ACOUSTIC EMISSION FOR IDENTIFICATION OF THE DOMINANT STRESS COMPONENT IN POLYMER COMPOSITES AT EARLY LOADS

1ST INTERNATIONAL ELECTRONIC CONFERENCE ON APPLIED SCIENCES

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MeMC
MECHANICS OF MATERIALS & CONSTRUCTIONS

PRESENTATION OUTLINE

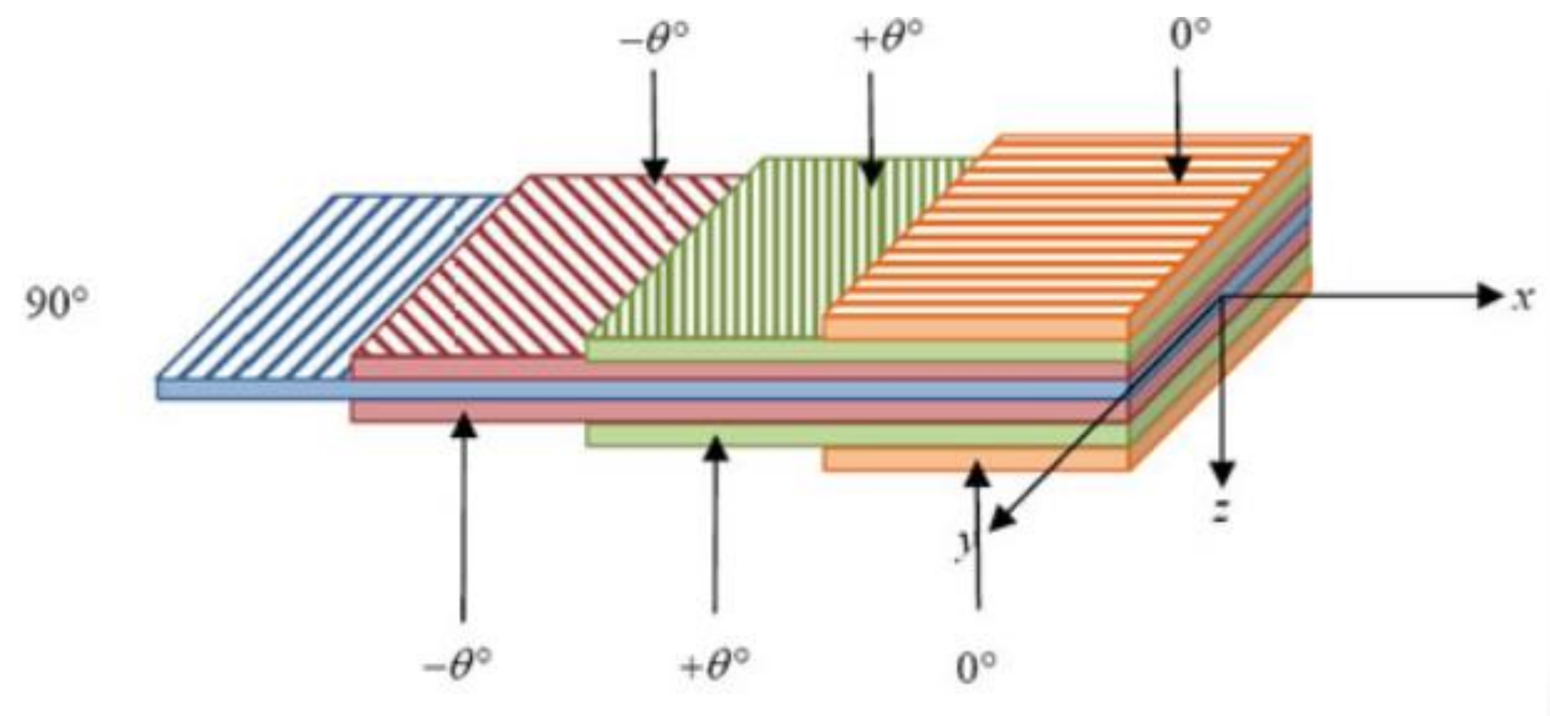
- Introduction
- Theoretical background
- Aim of the study
- Material and testing equipment
- Experimental results: quasi-static tests
- Experimental results: incremental loading tests
- Conclusions

INTRODUCTION

- Reduction of weight → primary target in many engineering fields
- Fibre reinforced polymer composite materials → promising for reducing weight and CO_2 emissions
- **Main advantage**: <u>lightweight materials</u>
- Carbon Fibre Reinforced Polymer (CFRP): extra advantages like exceptional durability, application flexibility, corrosion resistance

