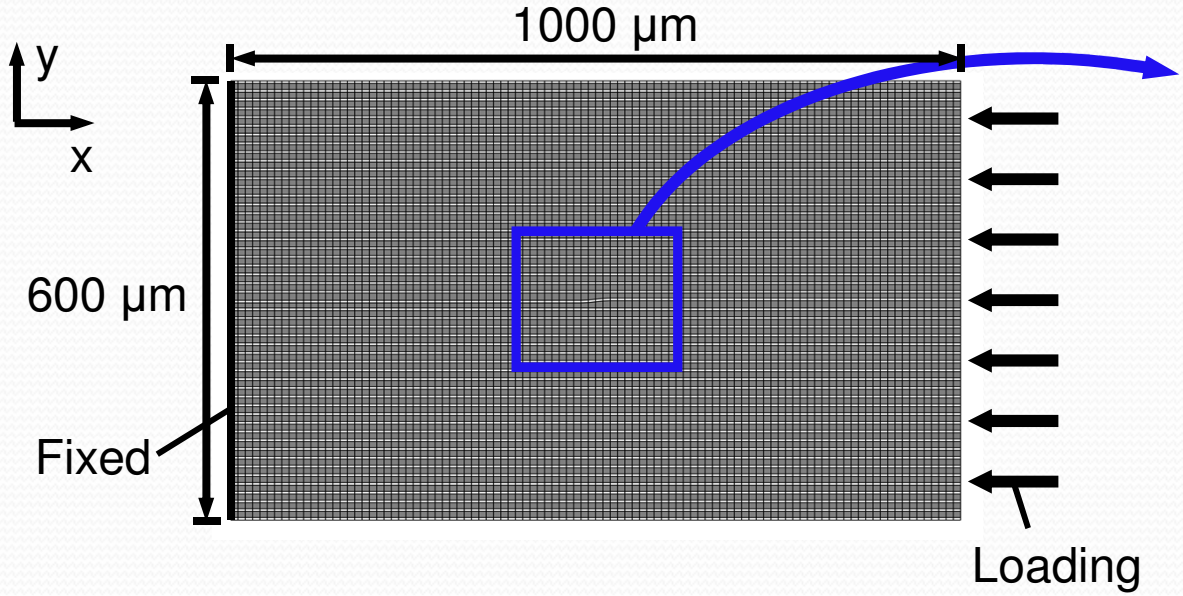


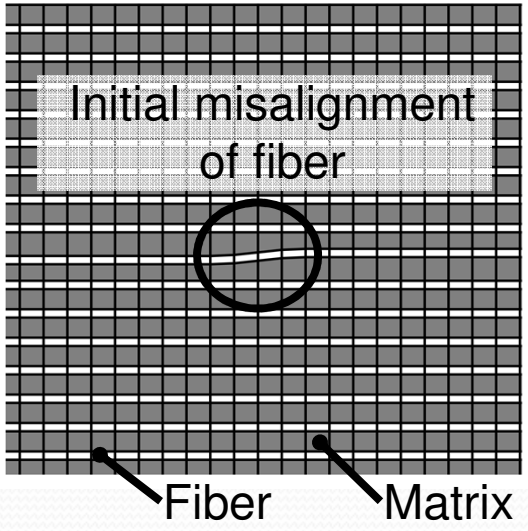


By applying computational analysis, manufacturing and operation process are expected to be understood more deeply.

J. LLorca, C. González, J. M. Molina-Aldareguía, J. Segurado, R. Seltzer, F. Sket, M. Rodríguez, S. Sádaba, R. Muñoz and L. P. Canal, 2011, "Multiscale Modeling of Composite Materials: a Roadmap Towards Virtual Testing" Adv. Mater., vol. 23, no. 44, pp. 5130-5147.

Numerical Simulation of Longitudinal Compressive Failure





Material property of fiber

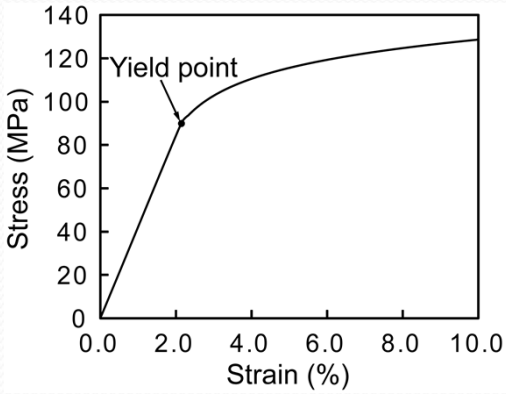
Elastic modulus in x- direction	225	GPa
Elastic modulus in y- direction	15	GPa
In-plane Poisson's ratio	0.2	
In-plane shear modulus	15	GPa
Transverse shear modulus	7	GPa

