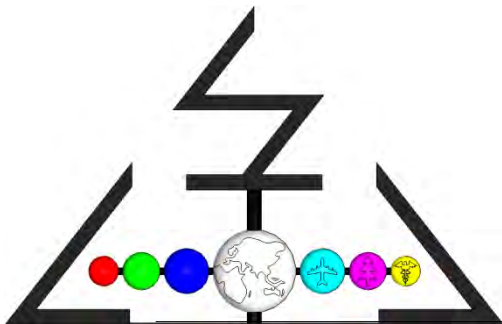




Micro Mechanical Exploration of Composites for Superior Properties

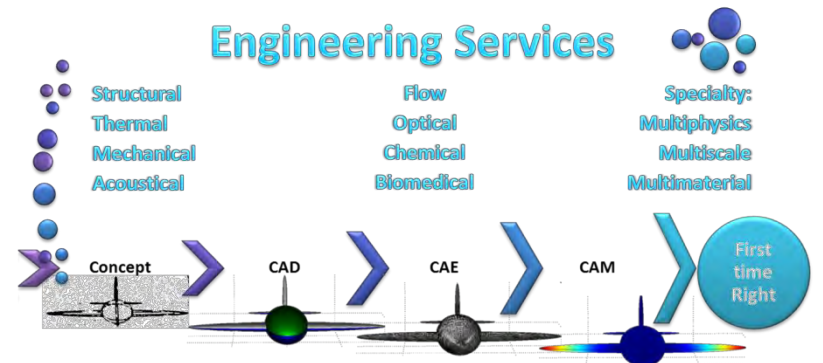
Raj C Thiagarajan and K V Chiranjeevi
ATOA Scientific Technologies Pvt Ltd



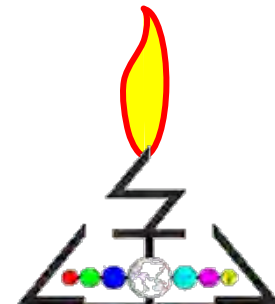
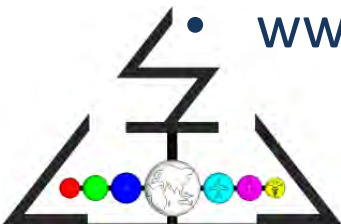
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- We Provide Multiphysics Engineering Design Solutions
- Driven by Material Unity Vision
- We are the first COMSOL Certified Consultant from India
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Engineering Design Simulations for the First time Right