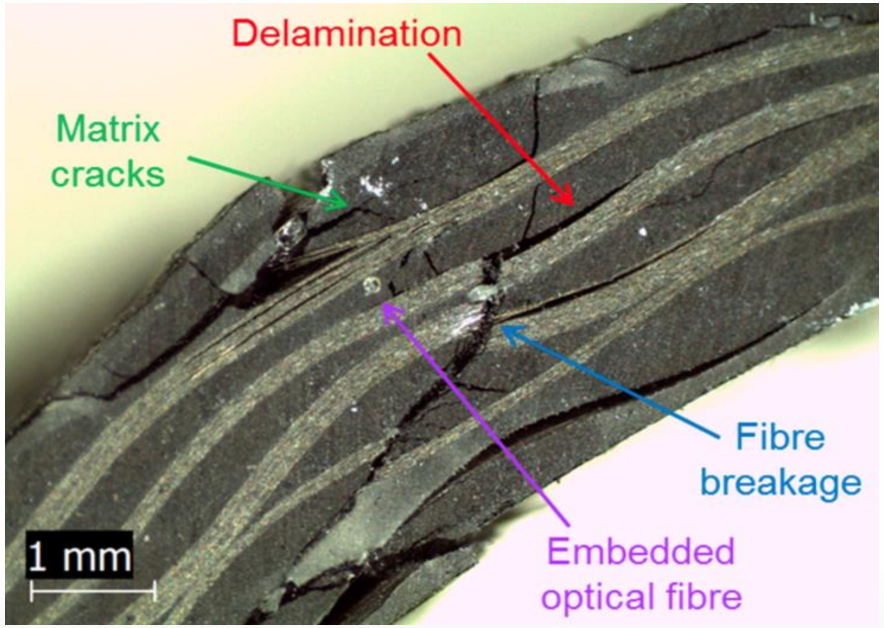
THEORETICAL BACKGROUND

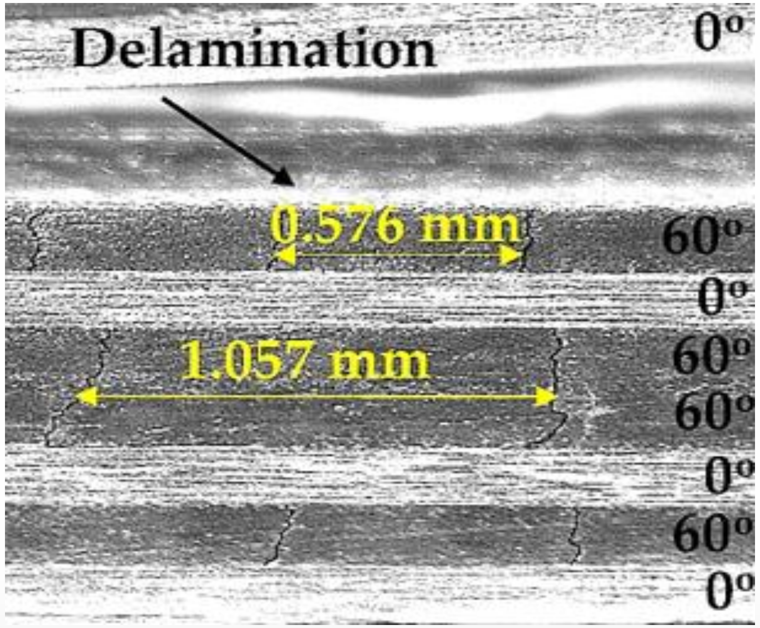
- Composites: **anisotropic materials**
- **Multiaxial stresses** occur in the composite laminas even under uniaxial loading due to different fibre orientations (internal multiaxiality)



THEORETICAL BACKGROUND

- **Damage sequence in composites** is complicated (interfacial debondings, matrix cracks, delaminations, fibre breaks)
- Even more complicated when multiaxial stresses occur → can lead to different mechanical response, influencing the structural integrity of the laminate

