

## **Ph.D. Thesis Review**

Author: Julian Niklas Rech

Thesis Title: Reinforcing mechanisms of polymer matrix composites: evaluation and modeling of matrix/dispersed phase interrelationship

Degree Programme: P0719D130002 Nanotechnology and Advanced Materials

Supervisor: Prof. Ing. Berenika Hausnerová, Ph.D.

Consultant: Prof. Dr.-Ing. Bernhard Möglinger

Institution: Tomas Bata University in Zlín

Reviewer: Prof. Ing. Petr Slobodian, Ph.D.

### Summary of the Thesis

Julian Rech's doctoral thesis presents a comprehensive and in-depth investigation of the mechanical behavior of polymer matrix composites (PMCs), with emphasis on:

- Process–structure–property relationships,
- Modeling of elastic and viscoelastic behavior,
- The role of interfacial adhesion between matrix and dispersed phase.

The thesis notably expands the classic Paul and Ishai-Cohen stiffness models by introducing the Elementary Volume Concept (EVC), incorporating an adhesion coefficient that quantifies imperfect filler-matrix bonding. This allows for more accurate modulus predictions and creep behavior modeling for both particle- and fiber-reinforced systems.

Additionally, the impulse excitation technique (IET) is validated as a fast, non-destructive method to characterize elastic moduli, with good agreement to conventional mechanical tests (tensile, DMA, and creep).

### Scientific Merit and Originality

The thesis demonstrates a high scientific level, particularly in:

- Providing a critical and structured review of mechanical models for composites,
- Developing new models that incorporate time-dependent interfacial adhesion,
- Validating these models experimentally across several polymer systems,
- Demonstrating the potential of IET for high-throughput material evaluation.

The originality lies in the multi-faceted integration of analytical modeling, advanced testing techniques, and practical verification with real composite systems.

### Structure and Presentation of the Thesis

The thesis is logically organized and clearly written in academic English. It consists of:

- A well-developed literature review (Chapter 1),
- A clearly defined research aim (Chapter 2),
- Comprehensive methodology (Chapter 3),
- Robust experimental results and thoughtful discussion (Chapter 4),
- A concise conclusion and practical implications (Chapters 5–6).

Annexes include a detailed list of figures, tables, abbreviations, nomenclature, and the candidate's publication record.

### Scientific and Practical Contribution

This work makes a valuable contribution to both scientific understanding and industrial applications by:

- Providing a reliable method for stiffness and creep prediction in PMCs,
- Introducing a model that accounts for interfacial behavior over time,
- Offering guidance on how to tailor filler-matrix combinations for mechanical performance,
- Enabling the use of fast, non-destructive testing (IET) for quality control or design.

The modeling approach and empirical data are particularly useful for applications in automotive, aerospace, or packaging industries using glass bead- or fiber-filled thermoplastics.

### Remarks and Suggestions

The dissertation is of outstanding quality. Minor suggestions include:

- A deeper discussion of how surface morphology (via SEM or AFM) correlates with the measured adhesion coefficients.
- Highlighting the limitations of the IET method—e.g., possible effects of sample geometry or anisotropy—could add nuance to its practical use.
- In the simulation section (Chapter 1.6), including an example of how RVE modeling was applied to a system from the experimental section would improve the connection between theory and practice.

These remarks are minor and do not detract from the scientific quality of the thesis.

### **Final Recommendation**

Julian Rech's dissertation is a rigorous, innovative, and well-executed piece of scientific work. It reflects the author's deep understanding of polymer composites, his ability to independently solve complex problems, and his commitment to scientific excellence.

I fully recommend that the thesis be accepted for defense and the doctoral degree (Ph.D.) be awarded.

Questions for candidate:

1. How can the model be applied to unknown polymer matrices where material properties are largely unknown?
2. How does the validity of the model change at higher filler contents above 20 vol.%? (included in the answers to the review of Mr. Filip)
3. How sensitive is the model to uncertainties in determining the interfacial adhesion coefficients?
4. What are the advantages of the impulse excitation technique (IET) compared to DMA and tensile testing? Where are its limitations?
5. Which aspects of your work are most relevant for industrial applications?

In Zlin 3<sup>rd</sup> August 2025

Prof. Ing. Petr Slobodian, Ph.D.