TeaM Cables

Project presentation

TeaM Cables– facts and figures

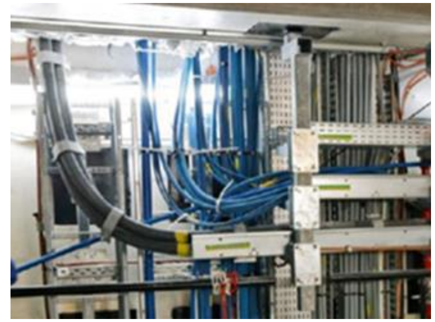
13 partners – 6 countries
Start: September 2017
Budget: 5.5 M€
EC Funding: 4.2 M€
End: February 2022

The TeaM Cables consortium involves participants covering the main players of the Nuclear Power Plant (NPP) cable research, including one cable manufacturer, renowned research institutes and academia and NPP industry:

1. Electricité De France (EDF)
2. Framatome GmbH (Former Areva GmbH)
3. Institut De Radioprotection Et De Sureté Nucléaire (IRSN)
4. Commissariat à l'Energie Atomique et aux Energies Alternatives (CEA)
5. UJV REZ, A.S.
6. ARTTIC
7. Nexans France S.A.S
8. Instytut Chemii i Techniki Jadrowej (INCT)
9. Fraunhofer Gesellschaft Zur Foerderung Der Angewandten Forschung E.V. (IZFP)
10. Teknologian tutkimuskeskus VTT Oy
11. Université d'Aix Marseille (AMU)
12. Ecole Nationale Supérieure d'Arts et Métiers (ENSAM)
13. Alma Mater Studiorum – Universita di Bologna

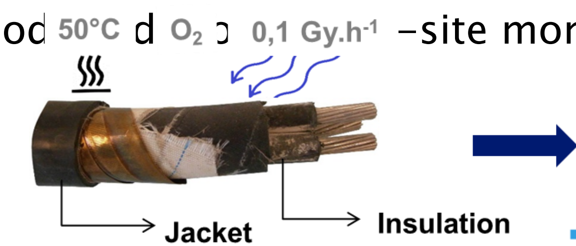
Rationale

- 1 Nuclear Power Plant unit
  - ~1,500 km of electrical cables
  - ~25,000 connections



- Electrical cables are the nerves and blood vessels of NPPs
- In the context of the long term operation (over 40 years) of the NPPs, complete cable replacement is not economically viable
- Electric cables are diverse with different designs and materials
- Polymer ingredients impact dramatically polymer properties and ageing (at least 5 ingredients in one industrial polymer)

⇒ Need for
  - Generic accurate predictive lifetime models
  - Generic method d –site monitoring of cables



Cable ageing ~ polymer layers ageing

Photo of a nuclear cable

TeaM Cables innovation

The main innovation of the project is the radically new way of estimating the lifetime duration of cables, using much more precise information and more relevant methods for analysing the data.

The approach is based on multi-scale studies of the materials.

Project aim

- TeaM Cables aims at providing NPP operators with a novel methodology for efficient and reliable NPP cable ageing management by

1. developing cable ageing models and algorithms based on multi-scale studies and addressing the problem of complex polymer formulation

2. developing methodologies for on-site monitoring and identifying associated criteria from multiscale relations

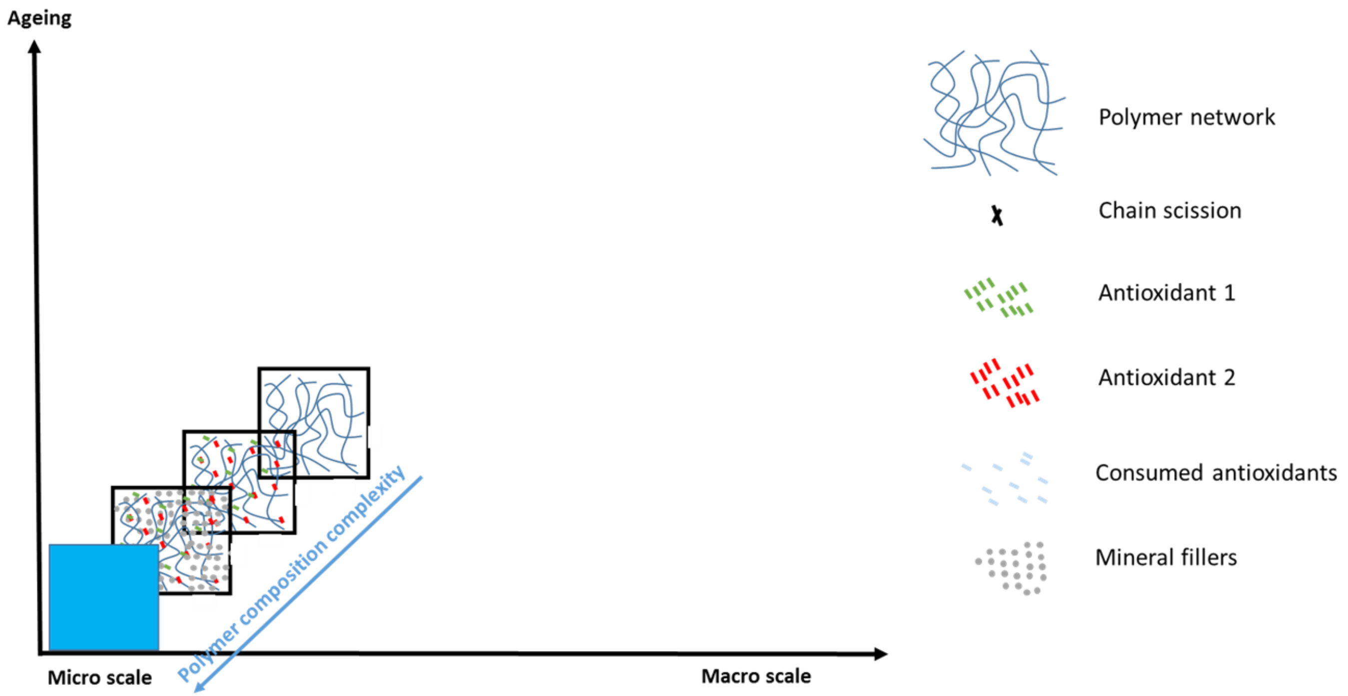
3. developing a novel numerical tool integrating the models developed and providing the residual lifetime of cables by crossing on-site measurements with predictive models and knowledge of cable exposure conditions (wiring network in the NPP).

