Advanced Modelling of Semi-Crystalline Polymers and Application for Micromechanical Modelling Predictions

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Motivation

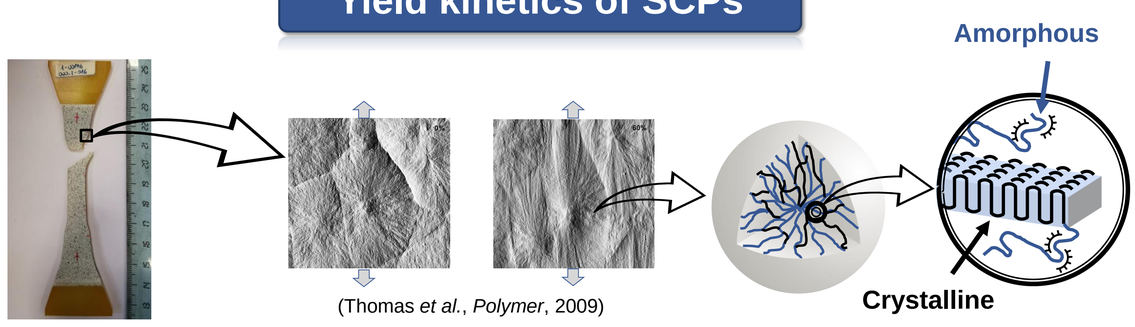
The modelling of **UD polymeric composites** requires a better understanding of the **nonlinear response of the polymer matrix**. The role of matrix on the **rate- and temperature-dependence**, **self-heating** and **thermal softening** effect of Fibre-Reinforced Polymer (FRP) composites remains still unclear.

Objective

The aim is to investigate the **thermomechanical behaviour of UD composites** at different **strain rates.** The **advanced polymer model** is developed and used for **micromechanical analysis of UD FRP.** This work investigates **local effects hidden at macroscale level** and develops a platform to **virtually validate ply-level models**.

I. Unified Semi-Crystalline Polymer Model

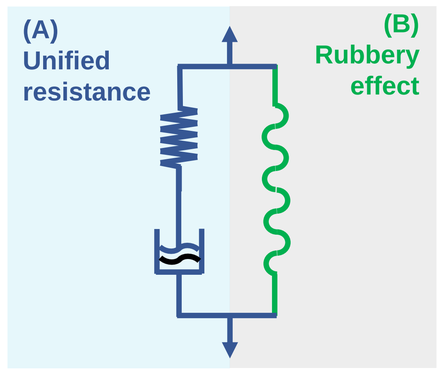
Yield kinetics of SCPs



(Thomas *et al.*, *Polymer*, 2009)

Specimen (mm size) — **Multi spherulitic morphology (μm size)** — **Spherulite (nm size)**

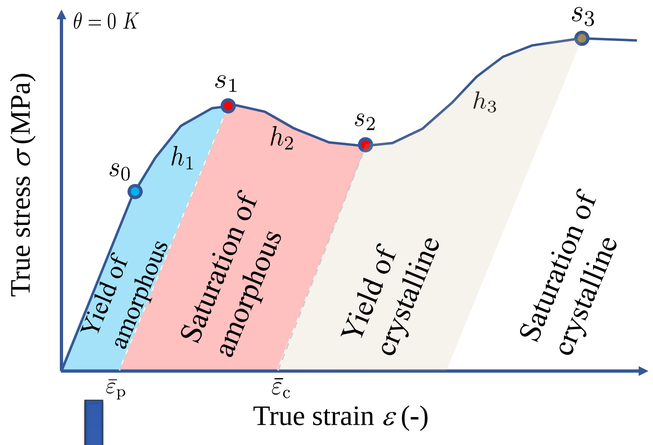
Unified SCP (USCP)



Deformation gradient: $\boldsymbol{F} = \boldsymbol{F}_A = \boldsymbol{F}_B$

Cauchy stress tensor: $\boldsymbol{\sigma} = \boldsymbol{\sigma}_A + \boldsymbol{\sigma}_B$

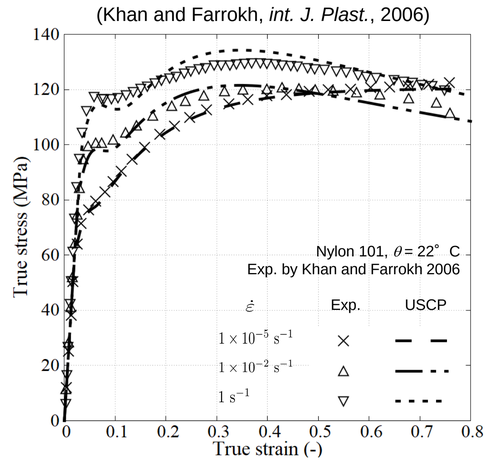
σ–ε response of SCPs



USCP model validation

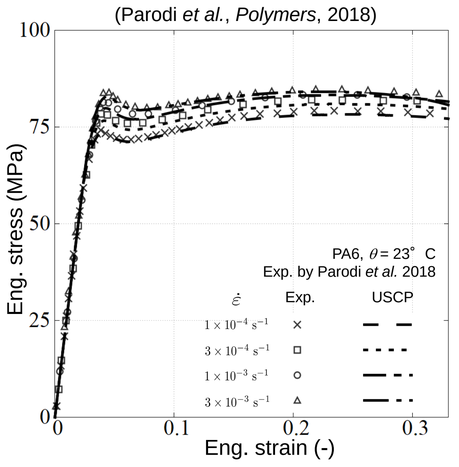
(a) Nylon 101 under compression

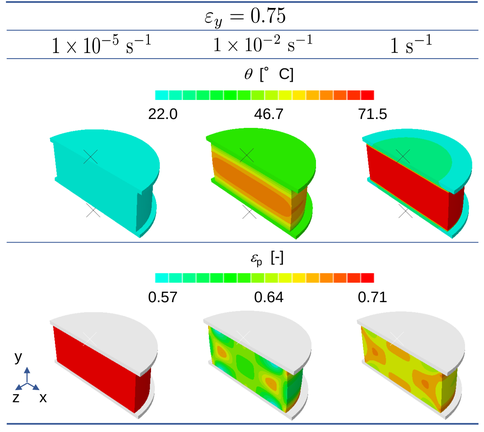
(Khan and Farrokh, *int. J. Plast.*, 2006)