Material property of matrix

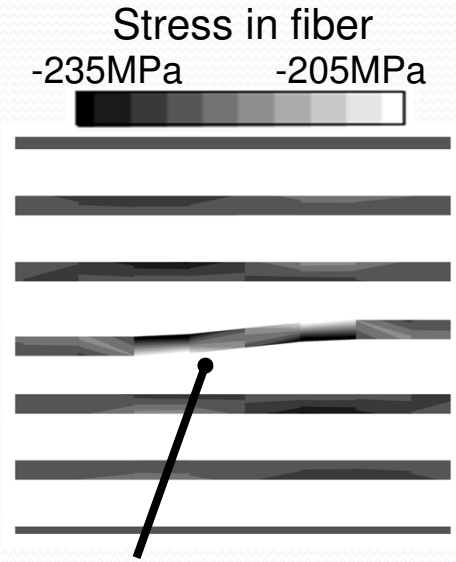
Elastic modulus	4.2	GPa
Poisson's ratio	0.34	
Yield stress	90	MPa

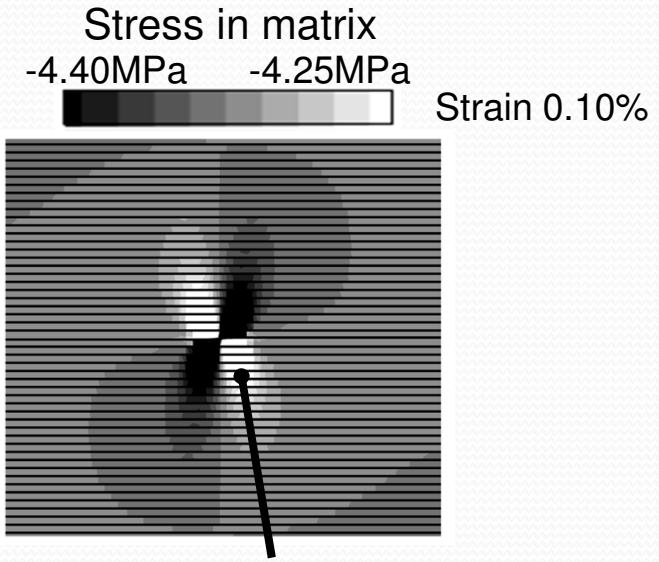
Carbon fiber/Epoxy resin AS4/3501-6 is assumed as the material.

Matrix stress-strain curve



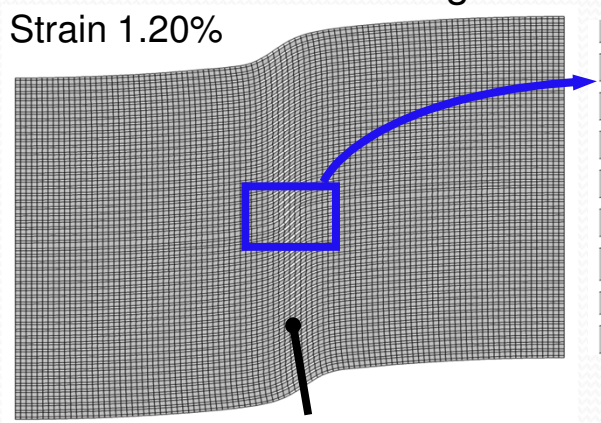
Numerical Simulation of Longitudinal Compressive Failure



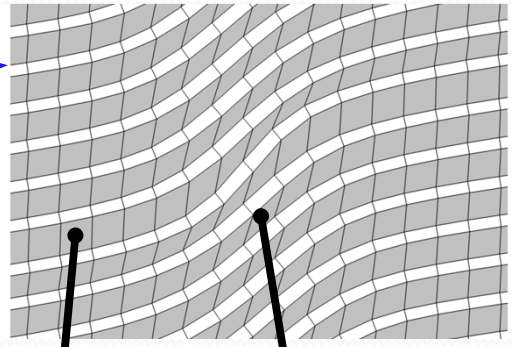


Bending stress occurs.

Stress concentration occurs.