Specific scientific and technical objectives

- Carry out accelerated ageing representative of service conditions inside a reactor building on model materials and on real cables to identify polymer additive contribution in ageing mechanisms
- Identify the impact of ageing on the behaviour of cables subject to accidental conditions
- Develop and validate a kinetic model for polymer ageing
- Develop multiscale models (mechanical, physical, electrical) based on output data of the kinetics models
- Contribute to standards on cable ageing characterisation
- Define criteria and deployment protocols for on-site monitoring techniques
- Provide and promote a tool for cable ageing management and lifetime prediction integrating the models developed

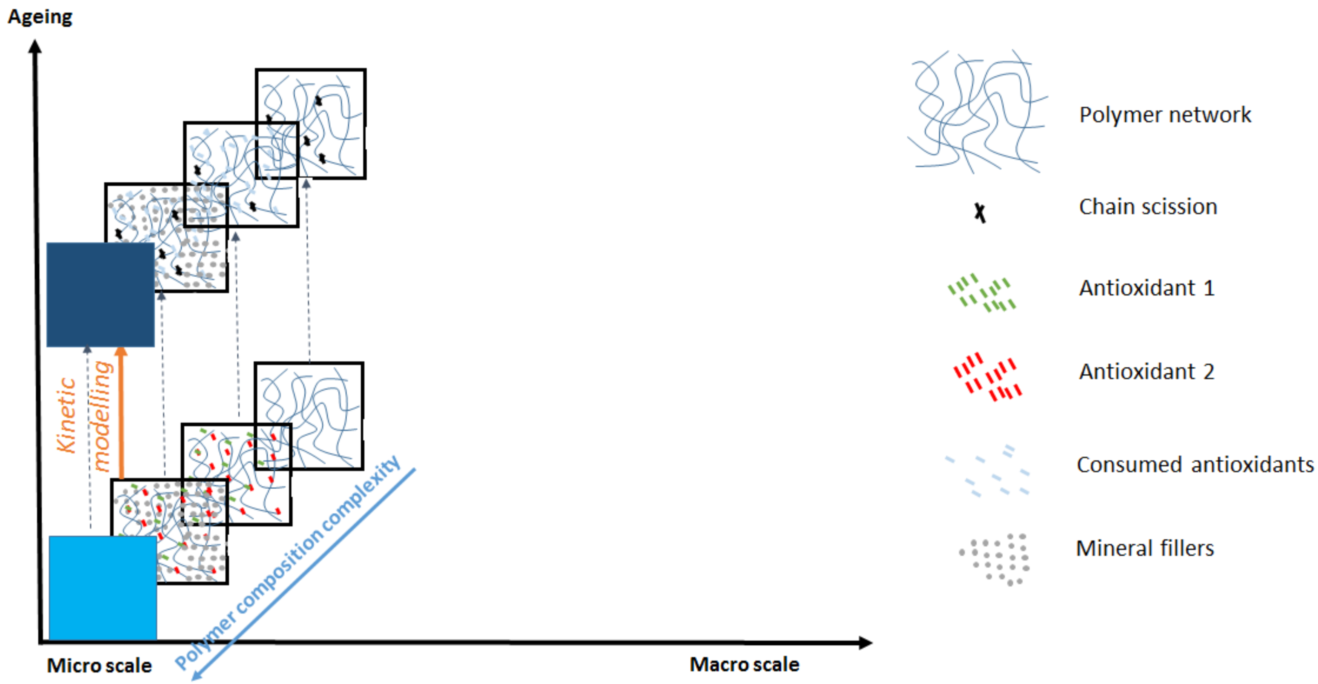
Scientific approach

- Polymers with growing formulation complexity to allow the role of each ingredient during the polymer ageing to be identified and modelled.