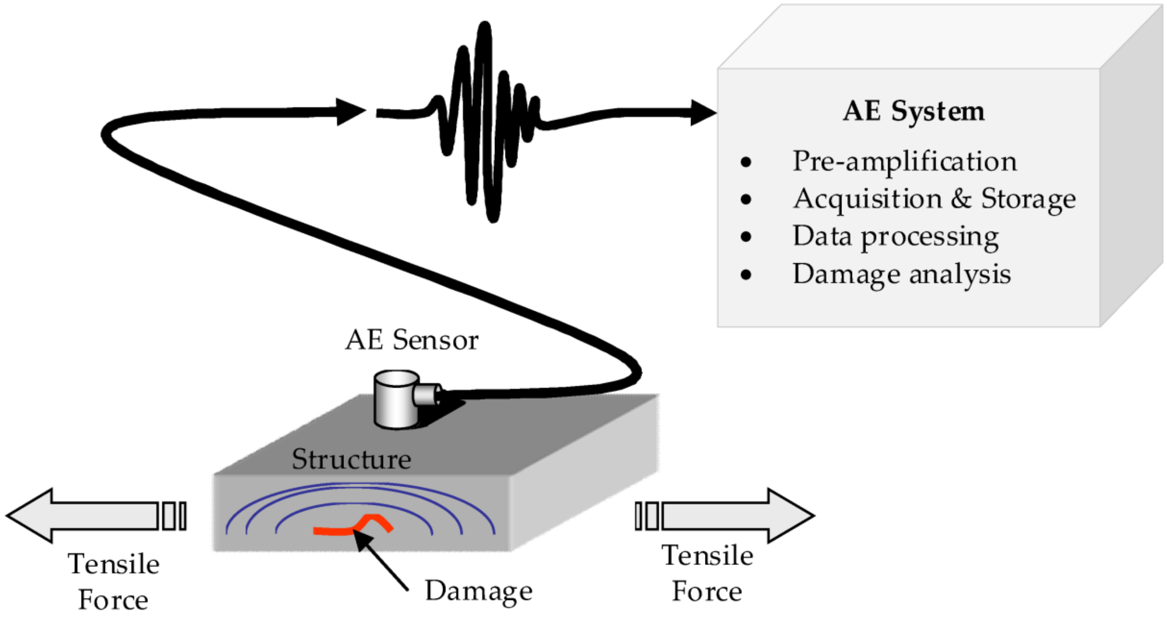




THEORETICAL BACKGROUND

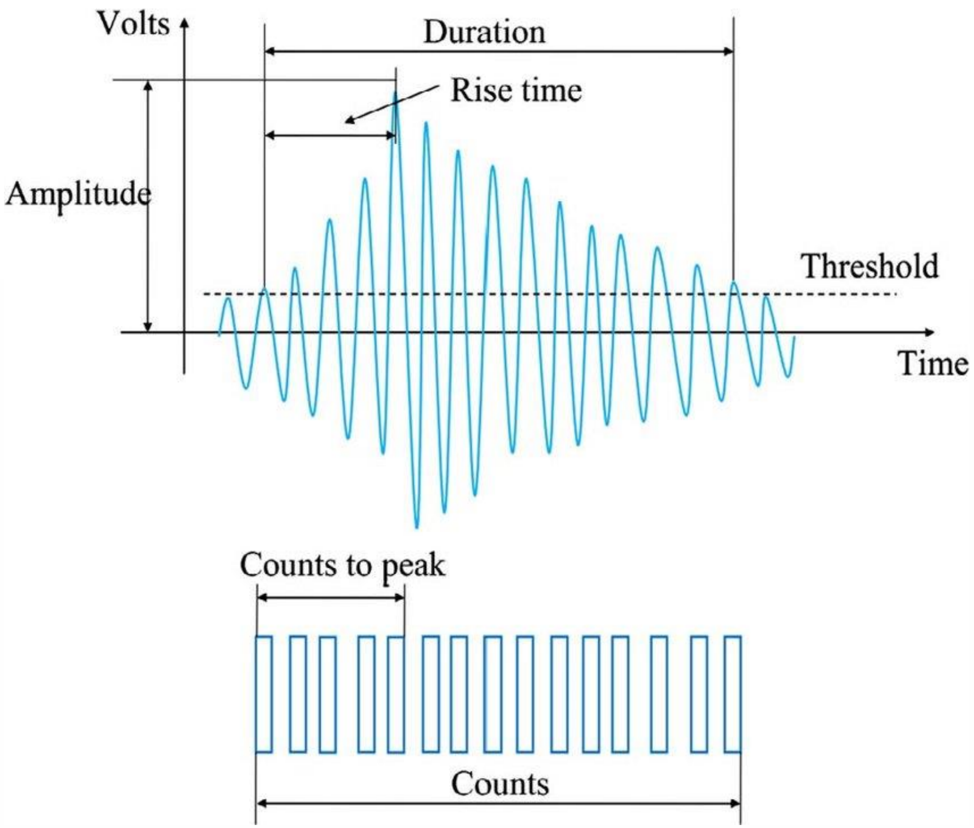
- **Multiaxiality** not extensively studied in literature
- **Monitoring of damage** with respect to different multiaxial stresses in lab conditions necessary → predictive tool for real applications
- **Prediction of stress states** and identification of dominant stresses essential even from early loading stages
- **Acoustic Emission (AE) CAN be used to give solutions to these problems!**