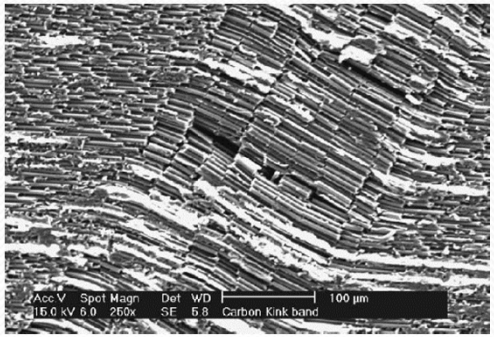


Localized deformation



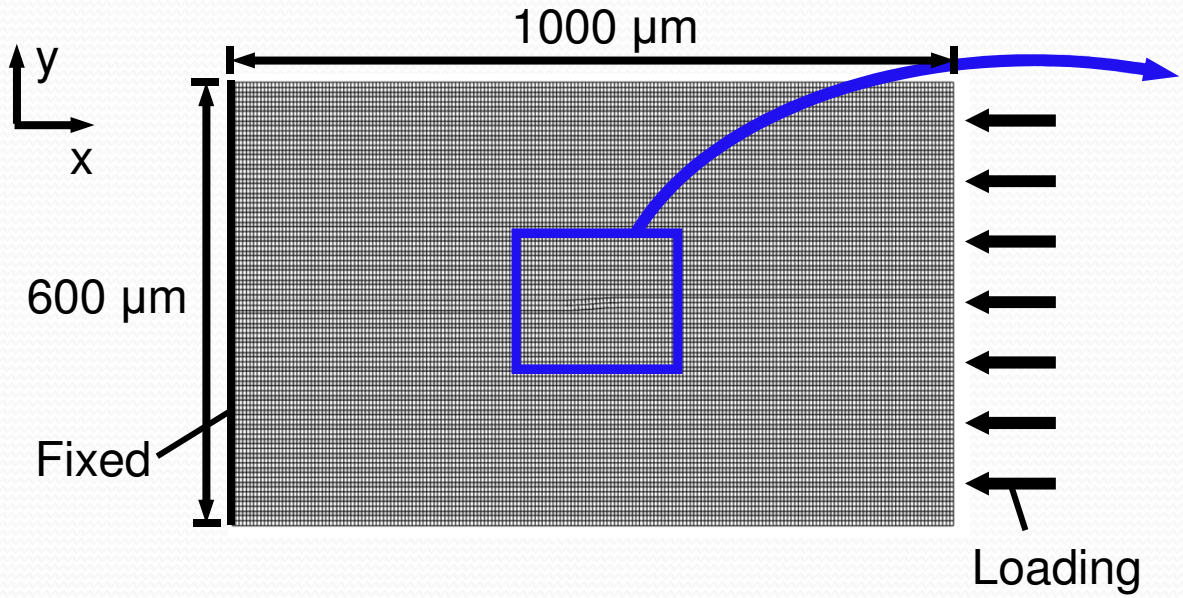
Rhombus shape (shear)

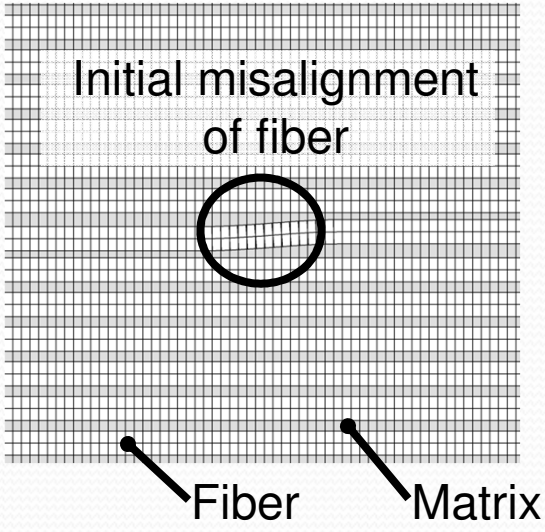
Rectangle shape (compressive)



C. S. Yerramalli and A. M. Waas, "A failure criterion for fiber reinforced polymer composites under combined compression–torsion loading," International Journal of Solids and Structures, vol. 40, no. 5, pp. 1139–1164, 2003.

In Case of Fiber Breaking





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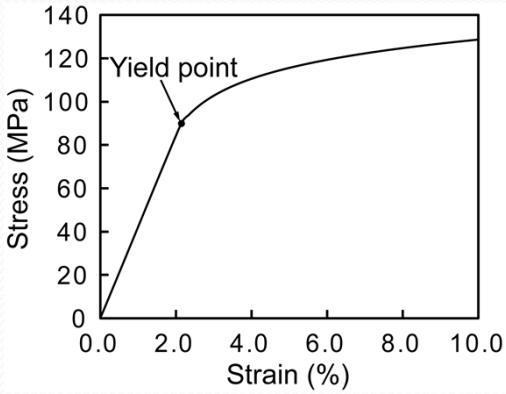