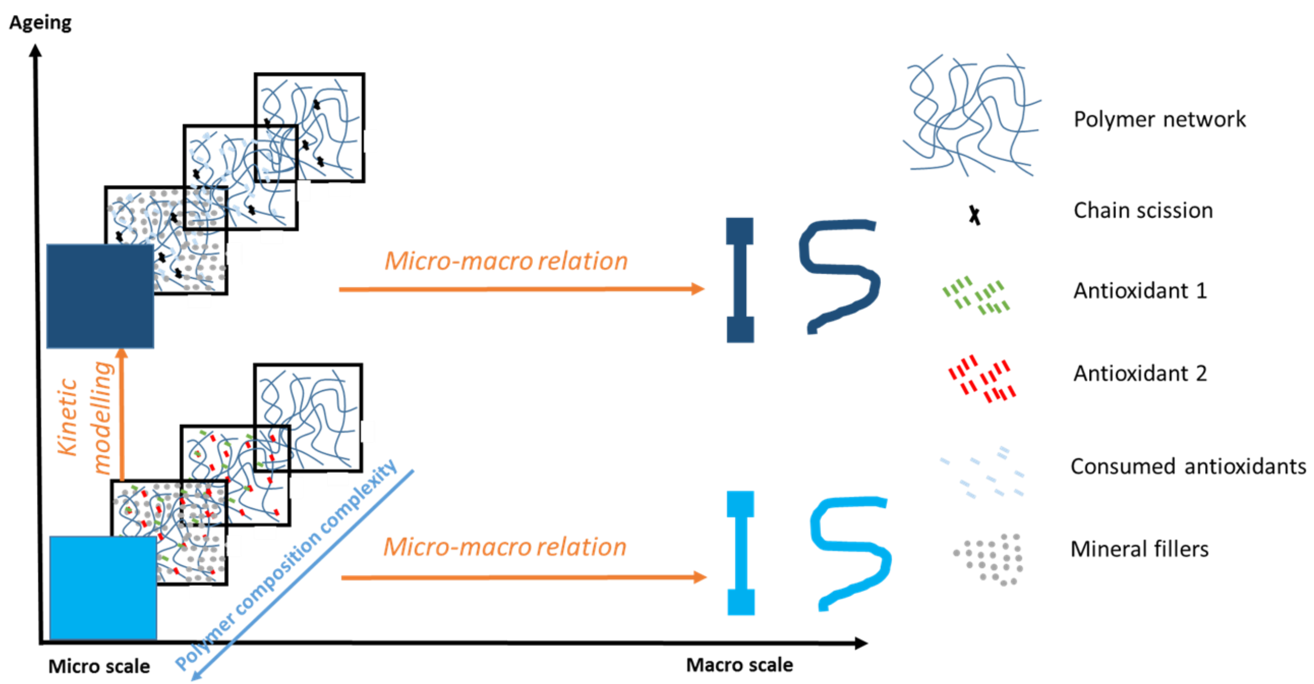
Scientific approach

- Identification and modelling of the impact of each ingredient at the micro scale.

