Experimental and Numerical Analysis of a Glass Fiber Reinforced Plastic

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Contents

Project Overview

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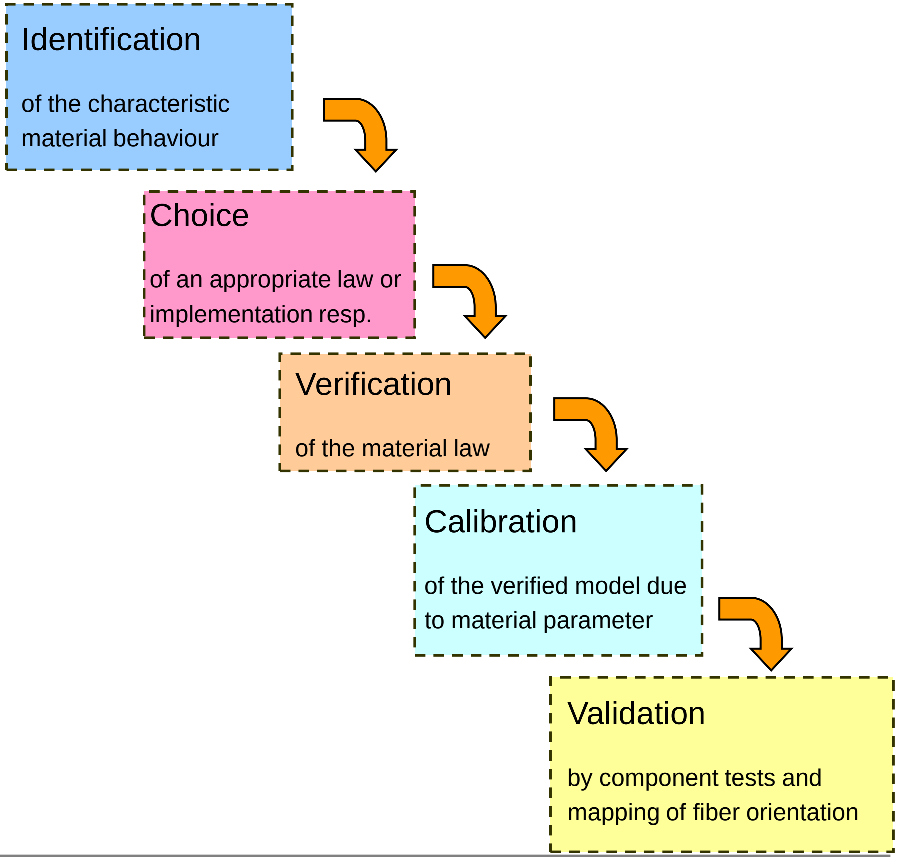
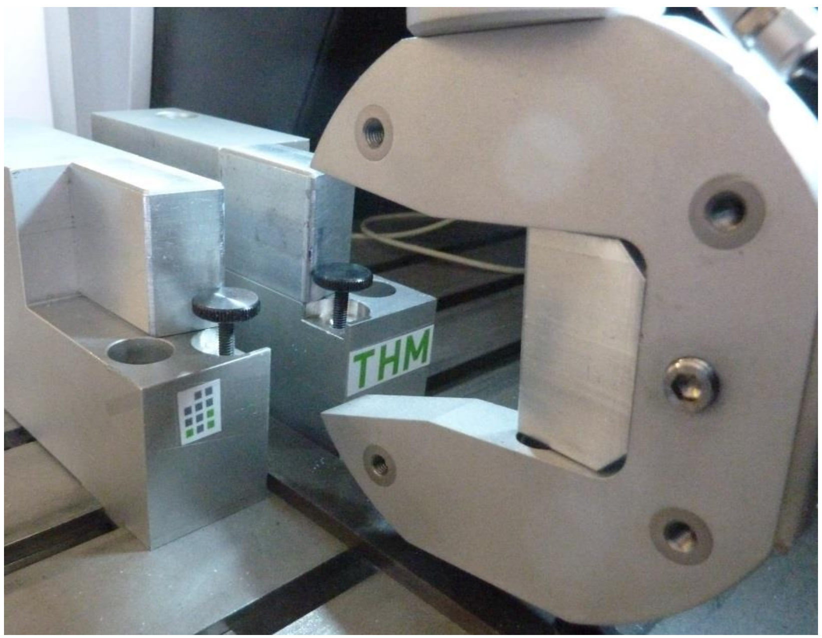
- Purpose: Generating a suitable model for simulating a specific reinforced plastic (PBT with 20 percent by weight of glass fibers) including failure
  - Conducting material tests
  - Generating material cards
  - Conducting component tests
  - Adding material failure
  - Mapping fiber orientation
  - Comparing different setups



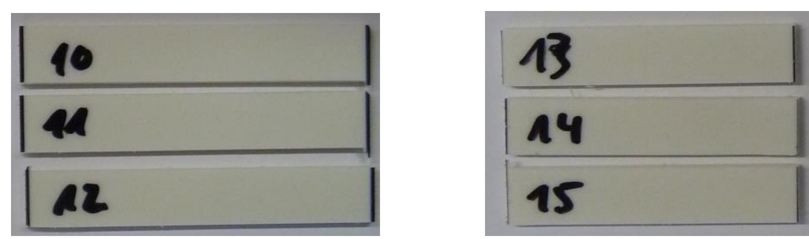
Material Testing

- Three-point bending tests using 4a impetus and Instron 5566
- Strain rates between 0.01/s and 50/s
- Specimens are sawed out of injection molded plates