THEORETICAL BACKGROUND



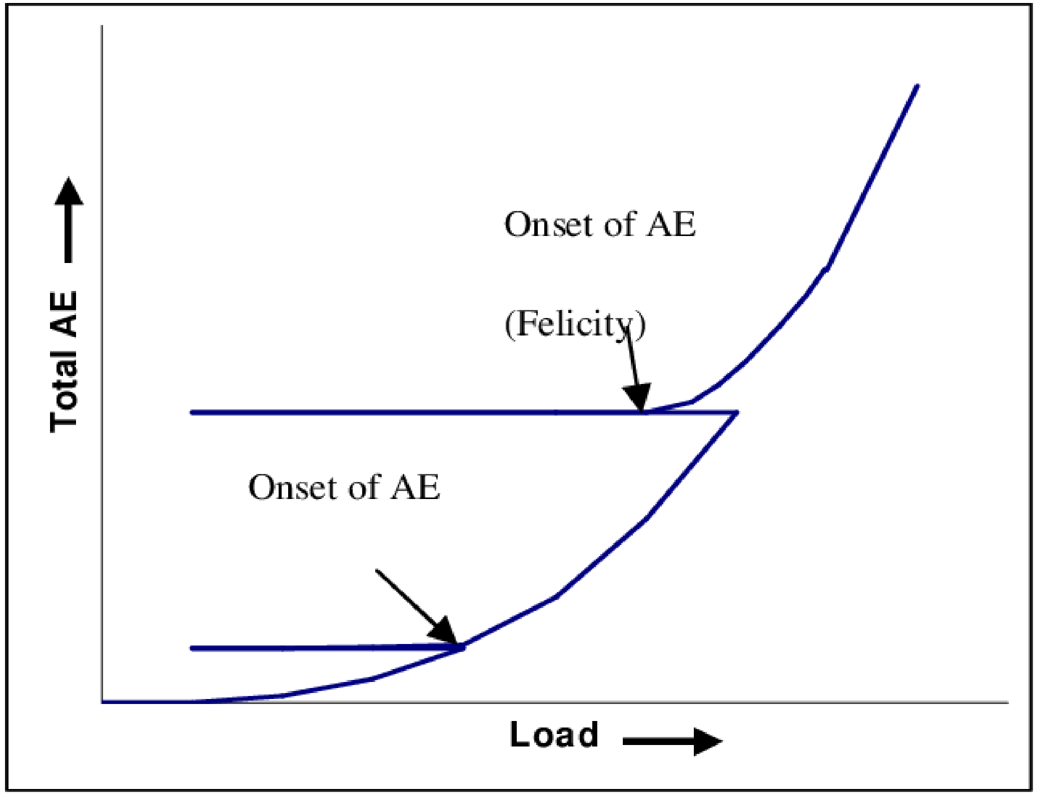
- **Acoustic Emission**: characterisation of damage of materials by interpreting the generated elastic waves
- Commonly applied in composite materials for investigations in the time domain and frequency domain
- Clustering approaches have been proposed
- No link to multiaxial stress states

THEORETICAL BACKGROUND



- **Feature analysis**: selection of the most appropriate signal features
- It has been used so far for damage mode classification
- **Rise Time (RT)** and **Average Frequency (AF)** among the most popular

THEORETICAL BACKGROUND



- **Kaiser effect**: the absence of detectable AE until the previously maximum applied stress is exceeded
- **Felicity effect**: the presence of detectable AE at stress levels below those previously applied → described by the **Felicity Ratio (FR)**
- $FR = \frac{\text{stress level at which AE resumes during a loading step}}{\text{maximum stress applied at the previous loading step}}$
- The **Calm Ratio (CR)** can be another damage parameter
- $CR = \frac{\text{AE activity during the unloading part of the cycle}}{\text{AE activity over the total cycle}}$

AIM OF THE STUDY

- To verify that AE **can distinguish the different damage modes** under multiaxial stress states
- Can AE **indicate the dominant stress/strain component** within the composite laminate from early loading stages?
- **Which AE parameters are the most effective** for such stress indications?