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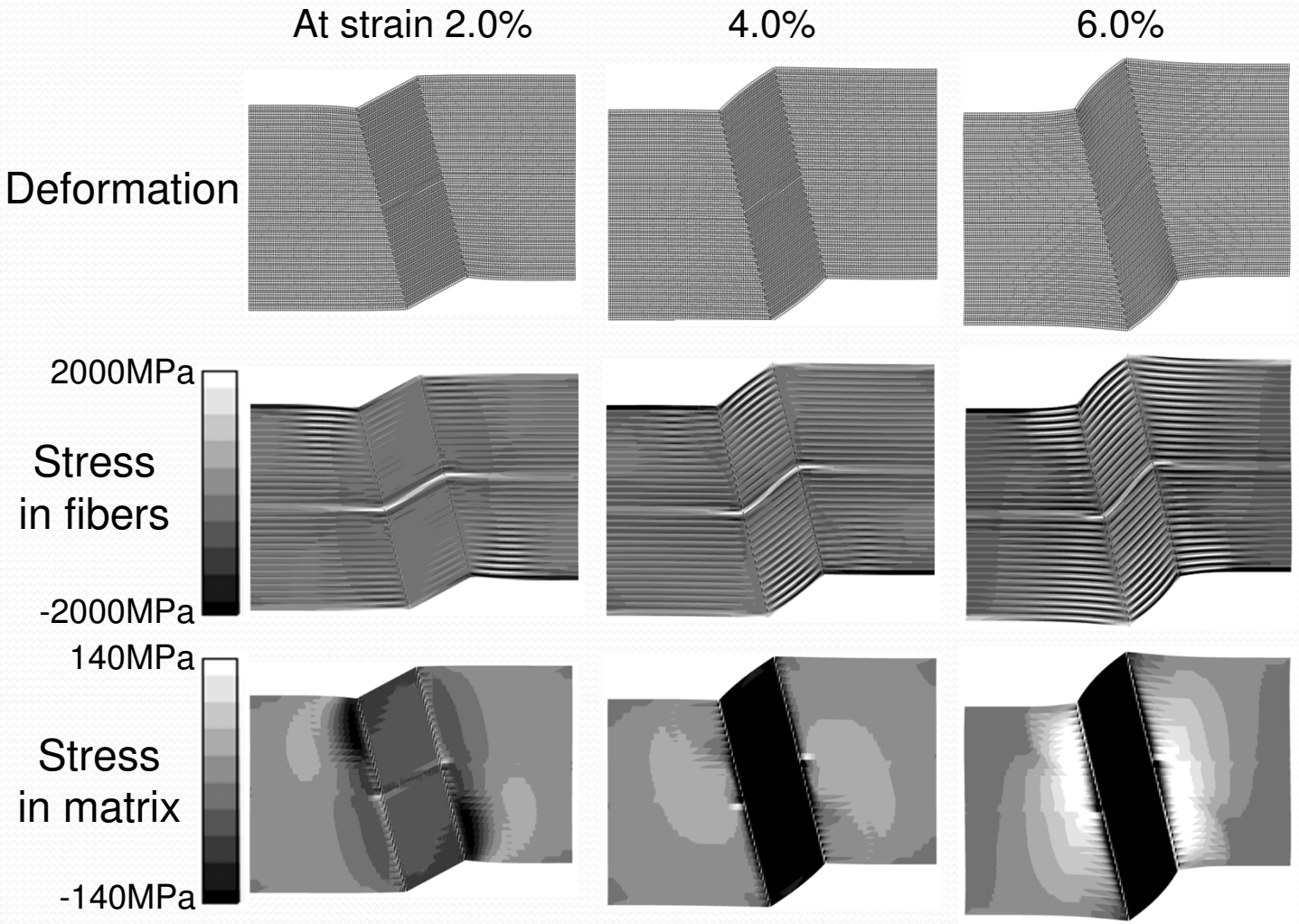