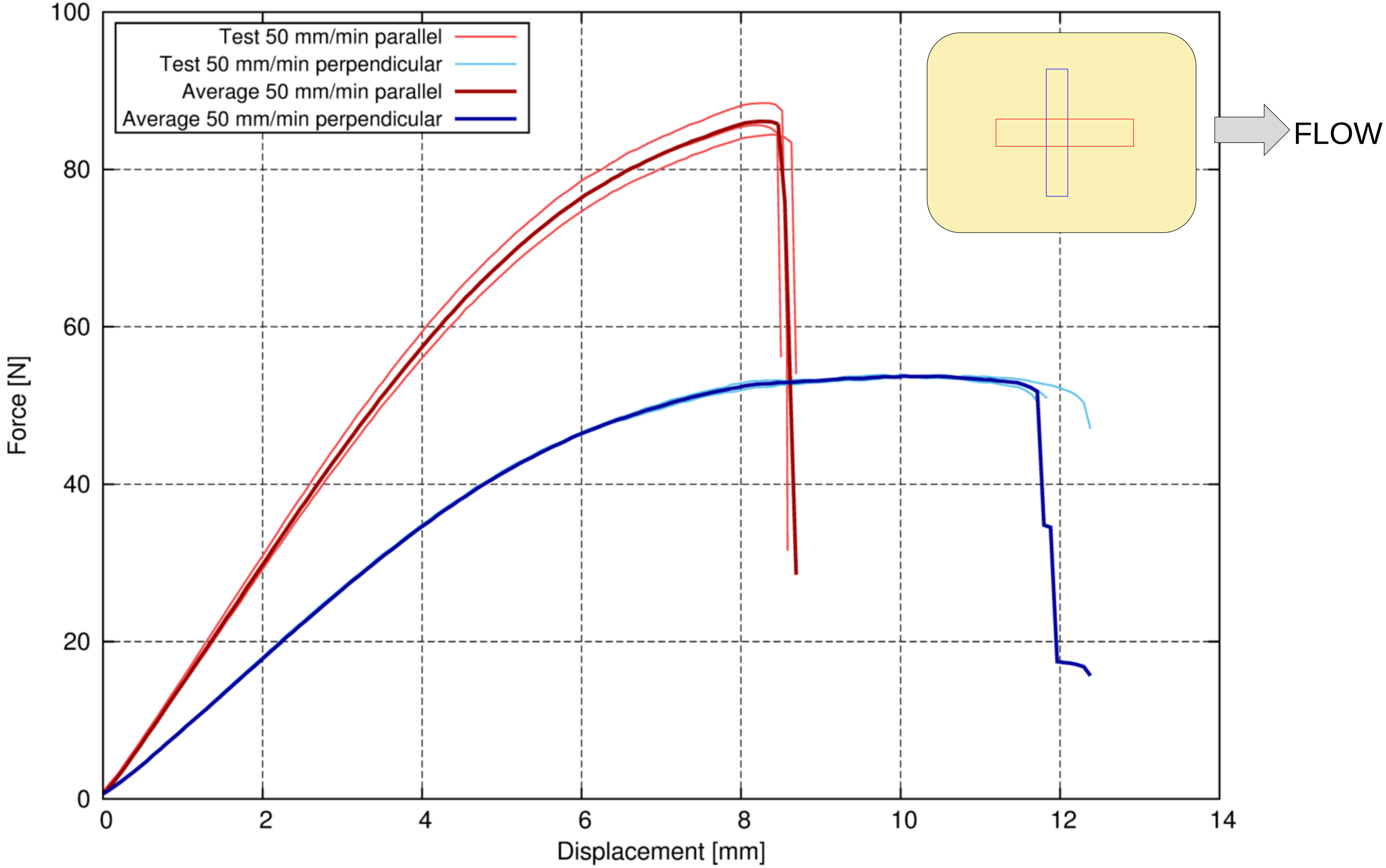
4a impetus pendulum with the three-point bending setup.