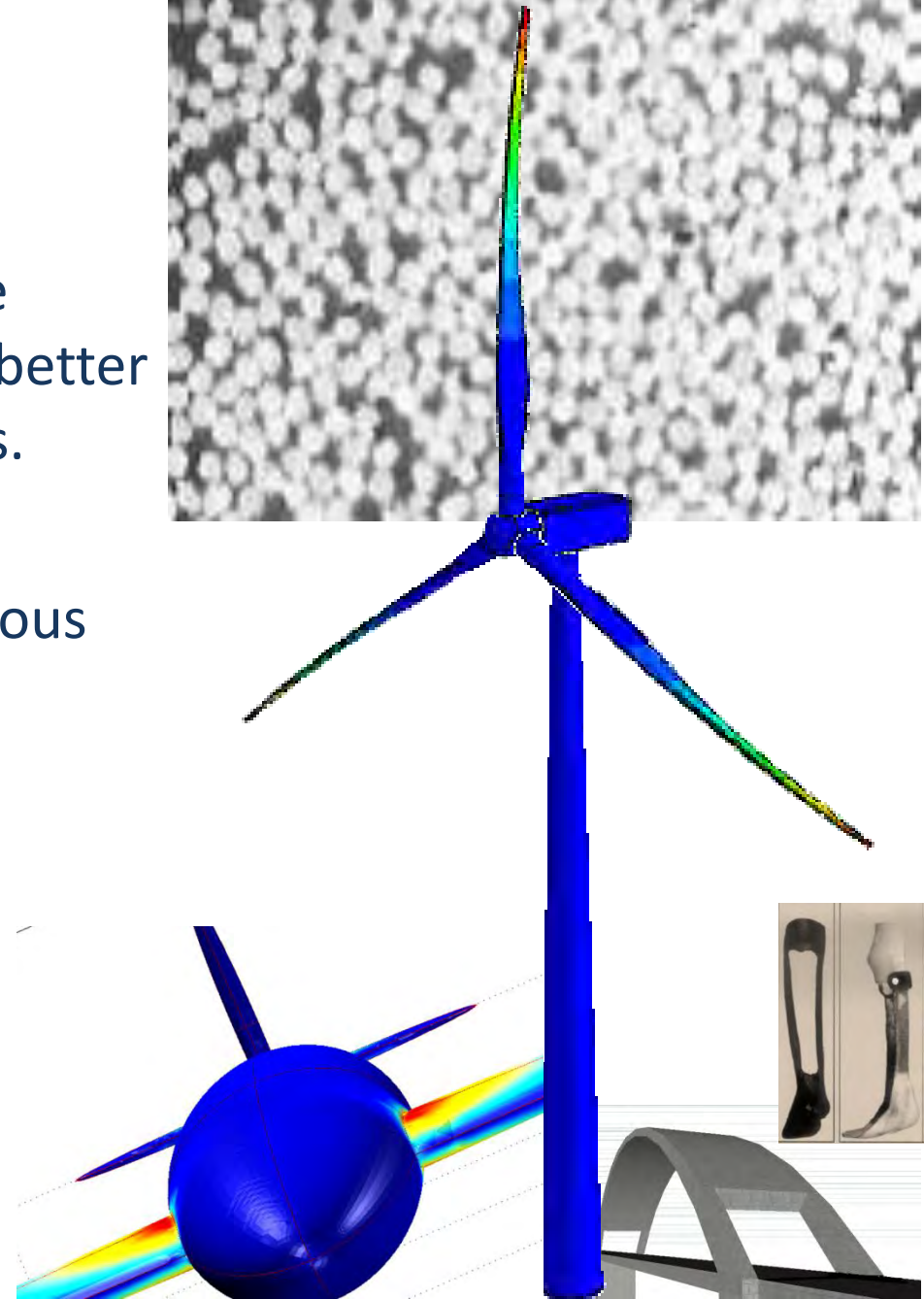
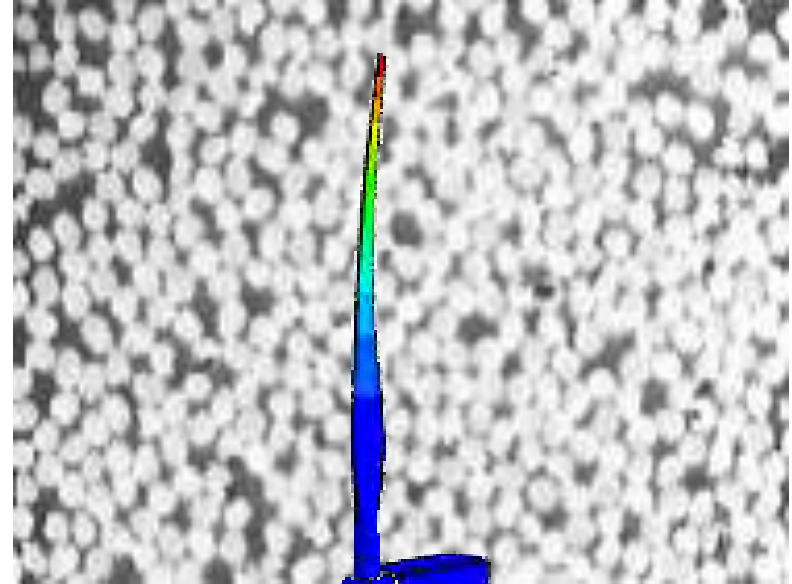
Micro Mechanical Exploration of Composites for Superior Properties

- Composites
- Super properties
- Micromechanics
- Simulation and prediction
- Results and Discussion