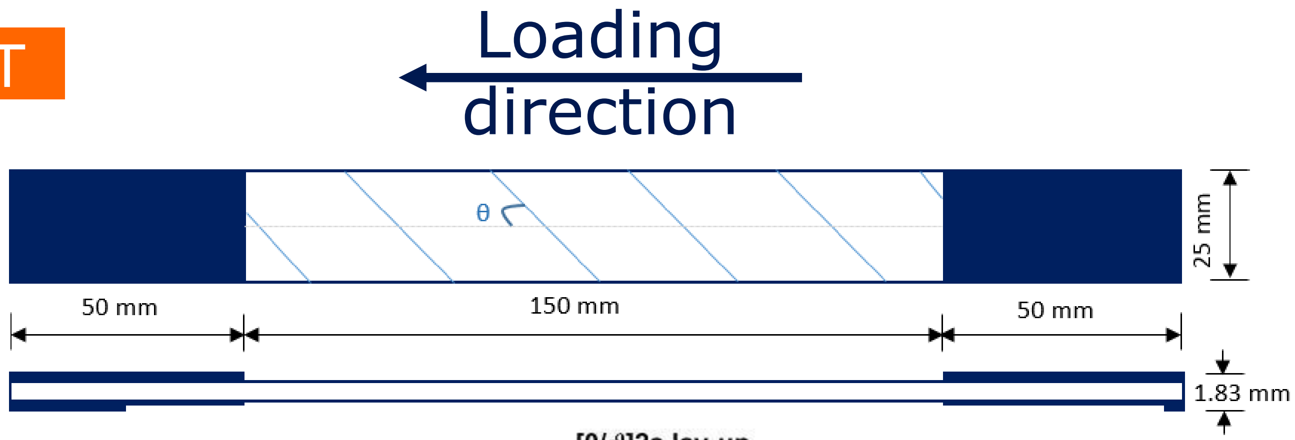
MATERIAL AND TESTING EQUIPMENT

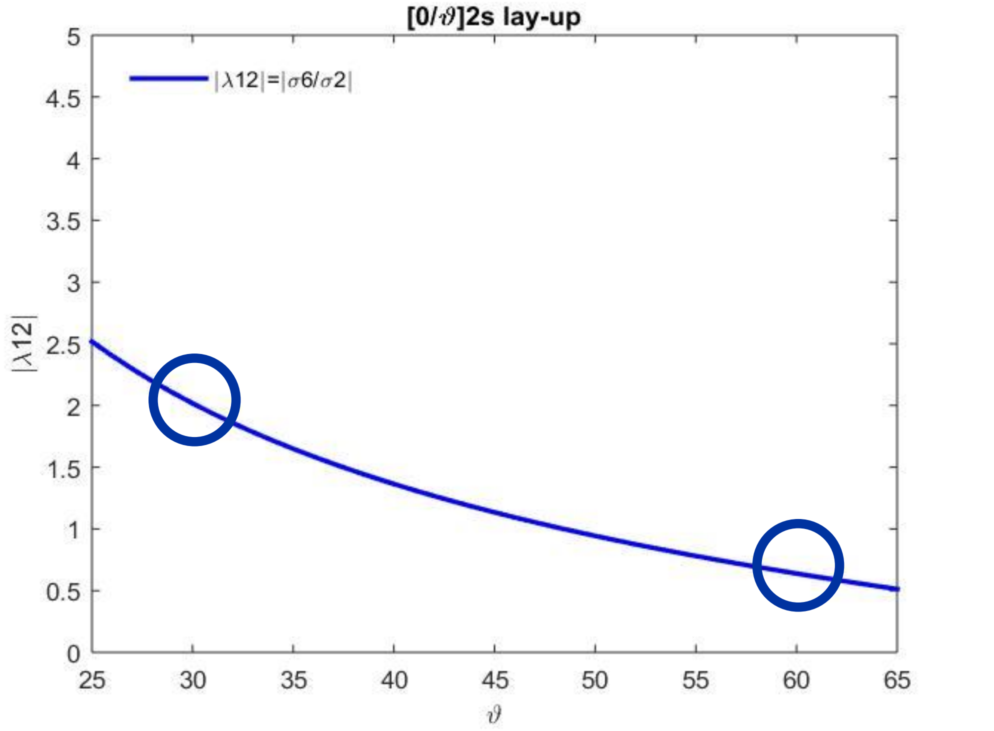
- To introduce different multiaxial stress states → two angle-ply carbon/epoxy laminates were tested

- Based on the **multiaxiality ratio $\lambda_{12}=\sigma_6/\sigma_2$**

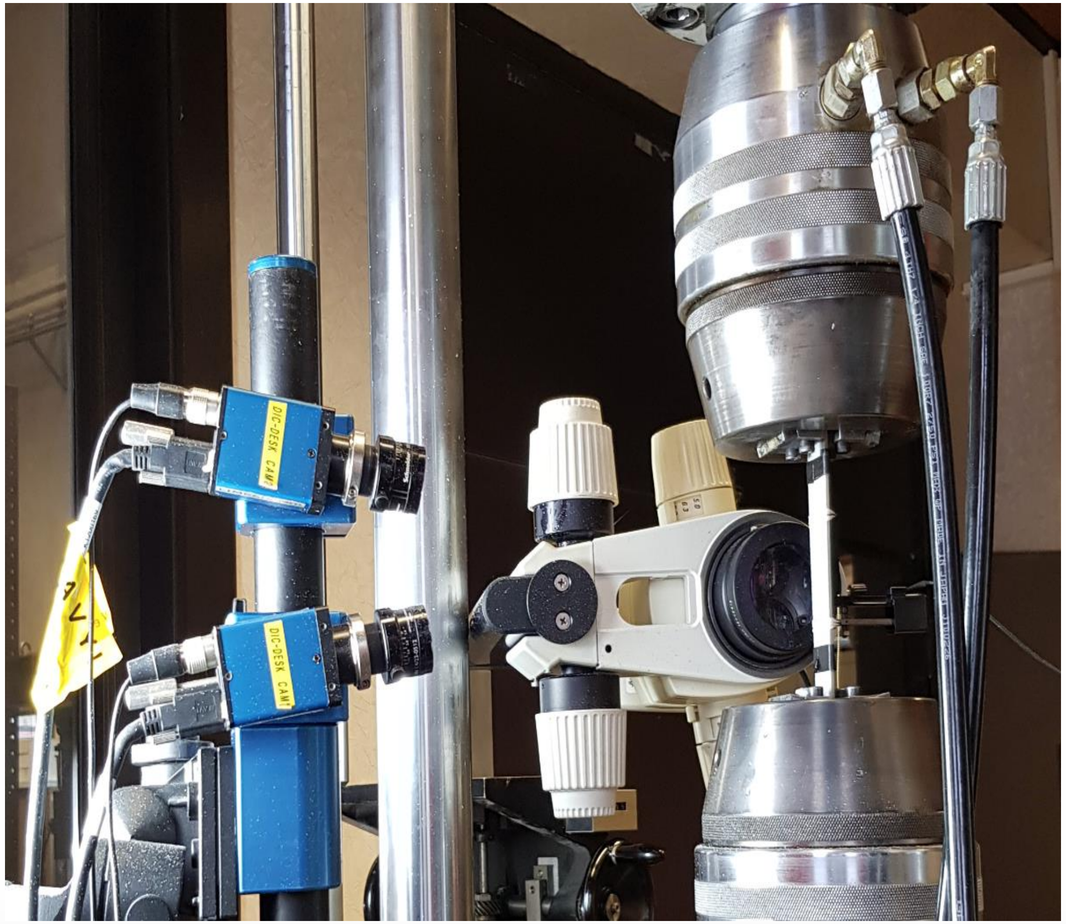
$[0^o/30^o]_{2s}$: $\lambda_{12}=2.02$
$[0^o/60^o]_{2s}$: $\lambda_{12}=0.64$