Testing speed	Specimen length [mm]
50 mm/min	60
1.0 m/s	60
2.5 m/s	50
4.0 m/s	40

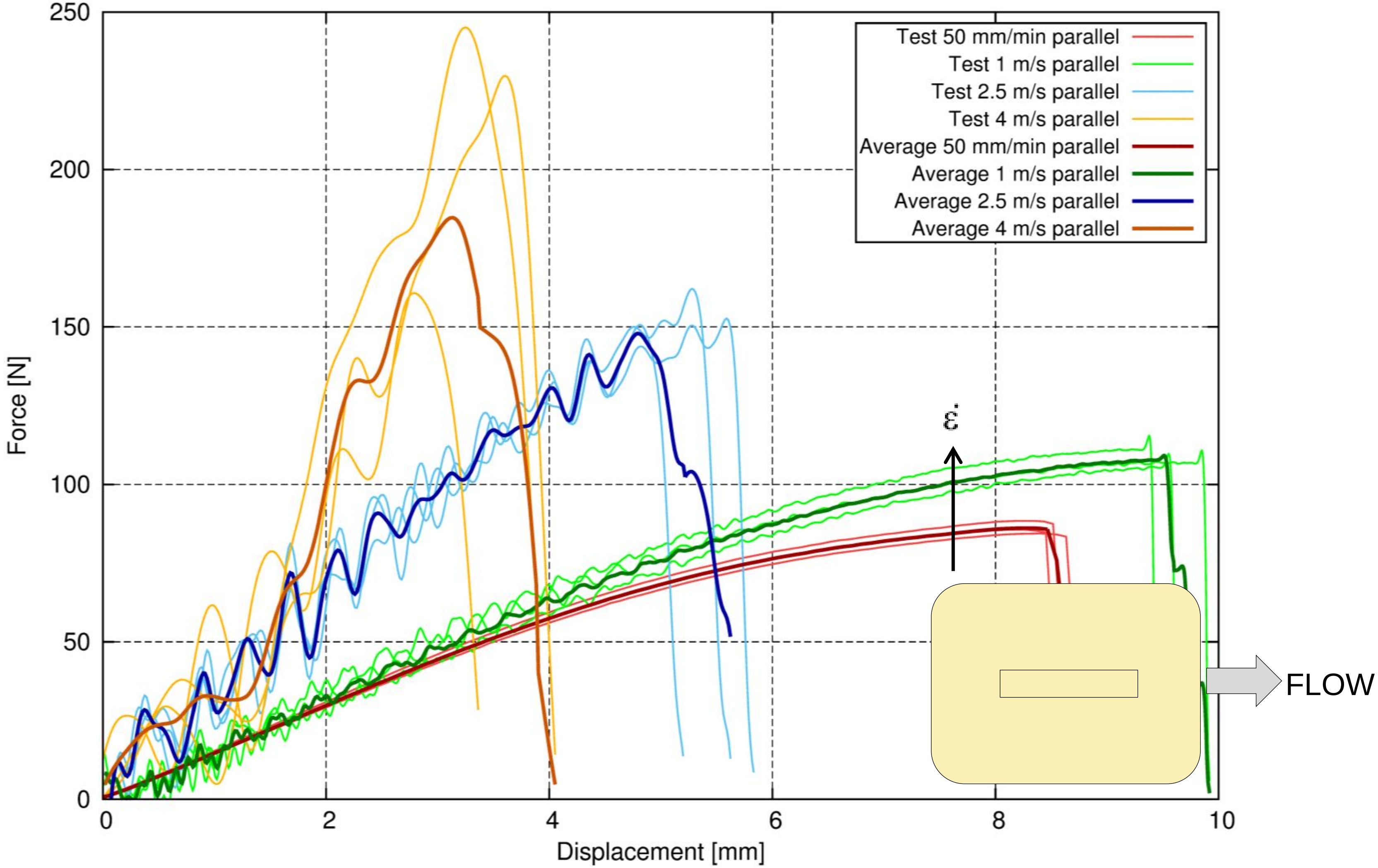


Three-point bending specimens of different lengths.

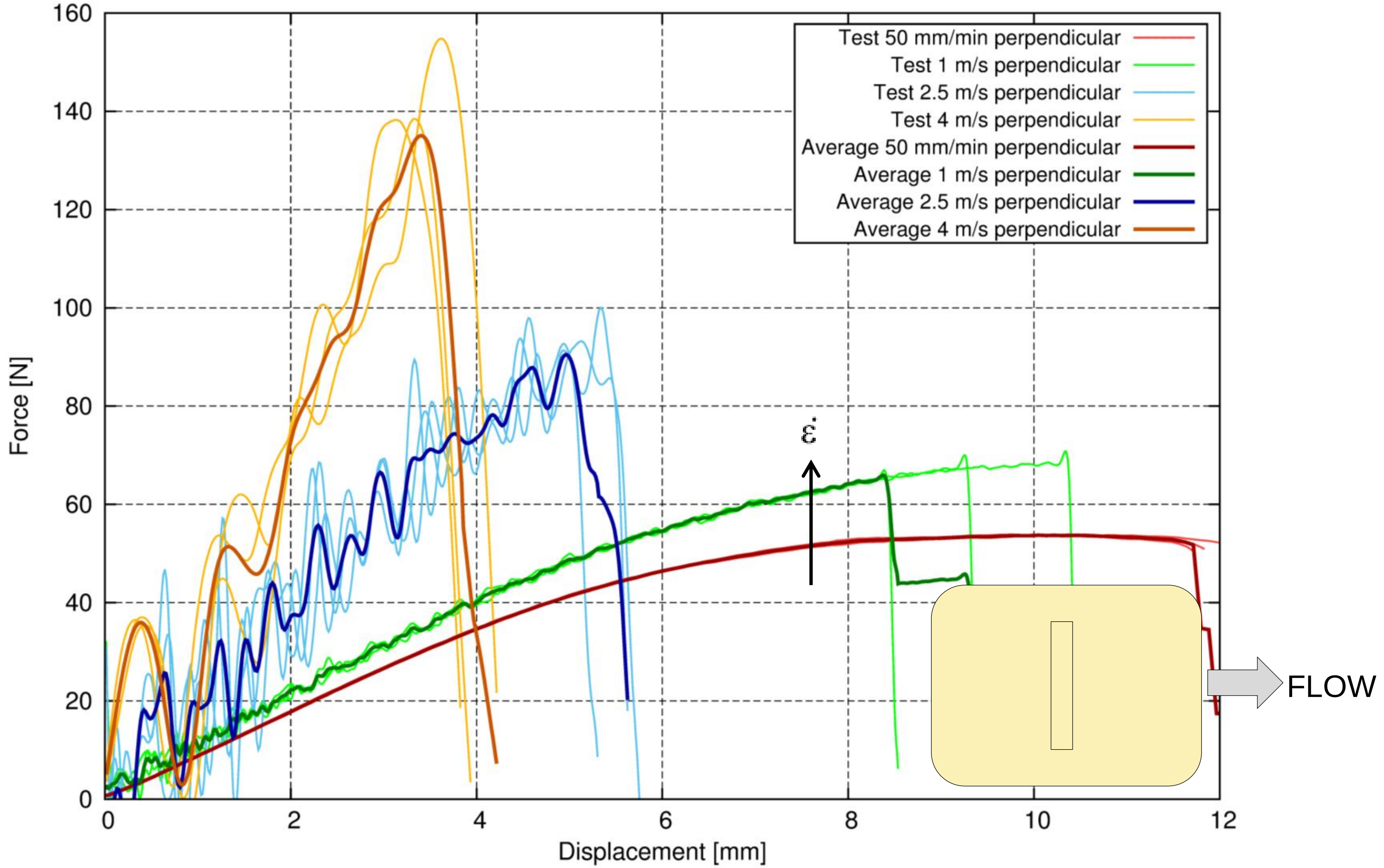
Material Testing quasi-static



Material Testing parallel



Material Testing perpendicular



Component Testing: Nutini Box

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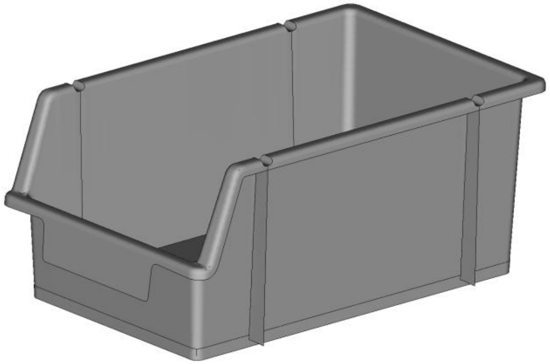
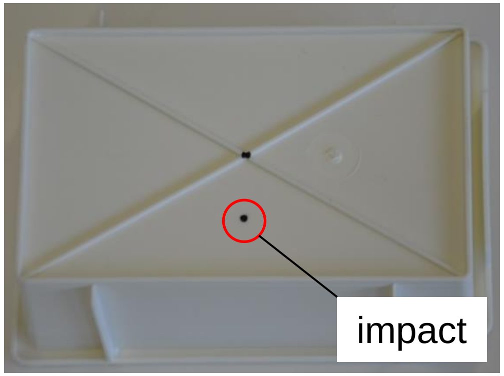
- Injection molded stackable box under impact loading
- Quasi-static impact tests using Instron 5566
- Dynamic impact tests using Instron CEAST 9350
- Testing velocities:
  - 5 mm/min and 50 mm/min quasi-static
  - 1 m/s, 3 m/s and 5 m/s dynamic