Composites

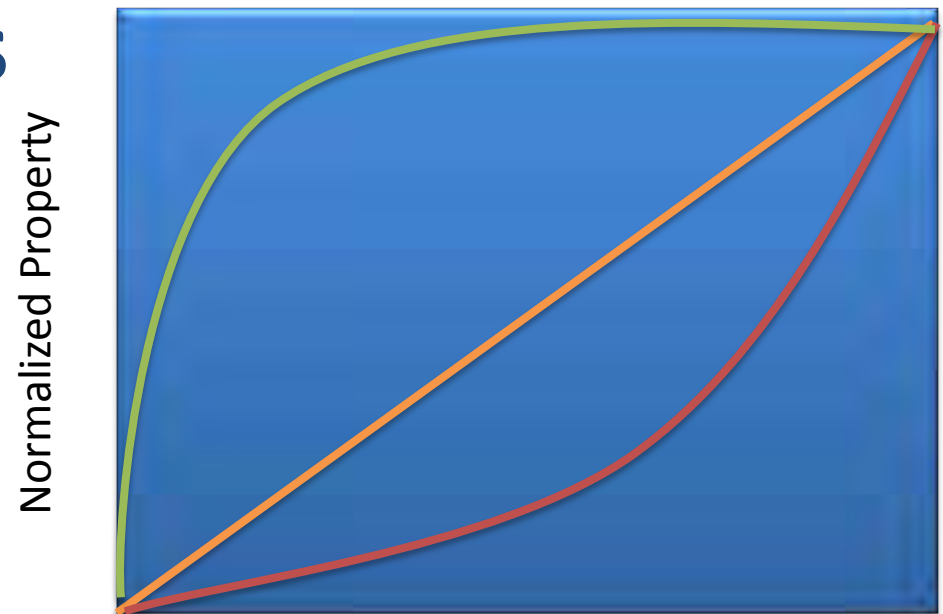
- Combination of any two are more materials to perform better than individual constituents.
- Macroscopically homogeneous and microscopically heterogeneous.
- Recent growth in industrial application of composites.



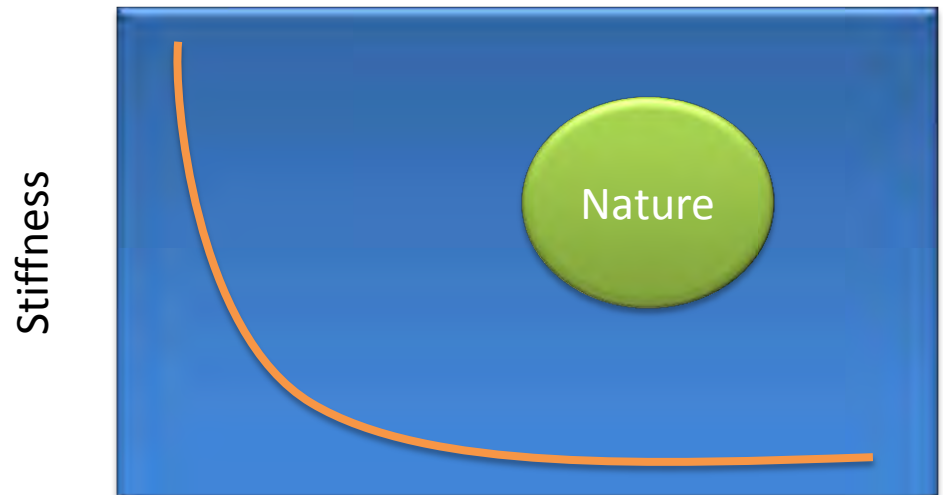
Super Properties

- Additive
- Product
- Super
 - Stiff and tough
 - Super elastic
 - Ultra low weight
 - Extremal
 - Nano
 - Meta

After US 7838108



Relative Density



Stiffness

Toughness



Micromechanics

- Continuum Micromechanics based on homogenization theory
 - Aims at finding a volume element (Representative Volume Element – RVE, periodic Micro field- PMA) response to prescribed mechanical loads.
 - Prediction of macro properties from micro structure and constituents.

Localization relationship

Micro fields	$\varepsilon(\mathbf{x}) = \mathbf{A}(\mathbf{x}) \langle \varepsilon \rangle$	Macro fields
	$\sigma(\mathbf{x}) = \mathbf{B}(\mathbf{x}) \langle \sigma \rangle$	

Homogenization relationship

$$\langle \varepsilon \rangle = \frac{1}{\Omega_s} \int_{\Omega_s} \varepsilon(\mathbf{x}) d\Omega = \frac{1}{2\Omega_s} \int_{\Gamma_s} (\mathbf{u}(\mathbf{x}) \otimes \mathbf{n}_\Gamma + \mathbf{n}_\Gamma \otimes \mathbf{u}(\mathbf{x})) d\Gamma$$
$$\langle \sigma \rangle = \frac{1}{\Omega_s} \int_{\Omega_s} \sigma(\mathbf{x}) d\Omega = \frac{1}{\Omega_s} \int_{\Gamma_s} \mathbf{t}(\mathbf{x}) \otimes \mathbf{x} d\Gamma$$