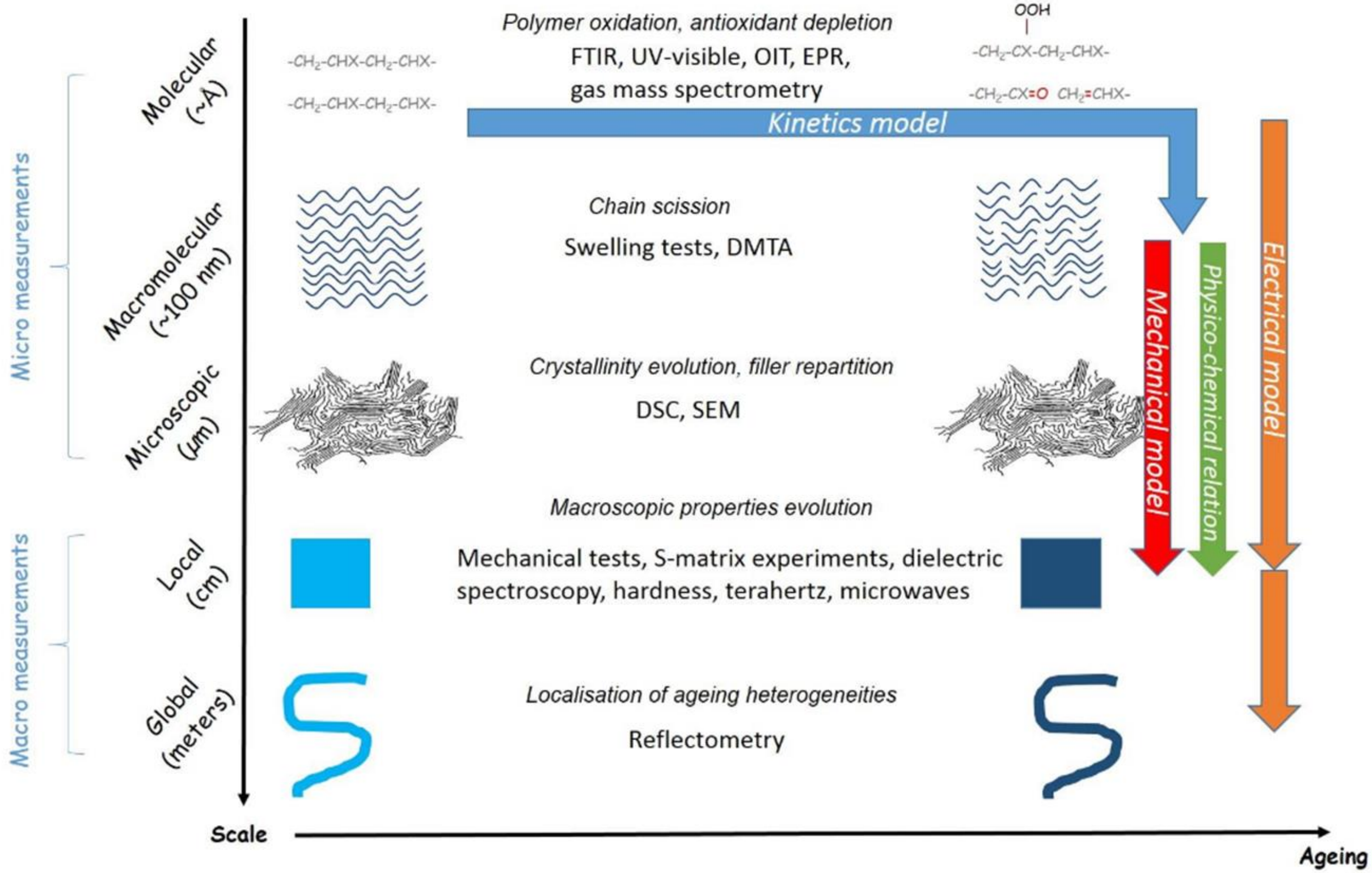


Scientific approach

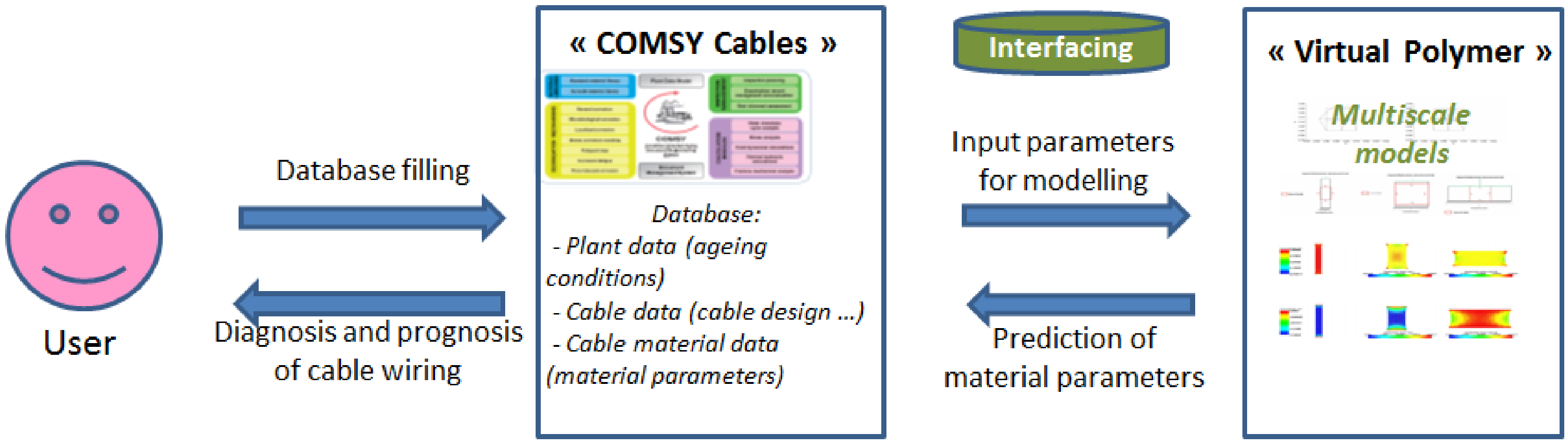
- Identification and modelling of the impact of changes at the micro scale on the macro scale.



Multiscale characterisation and modelling

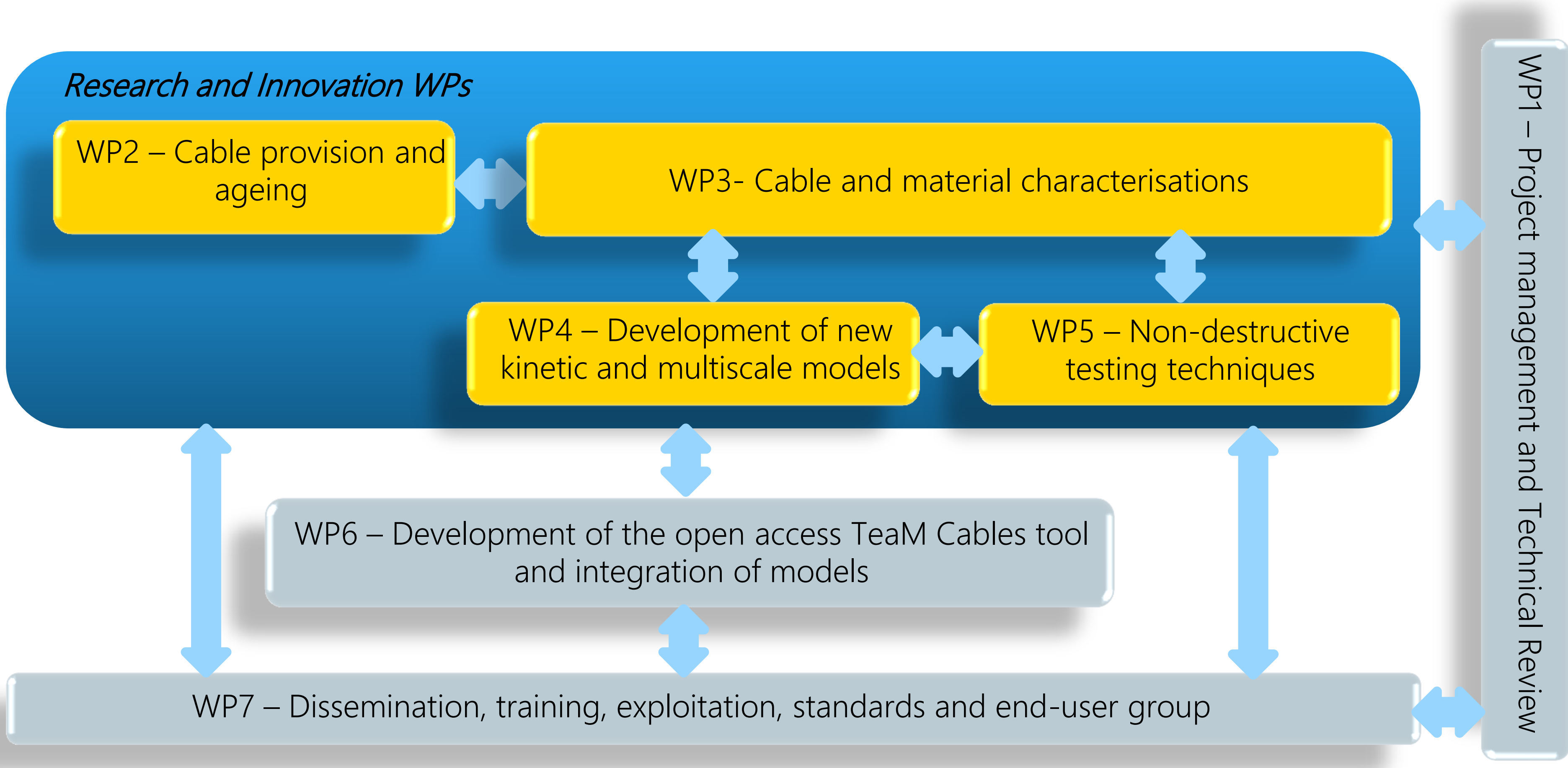


TeaM Cables tool for cable ageing management



TeaM CABLES production

Workplan structure



Expected project outcomes

- A partly publically available database with experimental results.
- A new multiscale modelling approach to predict polymer ageing addressing the problem of complex polymer formulation. This approach will be generic, thus applicable/transposable to various polymers families and formulations.
- Proposals for elaboration and revision of standards of characterisation tests.
- New methodologies for on-site monitoring giving access to data usable for residual lifetime calculation.
- An improved "TeaM Cables tool" integrating modelling and monitoring developments of this project for supporting the cable ageing management and lifetime prediction, and so leading to a more accurate level than what is possible today
- 2 workshops, 1 symposium, a website, a leaflet, dissemination of tools (training sessions …)