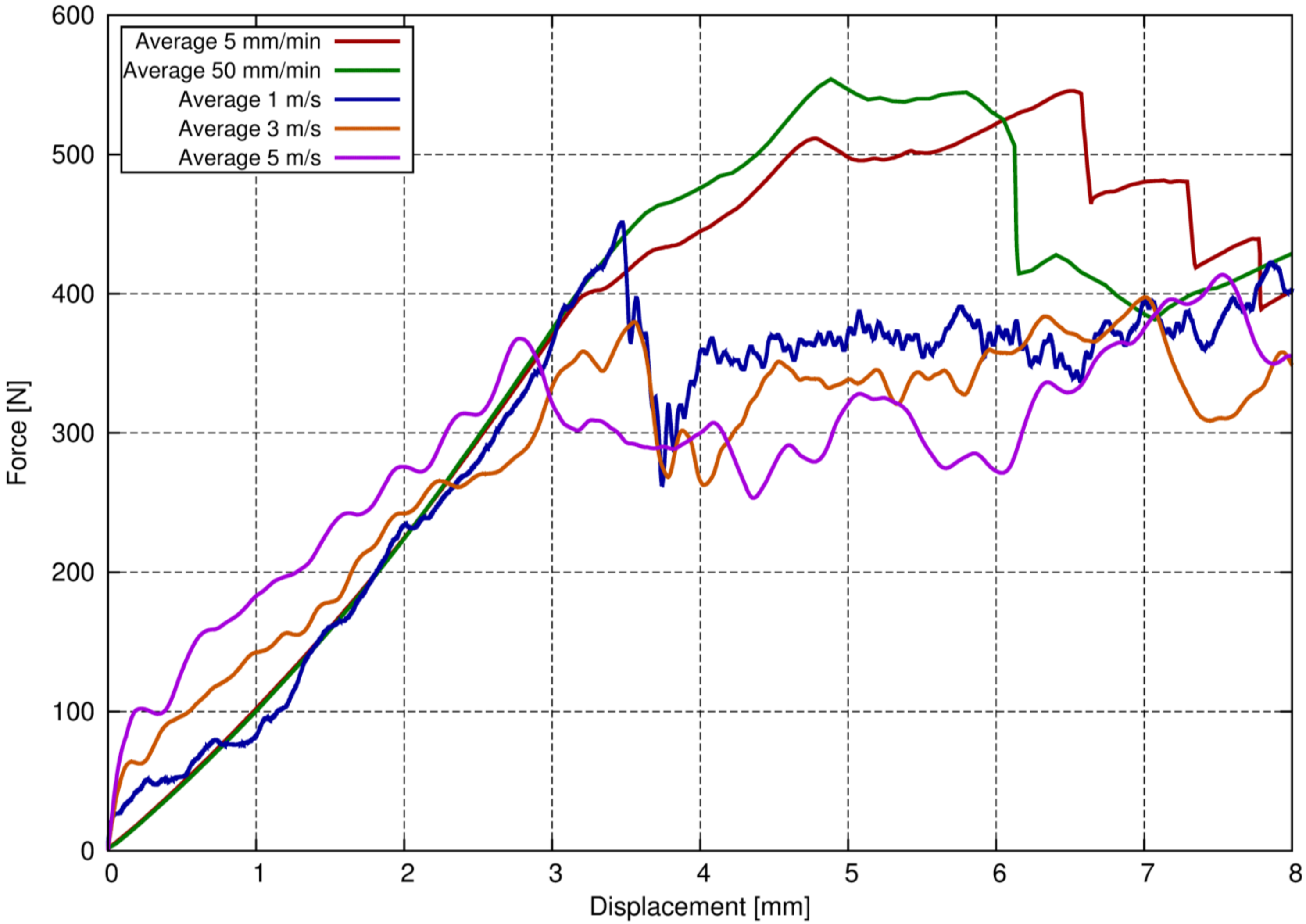
Model of the component used for filling simulation.



Component used for component tests.

Drop impact tester Instron CEAST 9350.

Component Testing



Material Cards – MAT024

- Linear elastic, isotropic viscoplastic model
- Seperate material cards for parallel and perpendicular orientation
  - Generated by optimizing material parameters to fit the three-point bending test curves
- Average card for quick and easy simulation
  - Both elastic modulus and load curves are averaged