$[0^o/30^o]_{2s}$: dominant shear stresses
$[0^o/60^o]_{2s}$: dominant transverse stresses



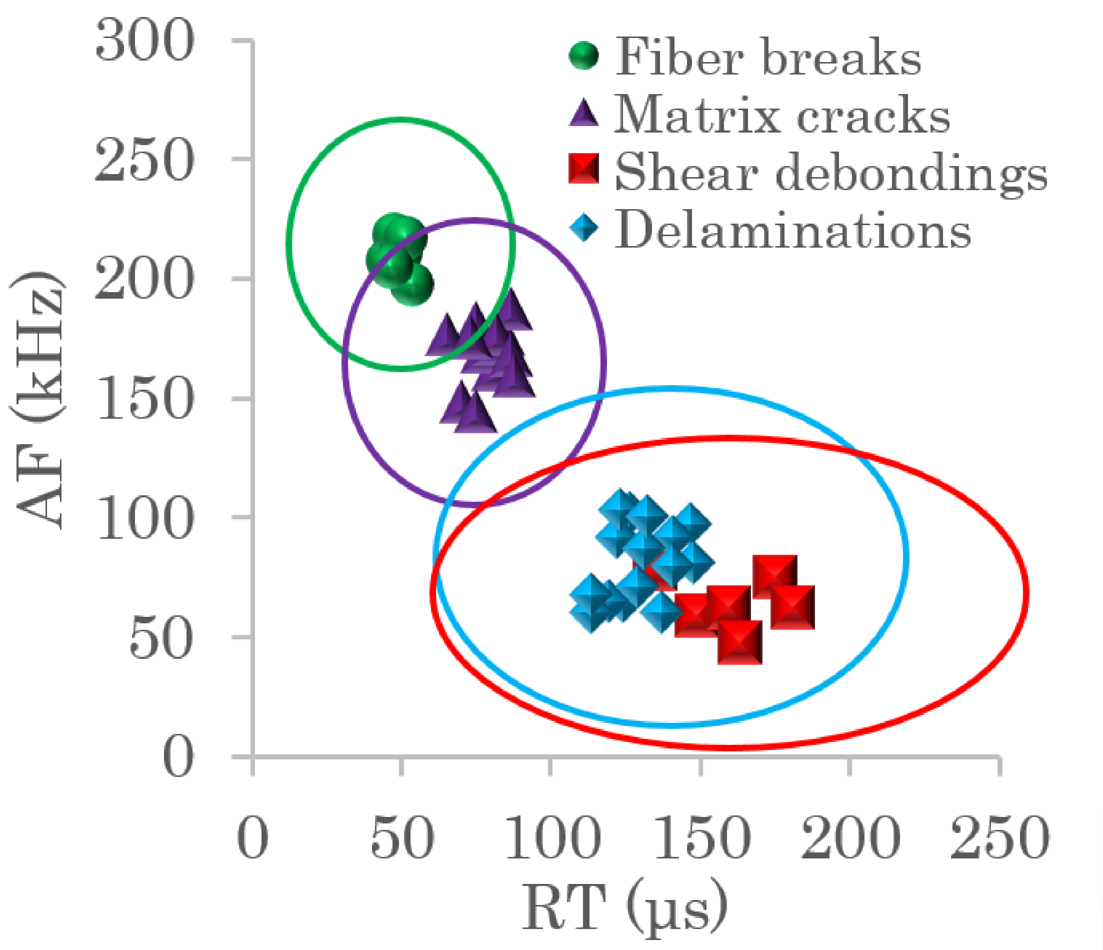


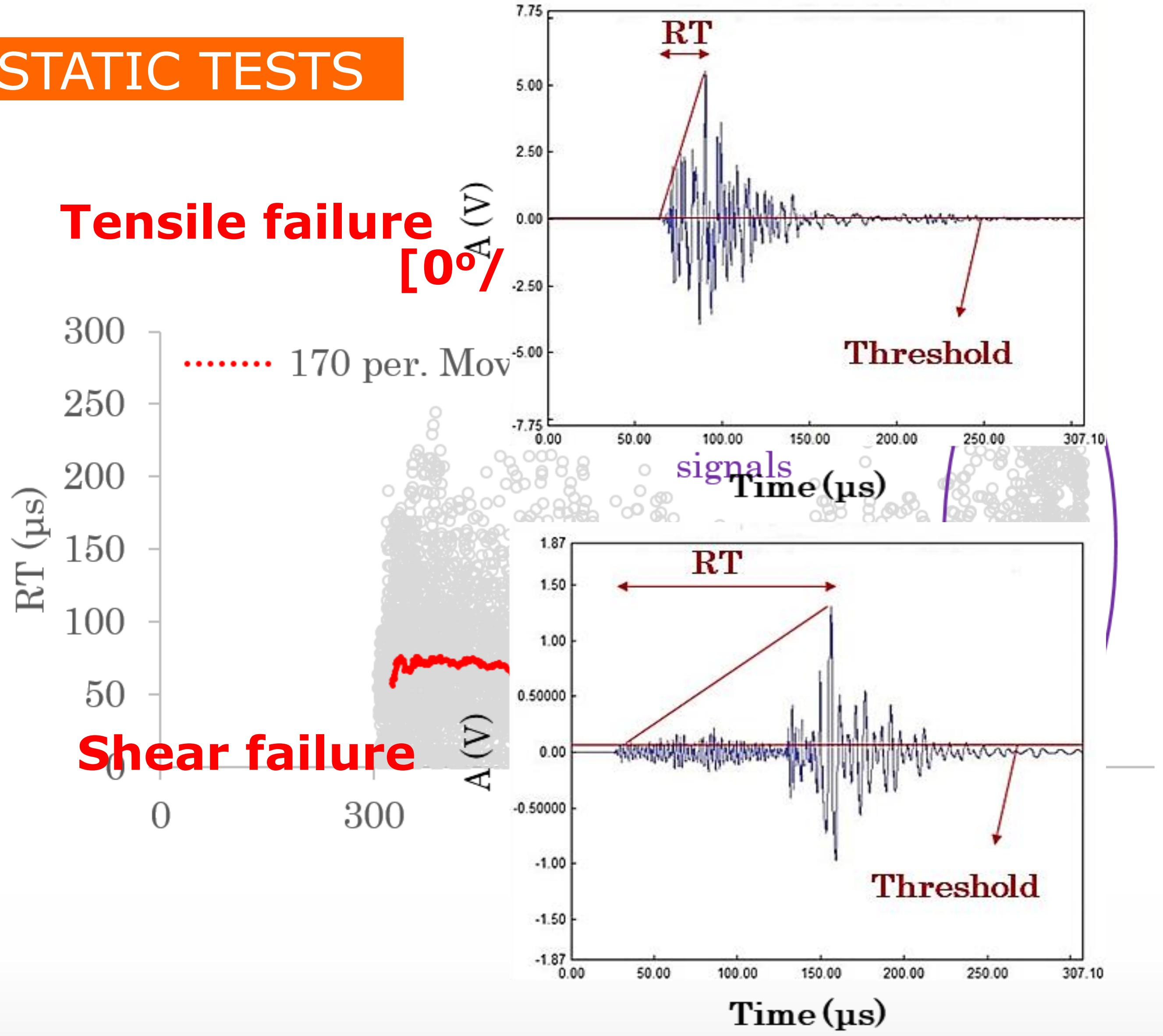
MATERIAL AND TESTING EQUIPMENT



- Continuous static tests and interrupted tests displacement controlled at 1 mm/min rate