Expected impact

Reinforce safety of generation II and II reactors

Contribute to new or improved standards within IEC/TC45 A, IEC/SC45A and CENELEC TC45 committees

Increase the confidence in the predictability of the lifetime of NPP cables in the context of long term operation

Improve the market profile of EU-based reactor designs

New knowledge on polymers and cables useful also in other industry sectors

Improve innovation capacity and integration of knowledge

Improve public perception of nuclear safety through specific dissemination actions

TeaM CABLES

European Tools and Methodologies for an efficient ageing management of nuclear power plant Cables

HORIZON 2020

TeaM Cables

Microstructural FEM simulations and aging in molecular dynamics simulations

Multiscale models

- MD simulations and graph simulations
  - To model the effect of aging to the polymer
- Microstructural models (FEM)
  - To understand how the fillers affect the matrix: determine stress distribution, study fracture processes and perform homogenization
- Sample scale models (FEM)
  - To reproduce real experiments and validate the material models on the macro-level

Material model (XLPE)

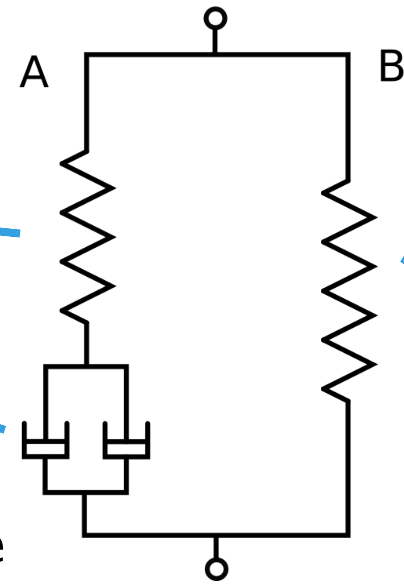
A thermo-elasto-viscoplastic constitutive model for XLPE:

- Strain rate dependent
- Temperature sensitive (including self-heating)

Part A:
crystallinity phase

Hencky hyperelasticity

Ree-Eyring viscoplasticity:
α-relaxation: full main chain segmental motion
β-relaxation: partial mobility of the main chain

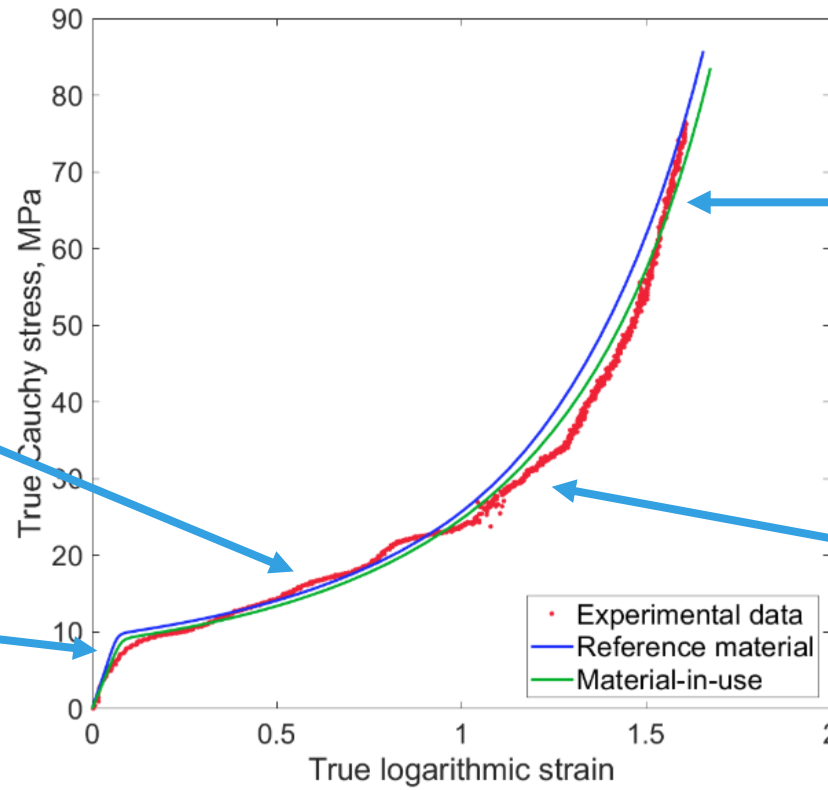


Part B:
orientational hardening due to polymer chains alignment
(eight chain model)

Material model (XLPE)