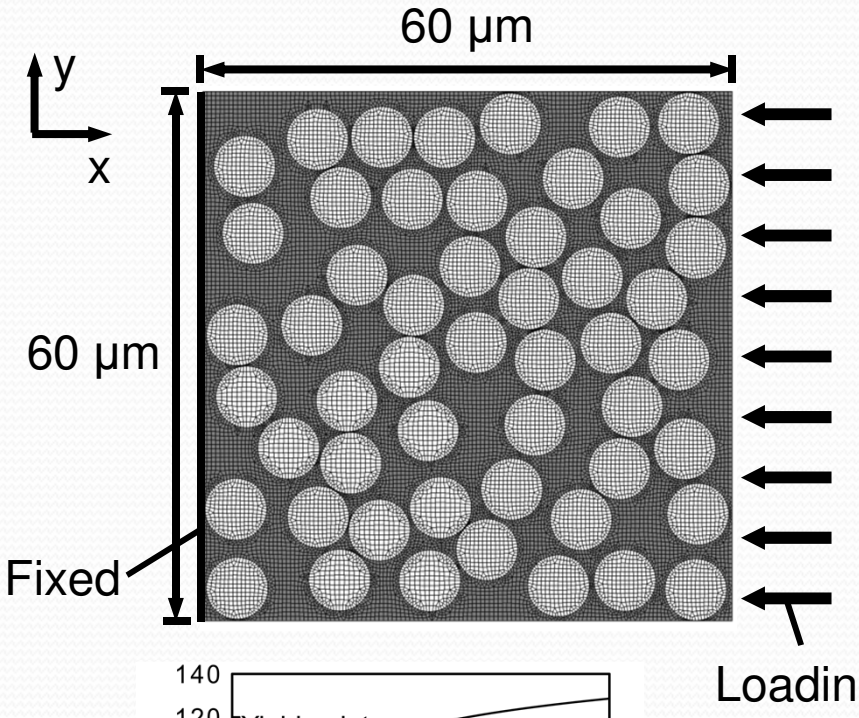
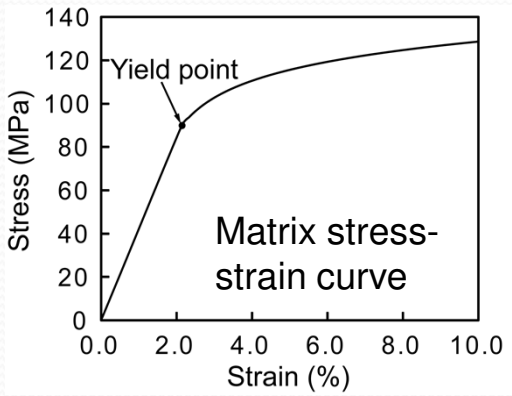
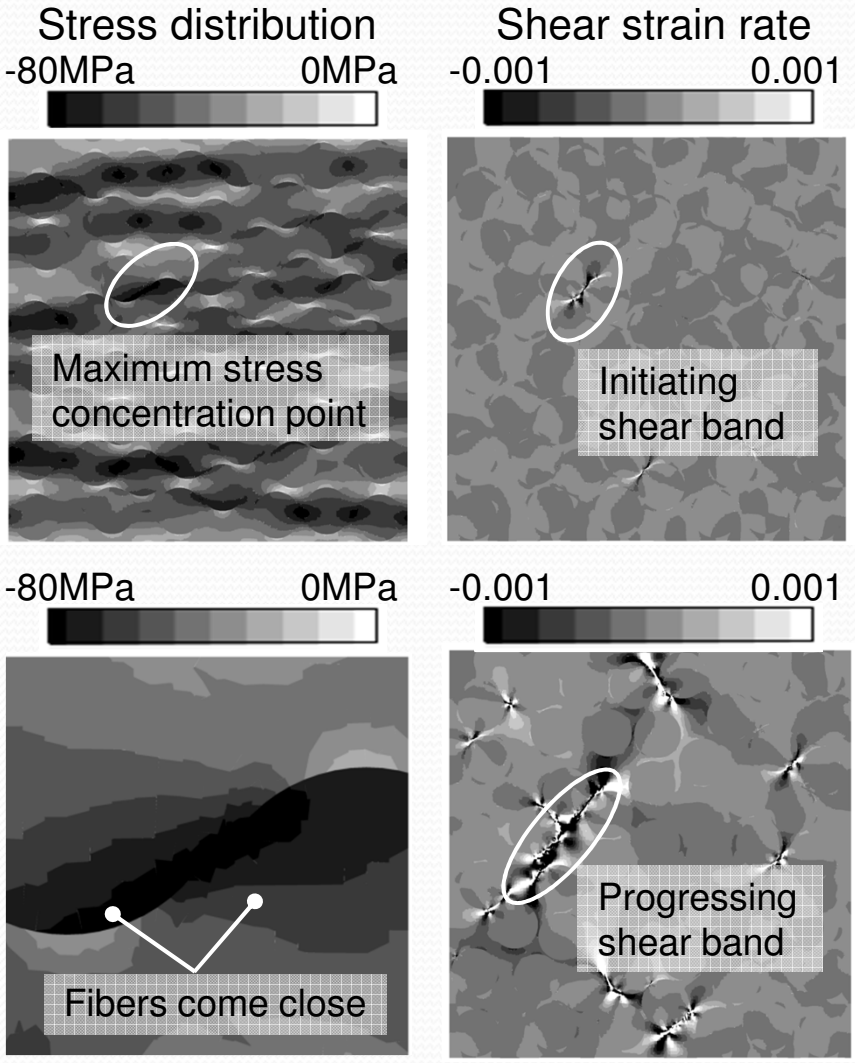