- Two Pico sensors for the AE acquisition → 35 dB threshold
- Digital Image Correlation (DIC) for strain measurements
- Through-the-thickness free-edge damage monitoring at regular steps with optical microscopy

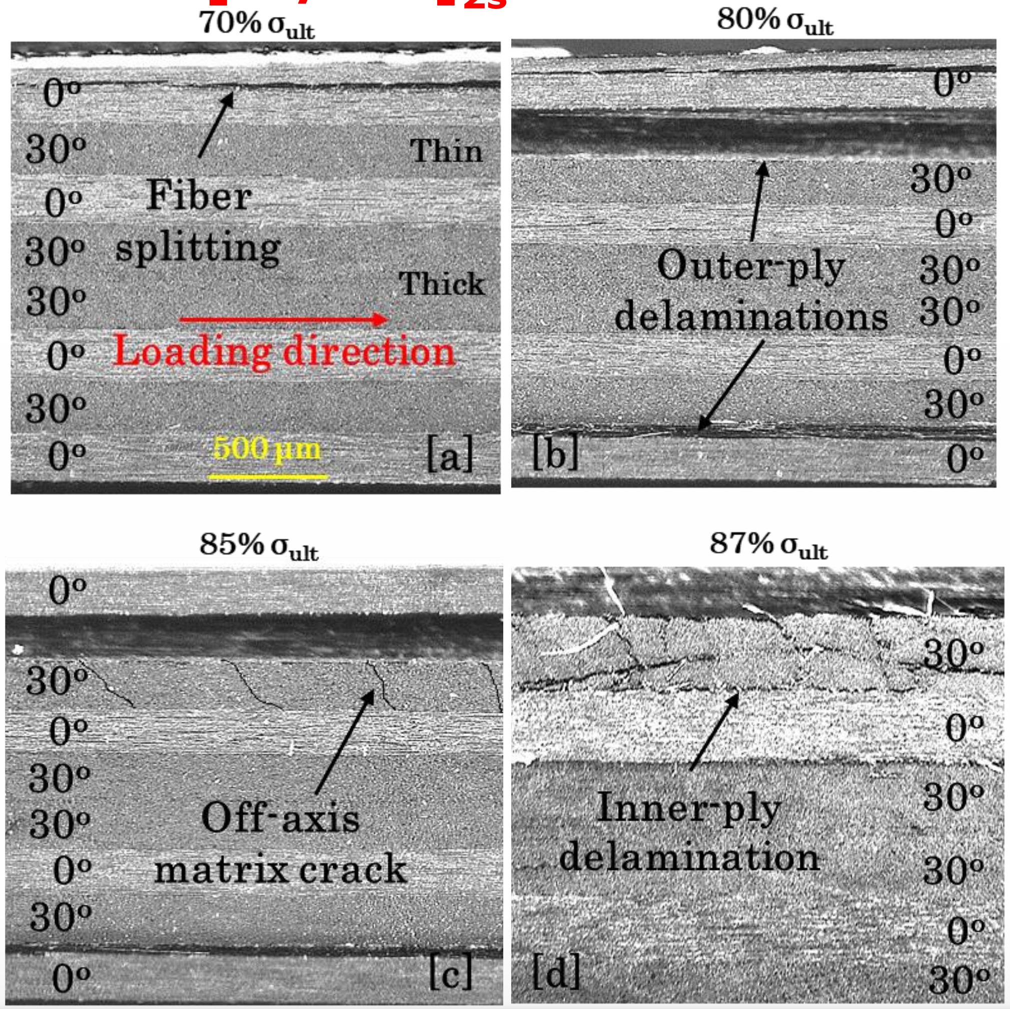
EXPERIMENTAL RESULTS: QUASI-STATIC TESTS