Crystalline phase: viscoplastic

Hyperelastic

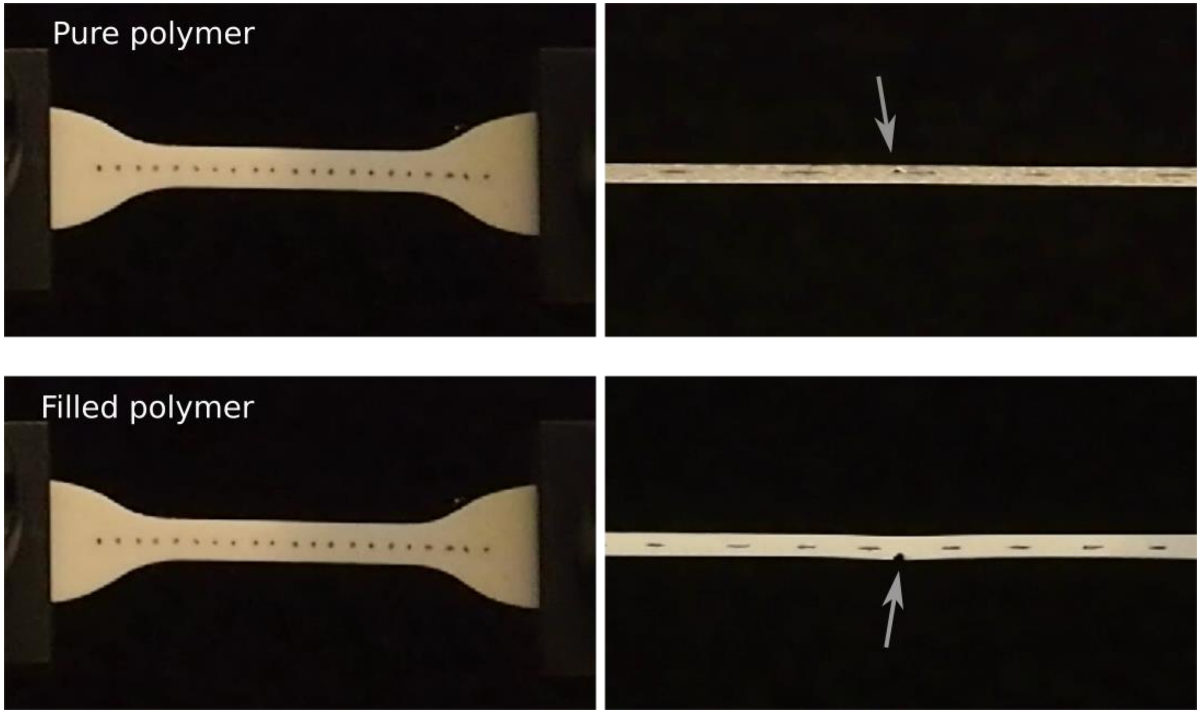


Strain hardening (chains alignment)

Entangled polymer flow (high strain rates)

Experimental data is based on the video analysis of tensile tests

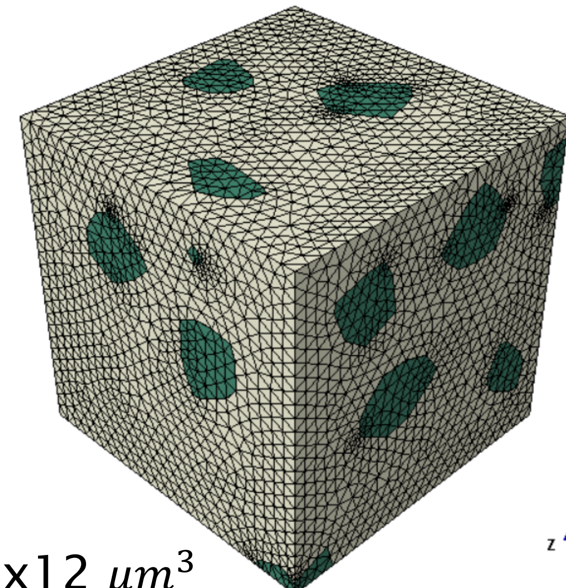
Video analysis



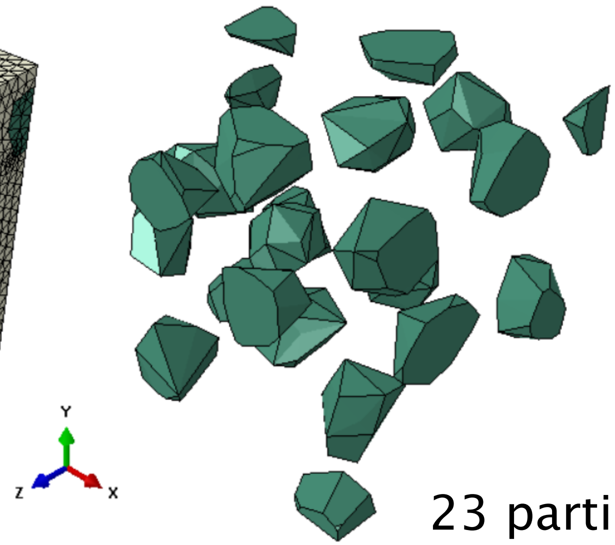
Different fracture behavior for the unfilled and filled polymer

Microstructural model

A representative volume for polymer with fillers:



Cube 12x12x12 μm^3



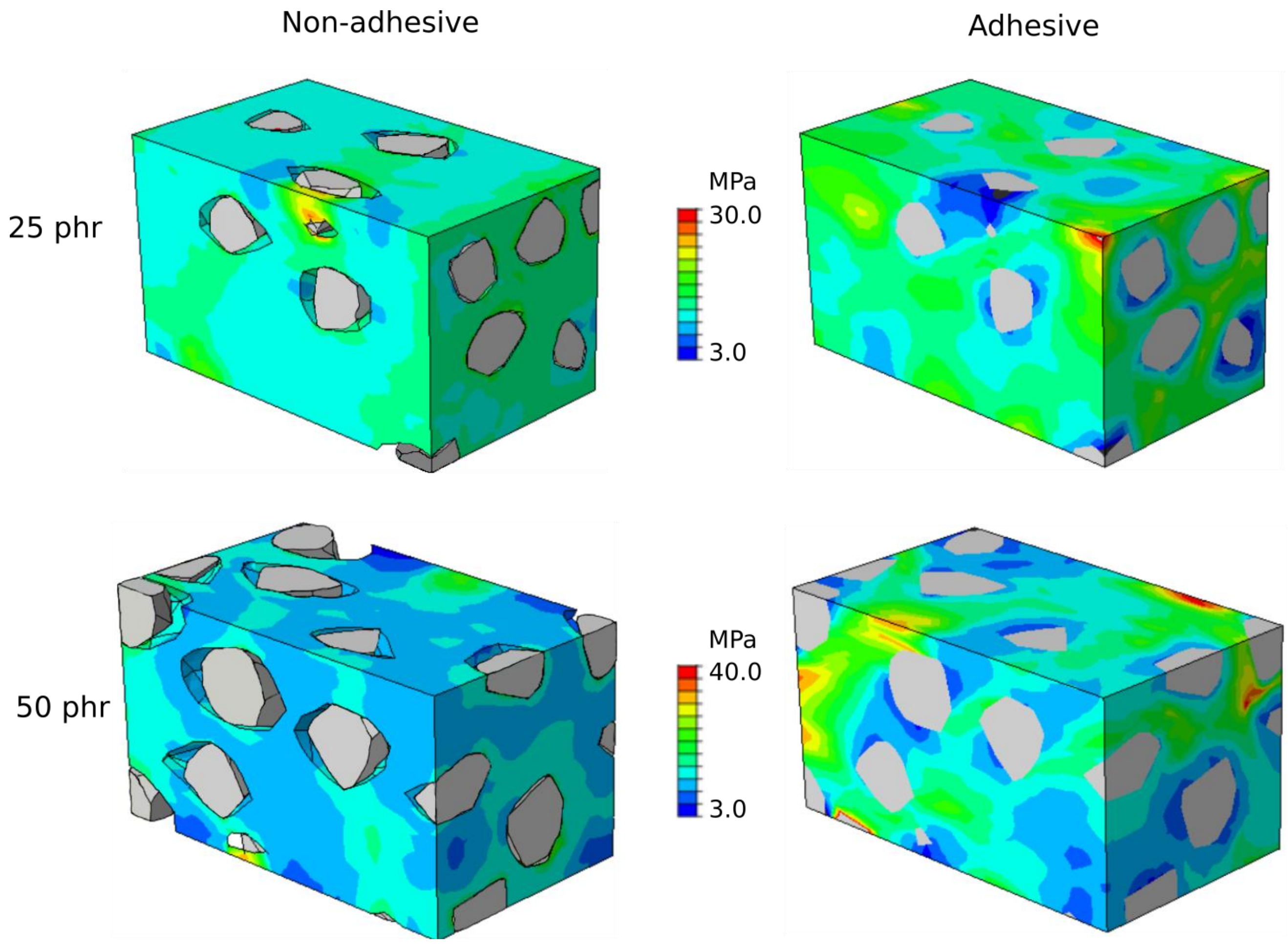
23 particles (25 phr)