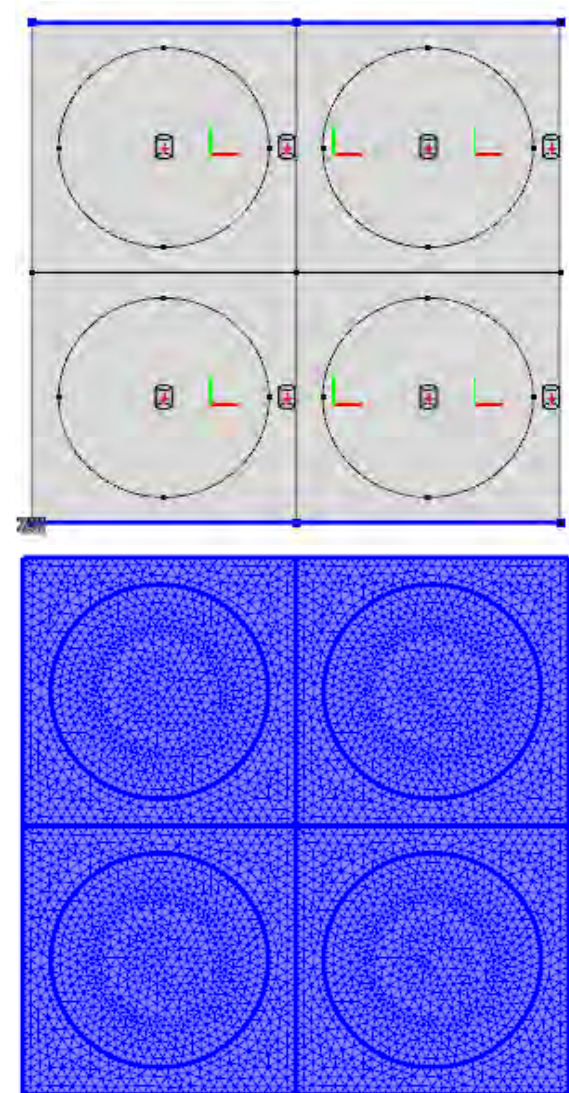
Where,

Ω – volume, Γ -surface,
 $\mathbf{u}(\mathbf{x})$ – deformation vector
 $\mathbf{t}(\mathbf{x})$ – surface traction vector
 \mathbf{n}_Γ – surface normal vector



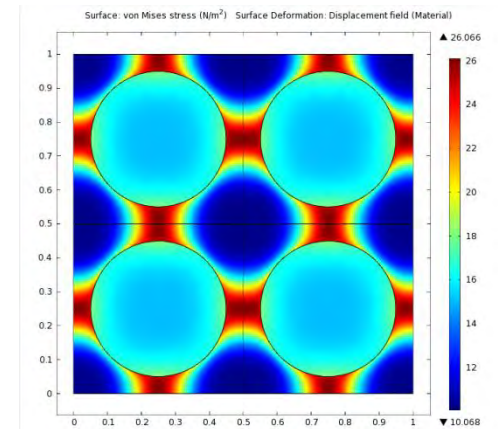
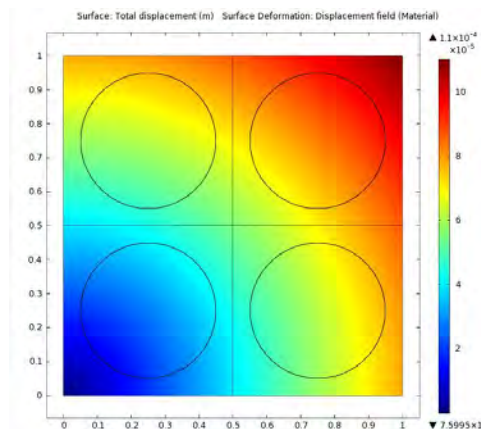
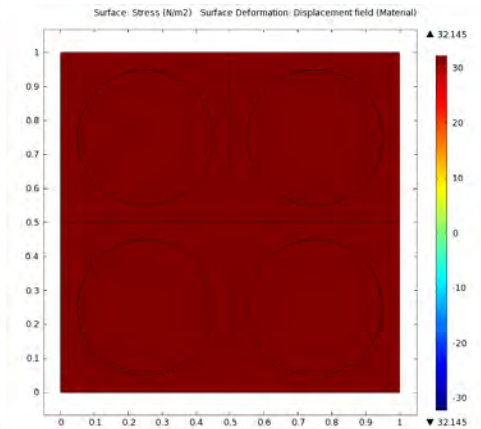
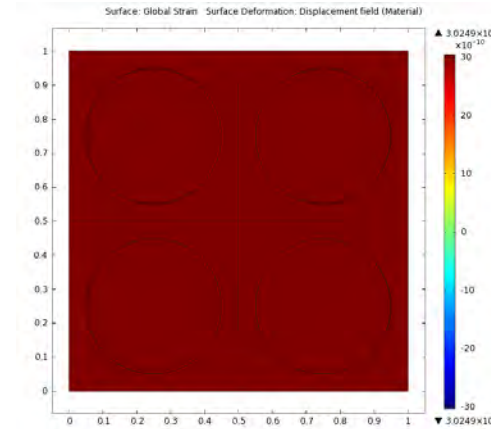
Numerical Implementation