Numerical Simulation of Transverse Compressive Failure







Numerical Simulation of Transverse Compressive Failure

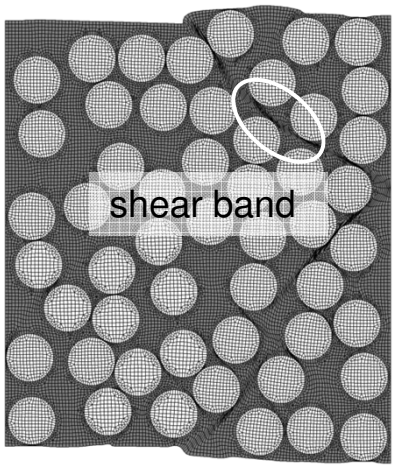
Deformation

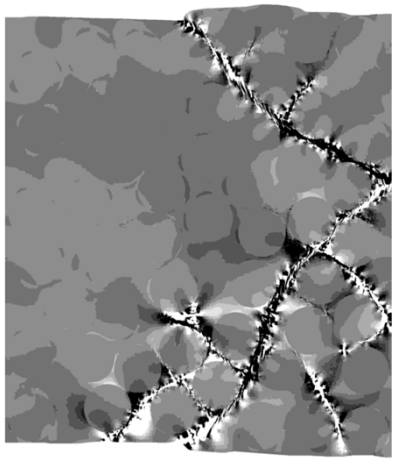
Shear strain rate

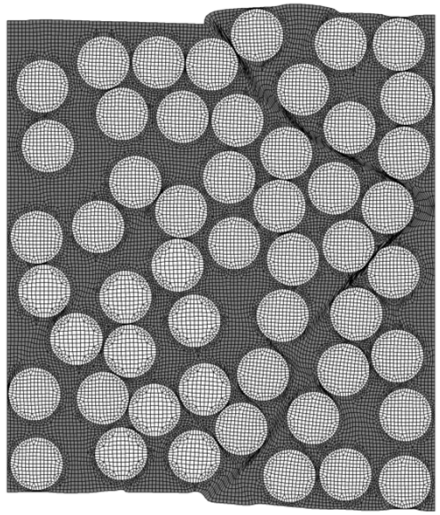
-0.001 0.001

Simulated deformation

Strain 6.0%

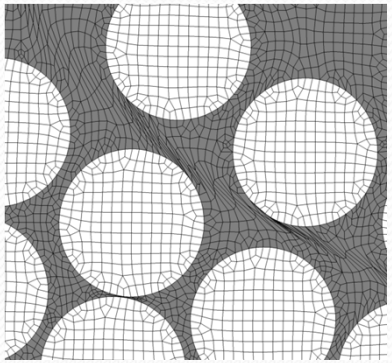


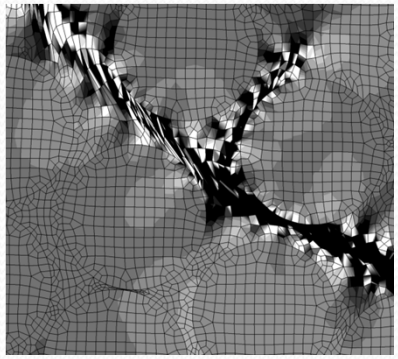




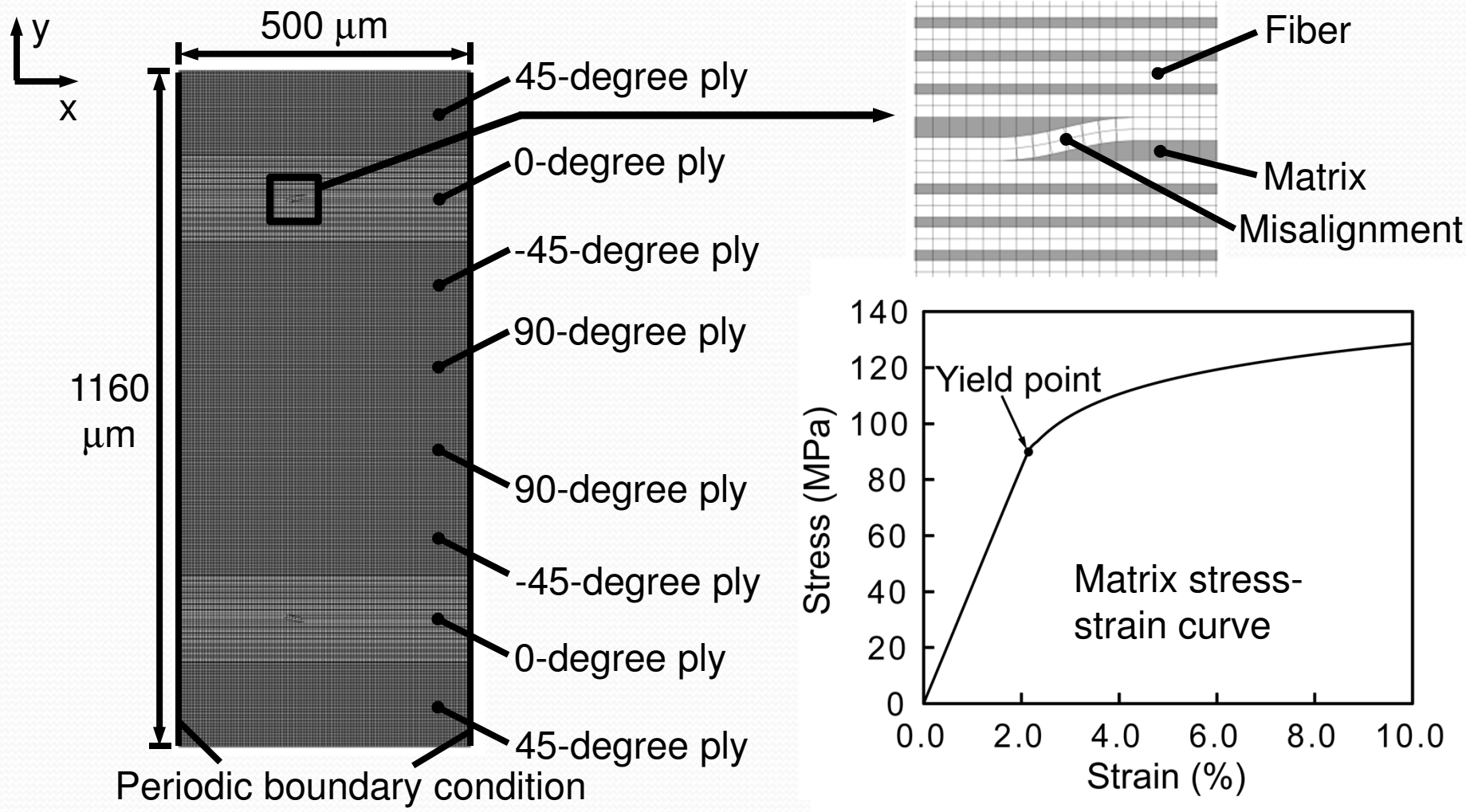
-0.001 0.001

Microscope photograph





Numerical Simulation of Compressive Failure in Laminated Plate