Material Cards – MAT157

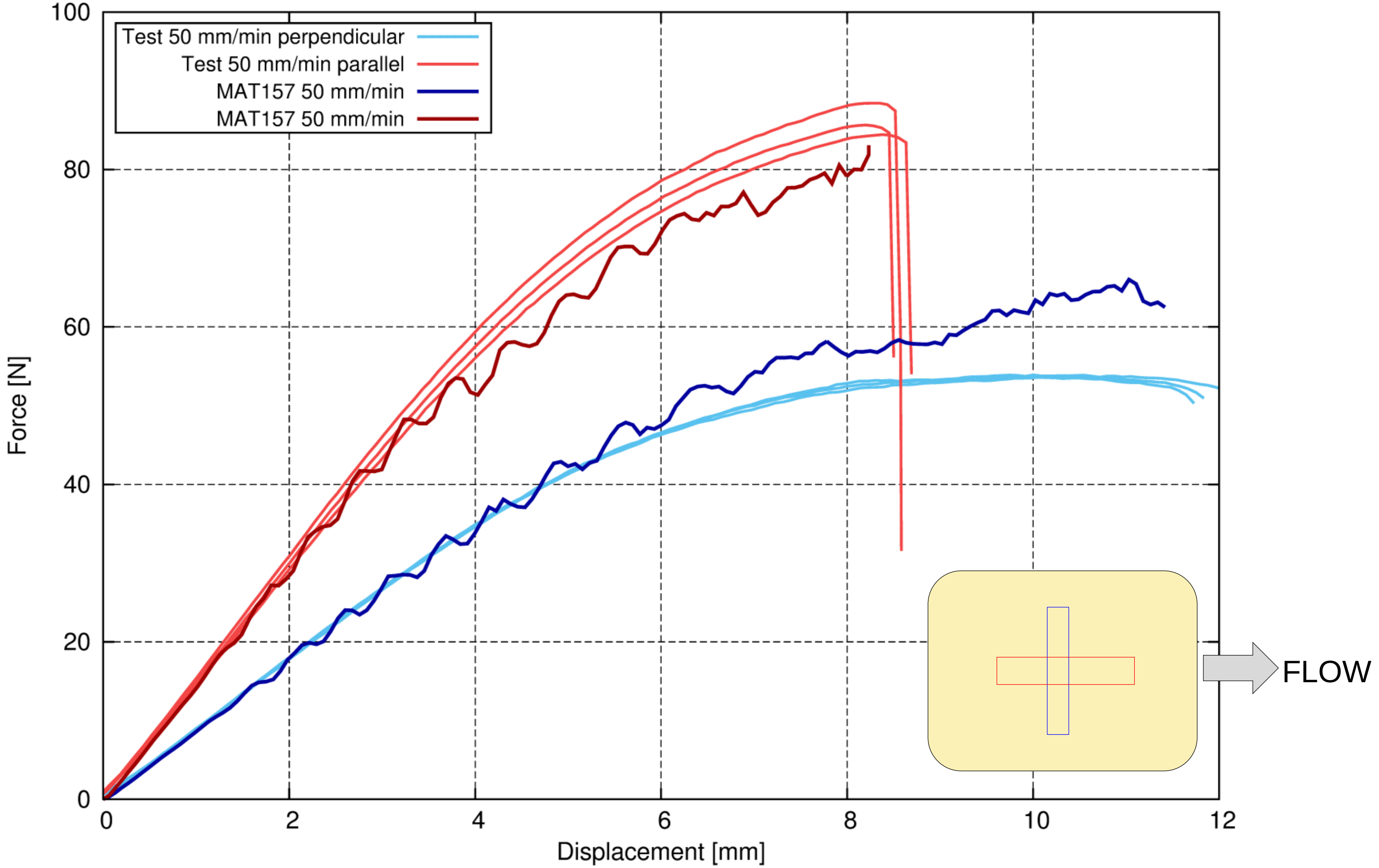
- Anisotropic elastic, anisotropic viscoplastic model
- R values are optimized to fit the three-point bending force-displacement curves parallel and perpendicular using the same card
- Orthotropic elasticity is realized by filling the constitutive matrix
  - E_a parallel elastic modulus
  - $E_b = E_c$ perpendicular elastic modulus
  - G_{bc}, G_{ac} and G_{ba} are shear moduli
  - $V_{bc} = v_{ac} = v_{ba}$ Poisson‘s ratio

$$C_L^{-1} = \begin{bmatrix} \frac{1}{E_a} & -\frac{\upsilon_{ba}}{E_b} & -\frac{\upsilon_{ca}}{E_c} & 0 & 0 & 0 \\ -\frac{\upsilon_{ab}}{E_a} & \frac{1}{E_b} & -\frac{\upsilon_{cb}}{E_c} & 0 & 0 & 0 \\ -\frac{\upsilon_{ac}}{E_a} & -\frac{\upsilon_{bc}}{E_b} & \frac{1}{E_c} & 0 & 0 & 0 \\ 0 & 0 & 0 & \frac{1}{G_{ab}} & 0 & 0 \\ 0 & 0 & 0 & 0 & \frac{1}{G_{bc}} & 0 \\ 0 & 0 & 0 & 0 & 0 & \frac{1}{G_{ca}} \end{bmatrix}$$

$$\frac{\upsilon_{ab}}{E_a} = \frac{\upsilon_{ba}}{E_b}, \frac{\upsilon_{ca}}{E_c} = \frac{\upsilon_{ac}}{E_a}, \frac{\upsilon_{cb}}{E_c} = \frac{\upsilon_{bc}}{E_b}$$

Constitutive matrix used in MAT157 [2].