Two loadings (25 and 50 phr)

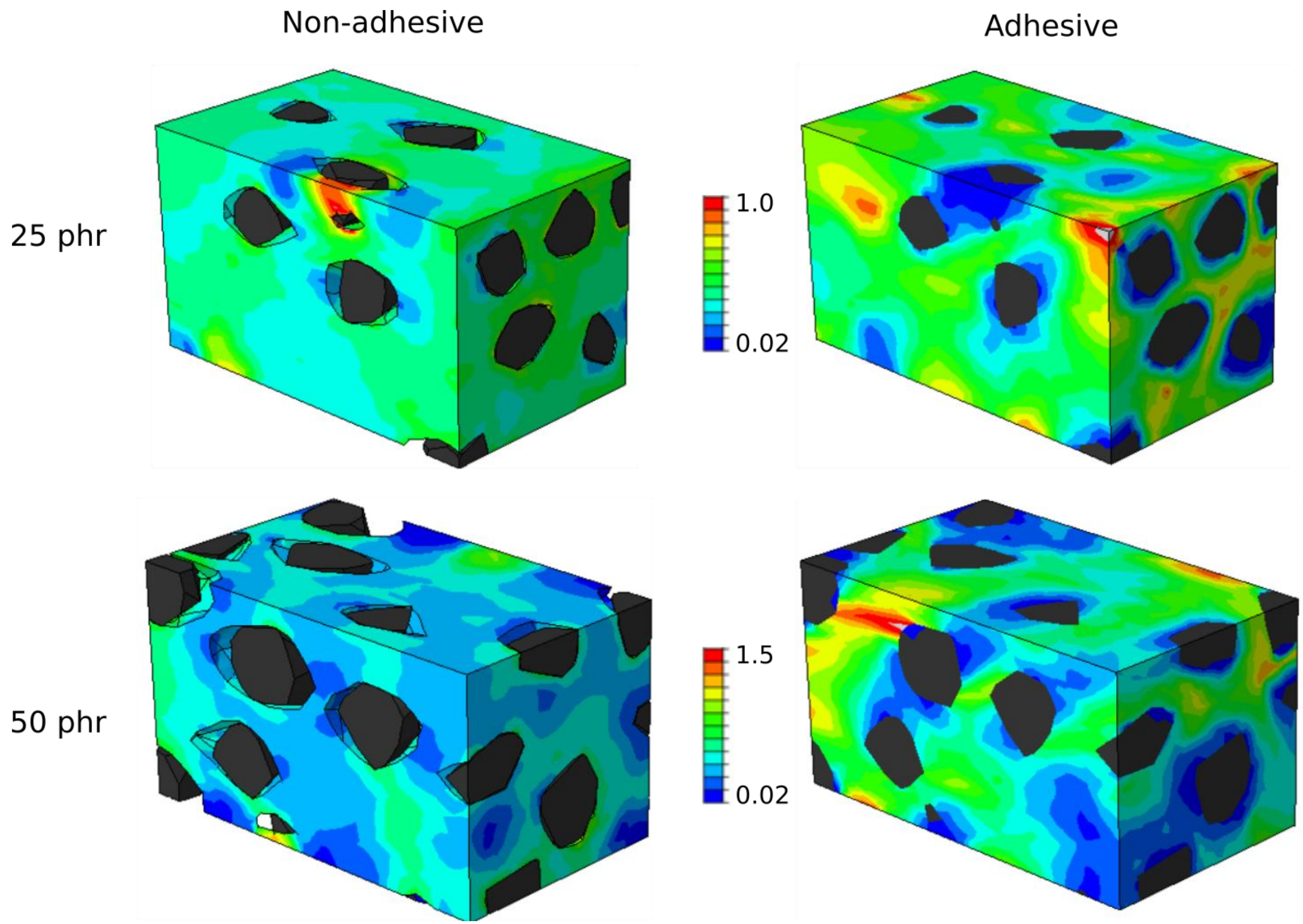
ATH fillers: simple elastic model

Two interaction models:
- Without adhesion
- With perfect adhesion

Von Mises stress



Logarithmic principal strain

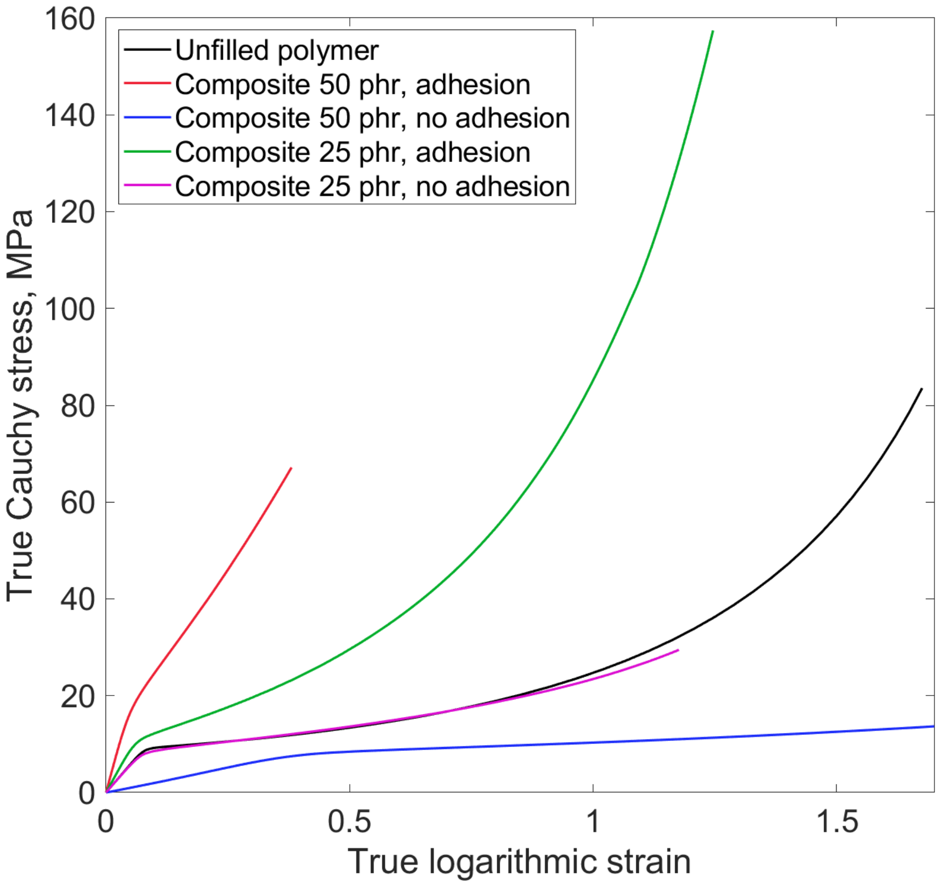


Stress-strain curves

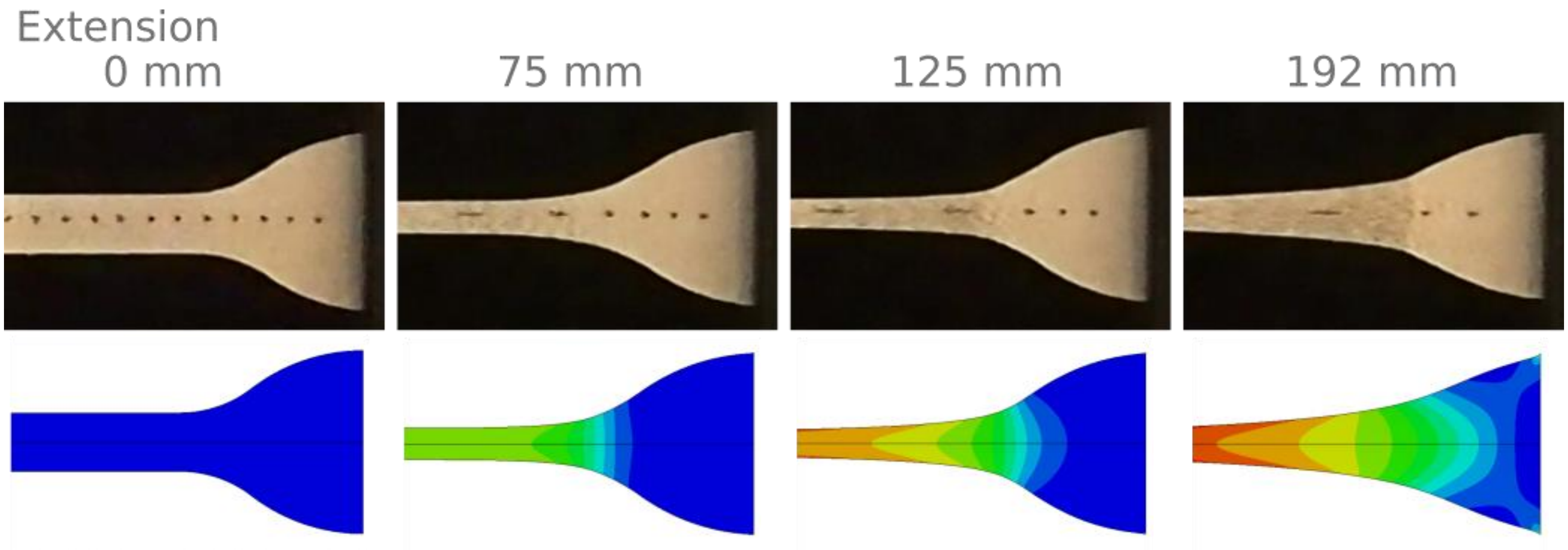
Experimental data:
Fillers give the reinforcing effect

Ongoing work: cohesive model for interactions between matrix and filler particles

Larger representative volumes for future tests



FEM simulations of real experiments



Future work: microstructure-based fracture model describing the failure of the specimens

Ageing and future work

- MD simulations will show how ageing affects the material properties
- FEM simulations of real experiments with aged material will be used for validation
- Improved interaction model between matrix and fillers will be used in the further simulations
- Fracture models should be introduced for better predictions of the material behaviour

Thank you!

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