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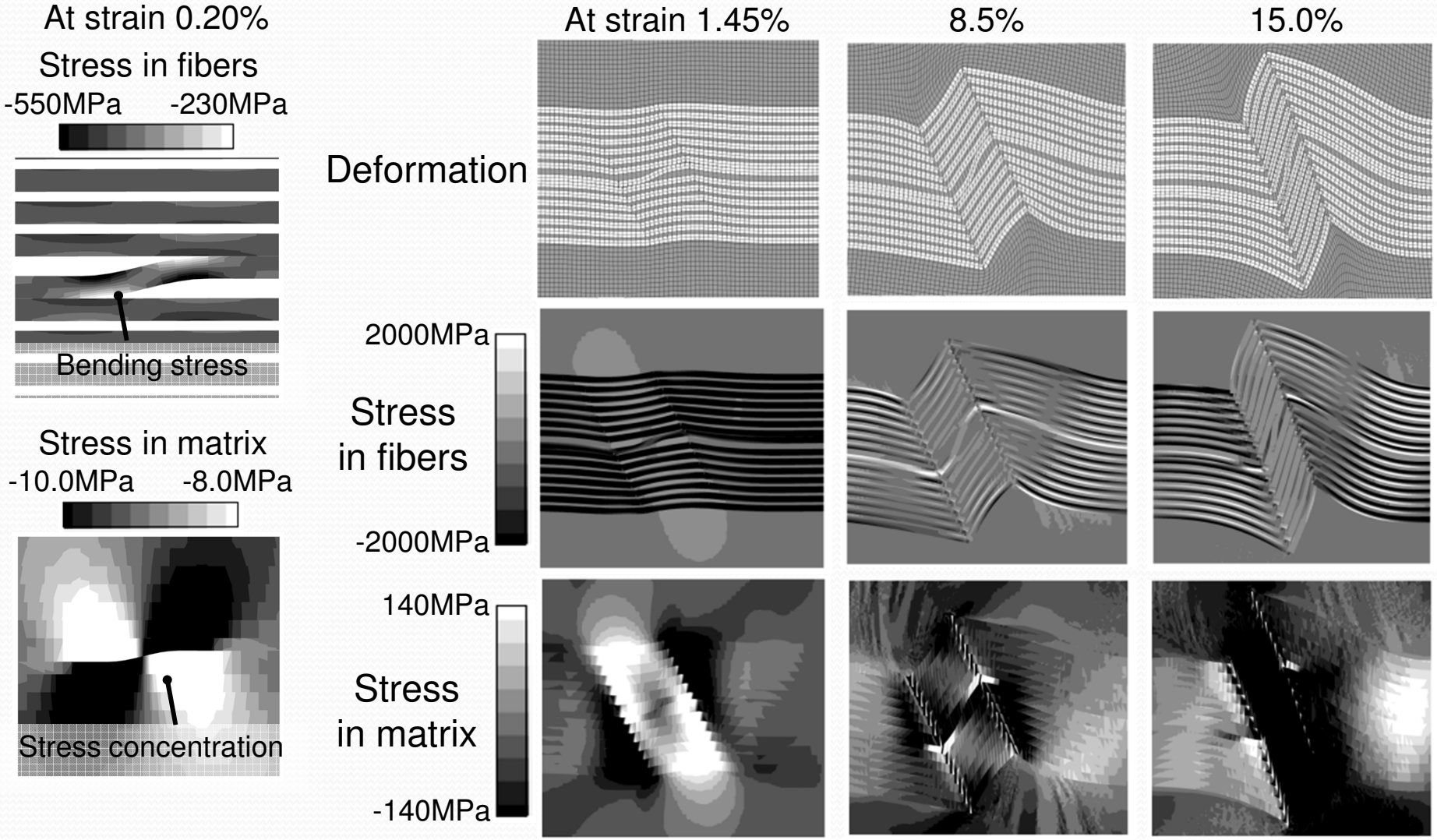
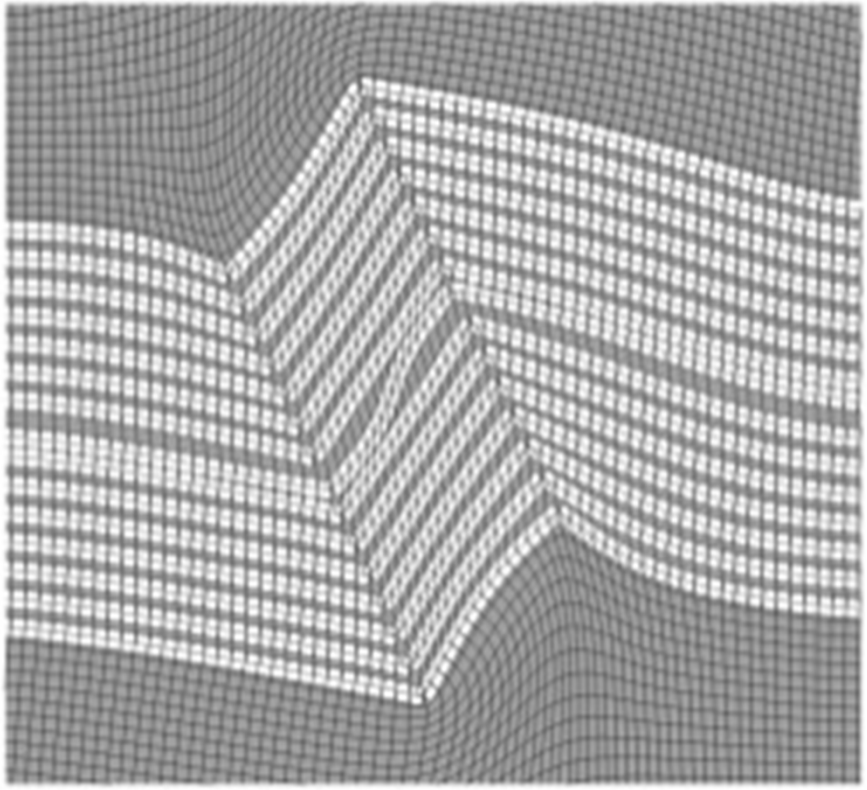
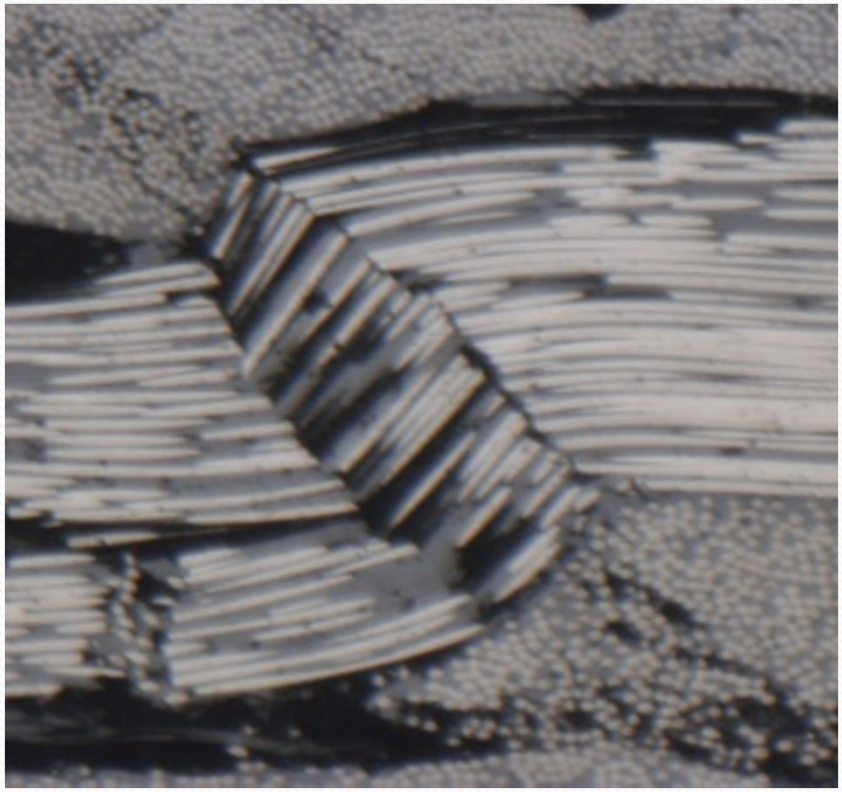


Numerical Simulation of Compressive Failure in Laminated Plate

Simulated deformation



Microscope photograph



Conclusions

This study investigates numerical simulation of fracture process of composite materials using computational analysis.

- In numerical simulation of longitudinal compressive failure, stress concentration occurs in the initial state of loading around initial misalignment of fiber, and at one moment of the loading, localized deformation appears in the material with originating from the initial misalignment part.

- In case of transverse compressive failure, stress concentration occurs in the material due to random placement of fibers, and after increase of applied strain, microscopic shear band appears from the maximum stress concentration point.

- Taking into account the fiber bending breaking, fiber kinking which appears in both unidirectional material and laminated plate is simulated in numerical simulation.

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