Material Cards - MAT157 quasi-static



Material Cards - MAT157 all velocities

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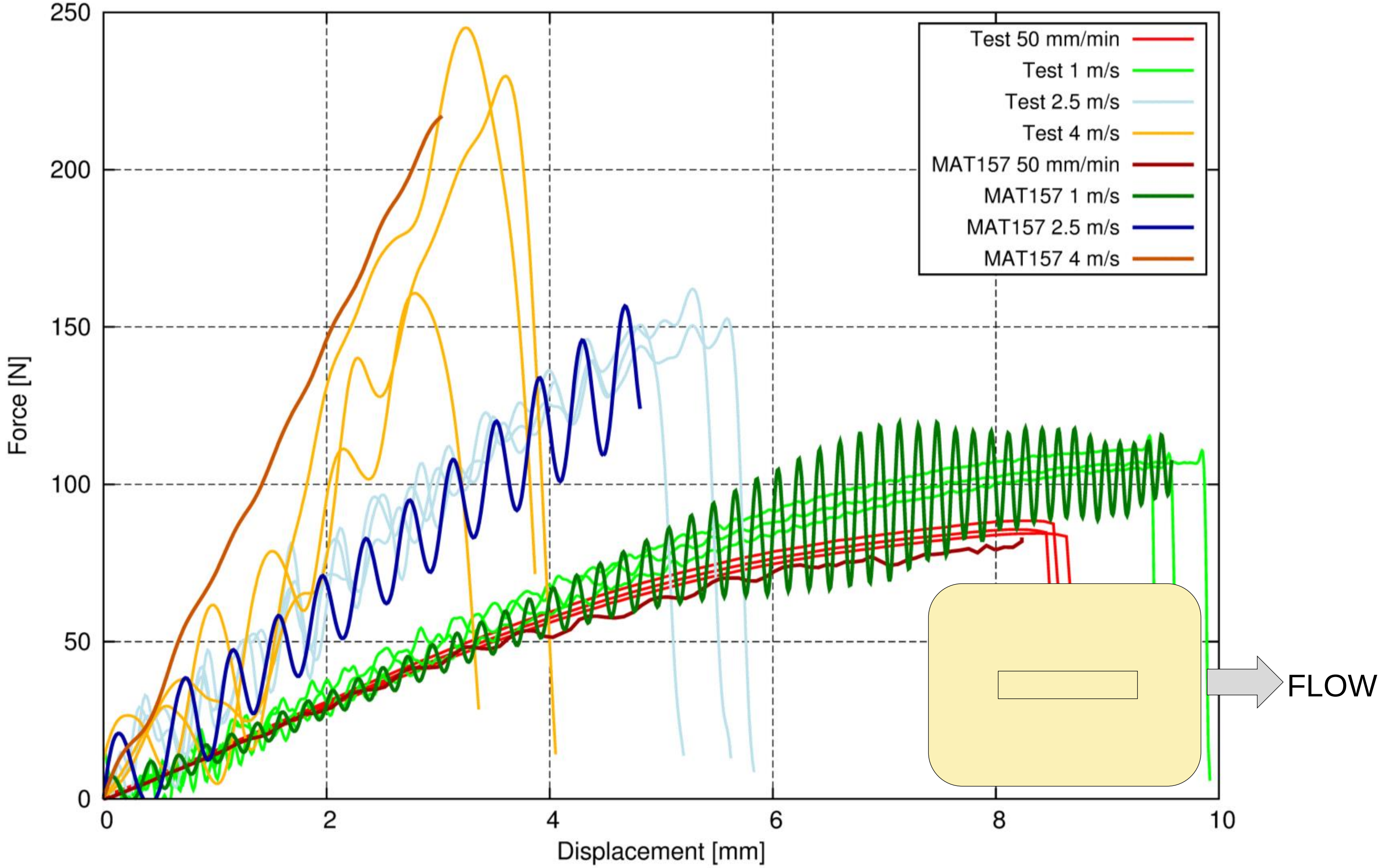
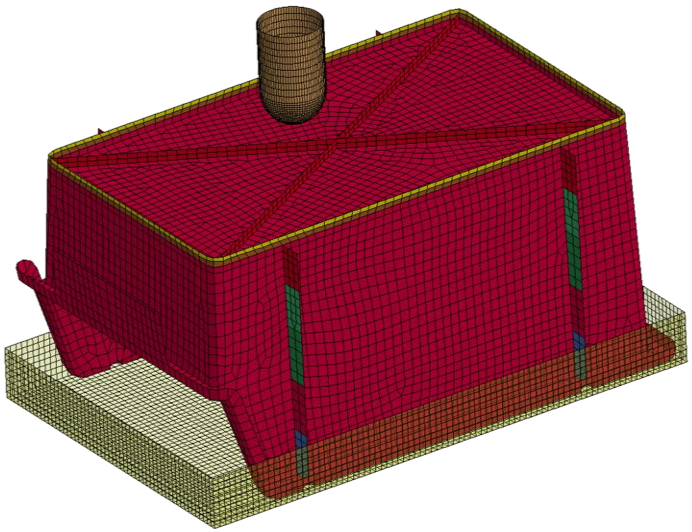


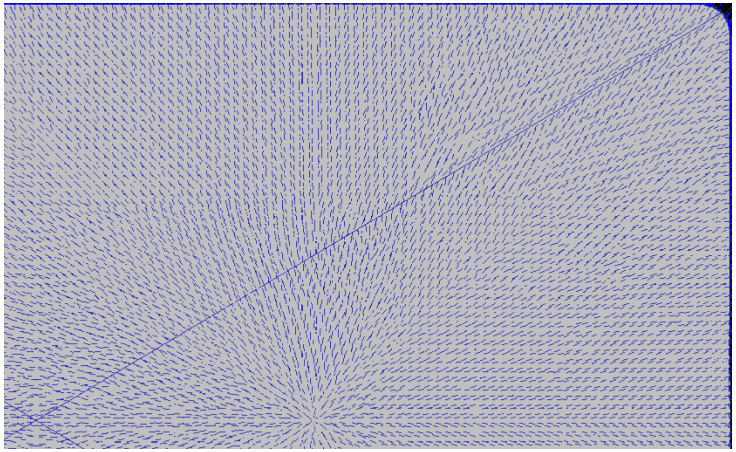
Component Simulation

- One layer of 3 mm shell elements
- Element formulation 2 (Belytschko-Tsay)
- Thickness differs throughout the model (1.0 mm – 2.2 mm)
- Element orientation is assigned via ELEMENT_SHELL_BETA
- The impactor and bearing are MAT_RIGID
- The impactor moves with an initial velocity between 1 m/s and 5 m/s and a mass between 5.5 kg and 31 kg

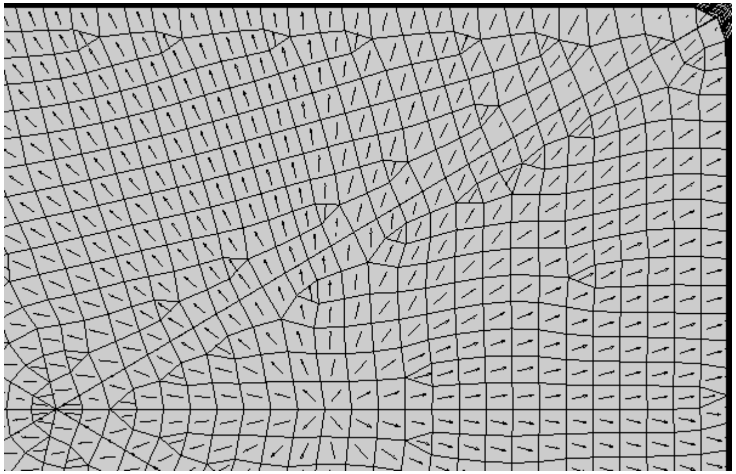


Mapping Fiber Orientation

- Average fiber orientation from filling simulation is mapped onto an FE model using 4a fibermap
- A specific orientation is assigned to each element by ELEMENT_SHELL_BETA