- Periodic boundary condition
 - $u_{xl} = u_{x0} + e_x$
 - $v_{yl} = u_{y0} + e_y$
- Load
 - Body force
- Global (macro) vs local (micro) stress and strain
 - Integration of variables
- Parametric model to predict the stress strain prediction



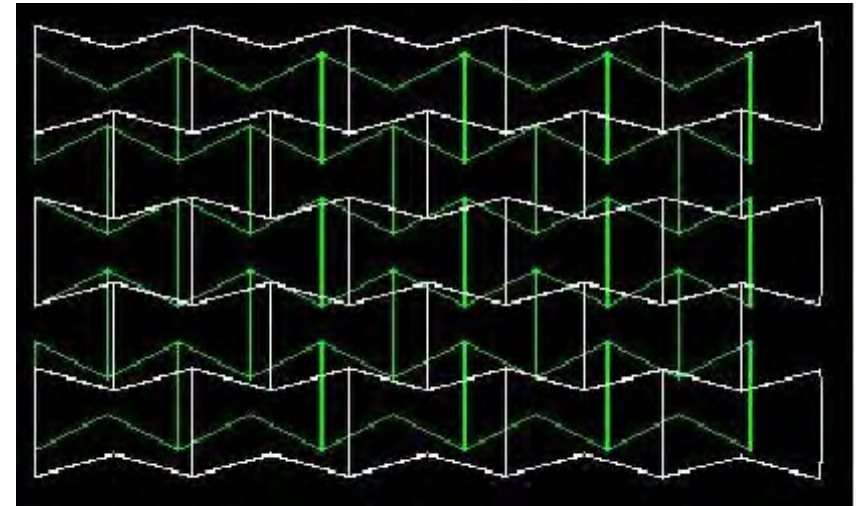
Results and discussion

- Isotropic property prediction
- Polymer composite property prediction
- Macro properties
- Micro mechanical exploration

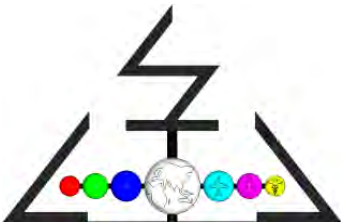


Results and discussion..

- Super property prediction
 - NPR effects
 - -1 to 0.5
 - Load vs deflection performance
- 3X improvement in performance
- Internal resistive mechanism due to NPR.



Matrix Poisson ratio	Fibre Poisson's Ratio	Composite Elastic modulus Predicted (GPa)	% of increase in Modulus
0.3	0.2	2.536	0.0
0.3	-0.5	2.576	1.6
0.3	-0.9	2.602	2.6
0.4	0.2	2.762	8.9
-0.4	0.2	2.879	13.5
-0.5	0.2	3.206	26.4
-0.6	0.2	3.701	45.9
-0.7	0.2	4.496	77.3
-0.8	0.2	5.937	134.1
-0.9	0.2	9.352	268.7



Future work

- 2D to Parametric 3D
- DoE to predict anisotropic properties.
- Extension to Thermal, Acoustical, Electrical, Magnetic, and Transport properties.
- Multiphysics Optimization for superior properties