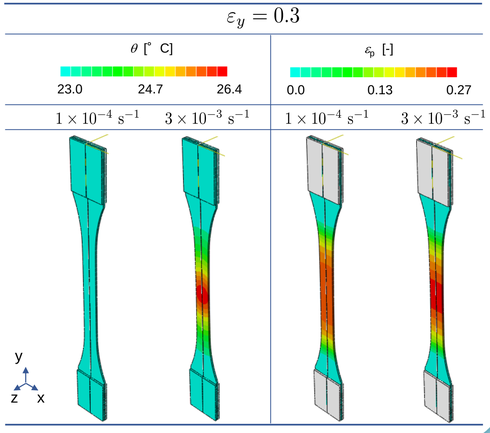


(b) Polyamide 6 under tension

(Parodi *et al.*, *Polymers*, 2018)

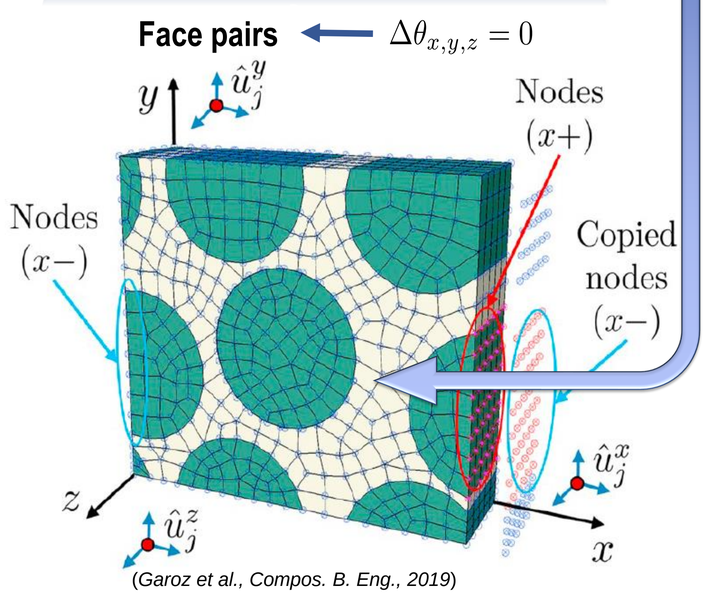






II. RVE-based Analyses

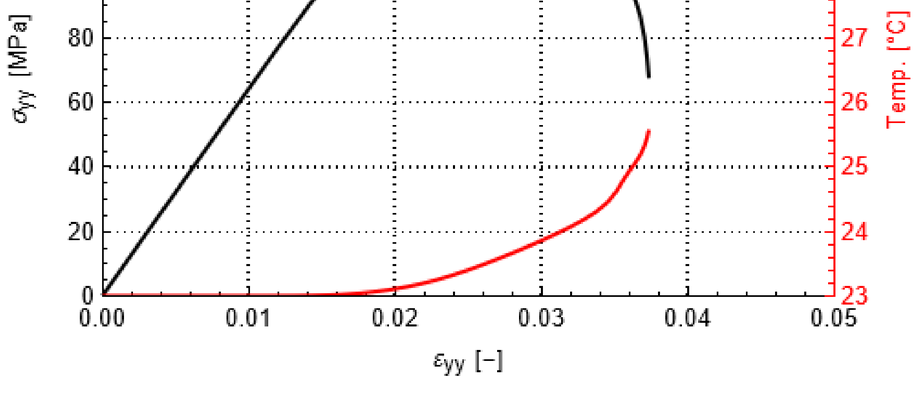
Thermomechanical periodic boundary conditions

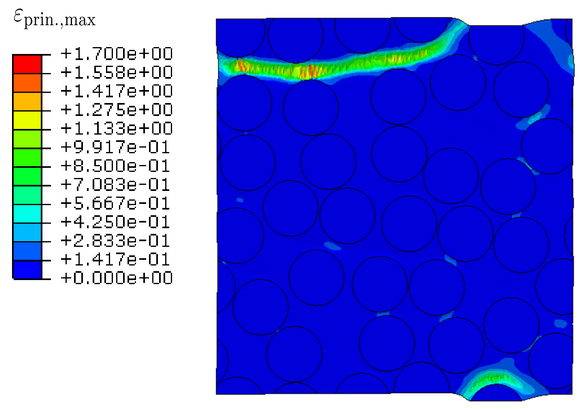


(*Garoz et al., Compos. B. Eng., 2019*)

Highly nonlinear SCP matrix

Homogenized σ–ε response self-heating effect





Conclusions

- **Unified SCP (USCP) model** captures accurately the **rate-** and **temperature-dependence**, **double yield** phenomenon, **self-heating** and **thermal softening** effects.
- **High local strain found using thermomechanical analysis** of UD composites.
- **Matrix failure mechanism** will be implemented.
- The homogenized thermomechanical response related to the **spatial packing of fibres**.

Valorization

- Advanced USCP model for industrial applications
- Low-cost calibration tests
- Parameter identification on σ–ε curves
- Multi-scale modelling

Acknowledgements

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