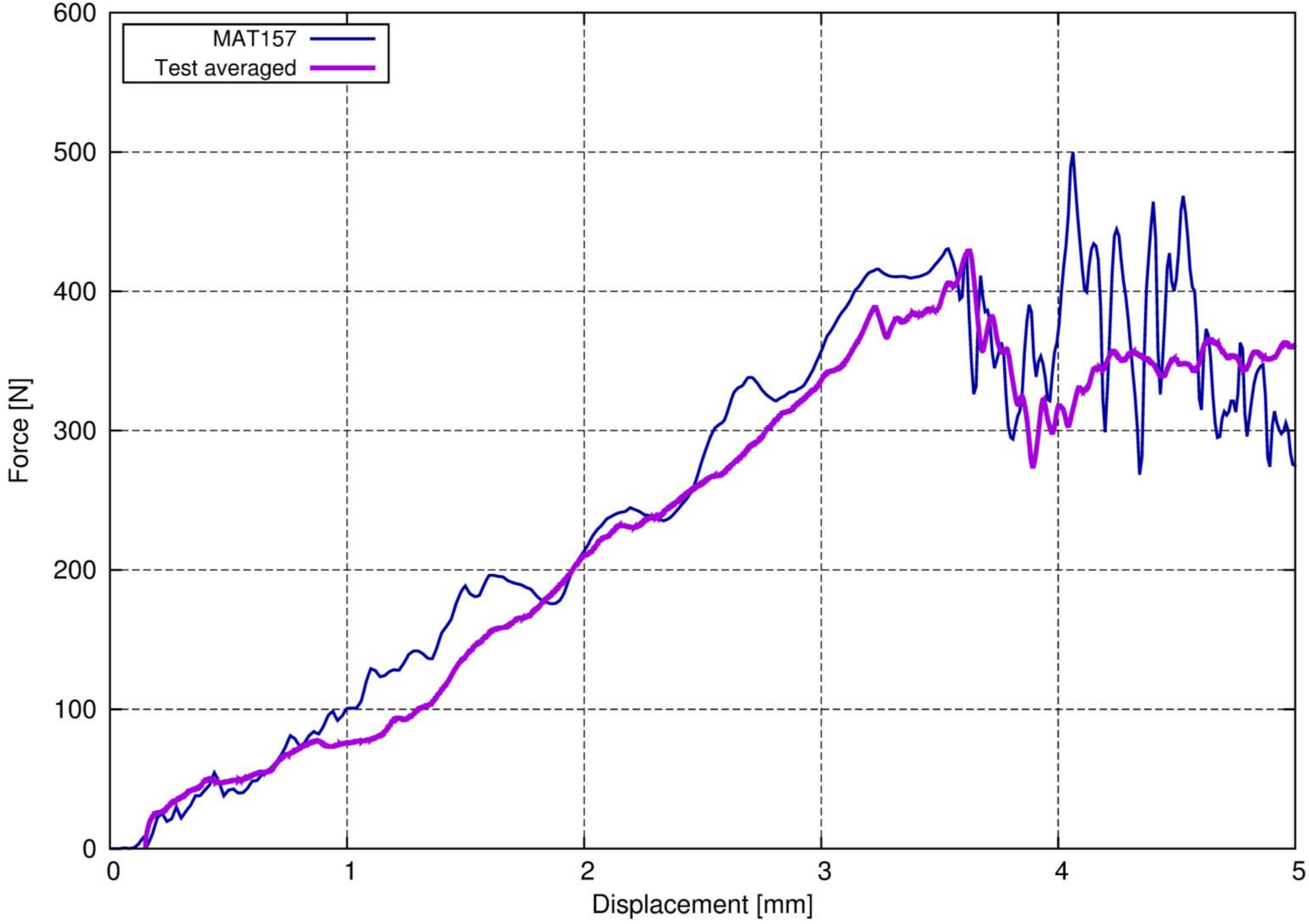


Part of the component's bottom with fiber orientations (Moldflow).



Part of the component's bottom with mapped element orientations.

Component Simulation 1 m/s



Component Simulation 1 m/s

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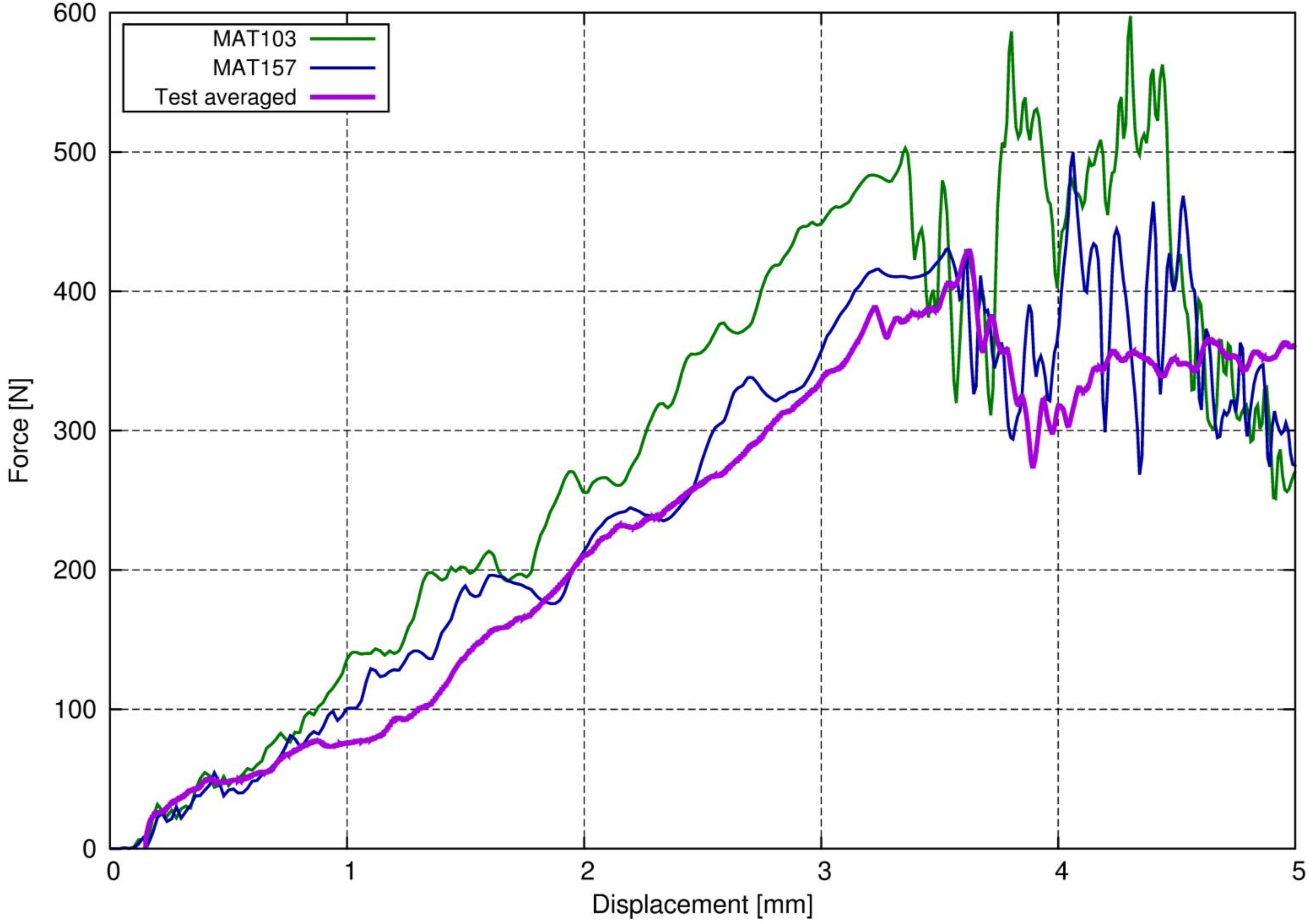

Component Simulation 1 m/s

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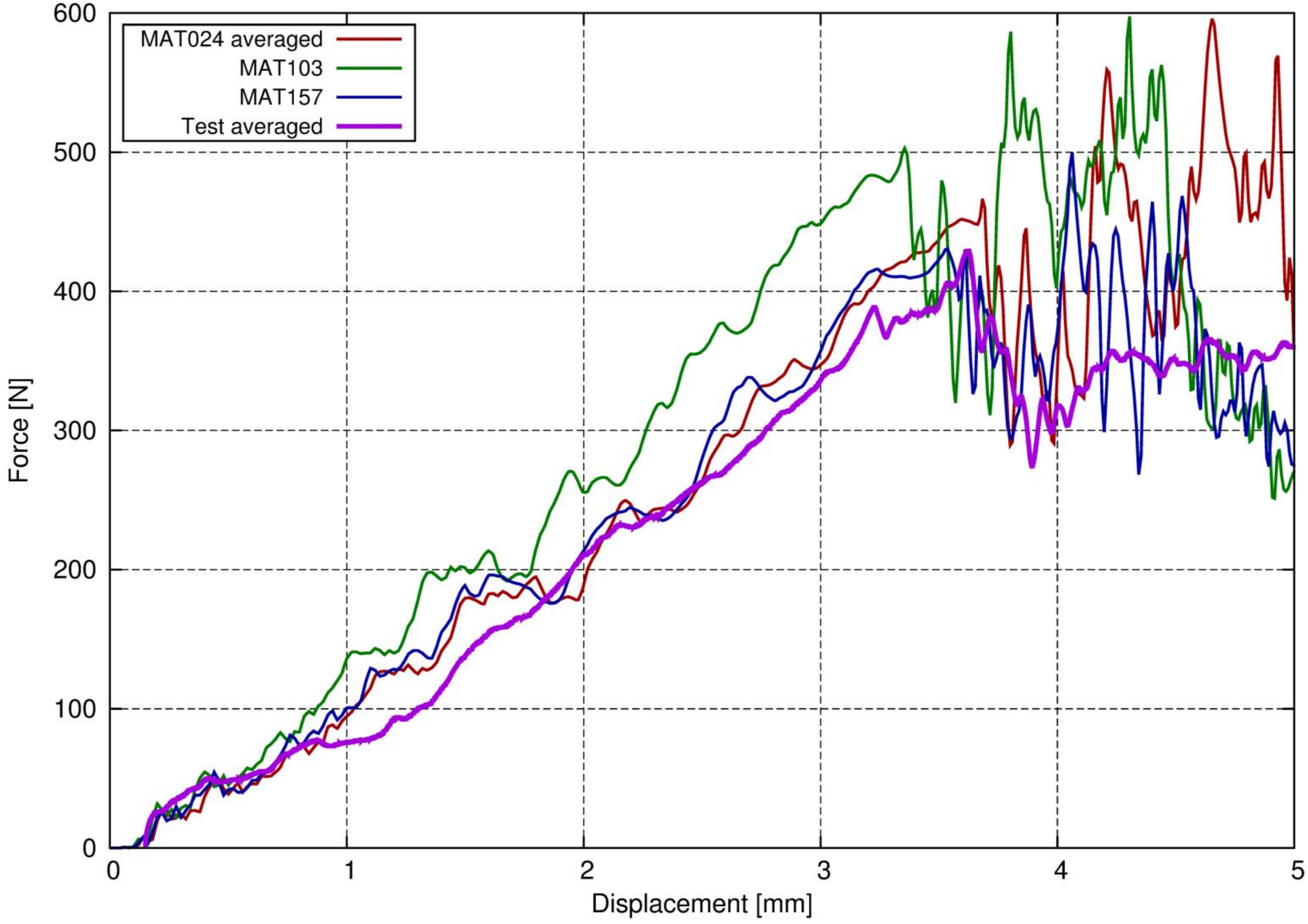

Summary

- The averaged MAT024 material model is sufficient for simulating deformation behavior without considering fiber orientation in this case
- For fully anisotropic simulation MAT157 can be used effectively
  - A model with mapped fiber orientation provides superior results
- Failure prediction is the weakest point in the simulation of reinforced plastics so far
  - The failure criterion must include the anisotropic material behavior like suggested by Vogler [3]

- As a workaround anisotropic failure will be attempted by layering MAT157 with MAT054 as proposed by Schöpfer in [4]

Literature

- [1] M. Nutini, M. Vitali: *Simulating anisotropy with Ls-dyna in glass-reinforced, polypropylene-based components*. 2010.
- [2] LS-DYNA User's Manual
- [3] M. Vogler, J. Schöpfer, S. Kolling, S. Mönnich, R. Glöckner: *Short Fiber Reinforced Polymers: Part II - Anisotropic Extensions of the SAMP-Model*. 11th LS-DYNA Forum, 2012.
- [4] J. Schöpfer: *Spritzgussbauteile aus kurzfaserverstärkten Kunststoffen: Methoden der Charakterisierung und Modellierung zur nichtlinearen Simulation von statischen und crashrelevanten Lastfällen*. 2011.

Backup: Component Testing