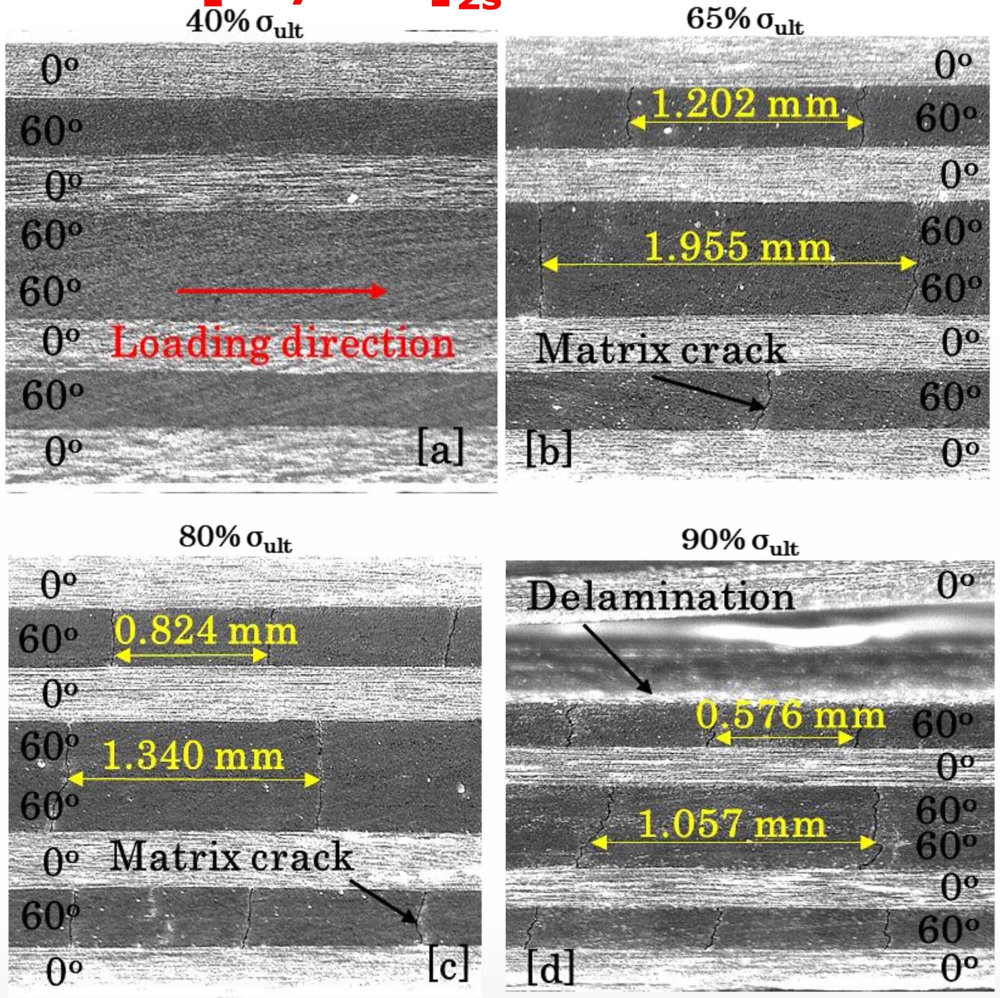


EXPERIMENTAL RESULTS: QUASI-STATIC TESTS

$[0^o/30^o]_{2s}$ laminates



$[0^o/60^o]_{2s}$ laminates



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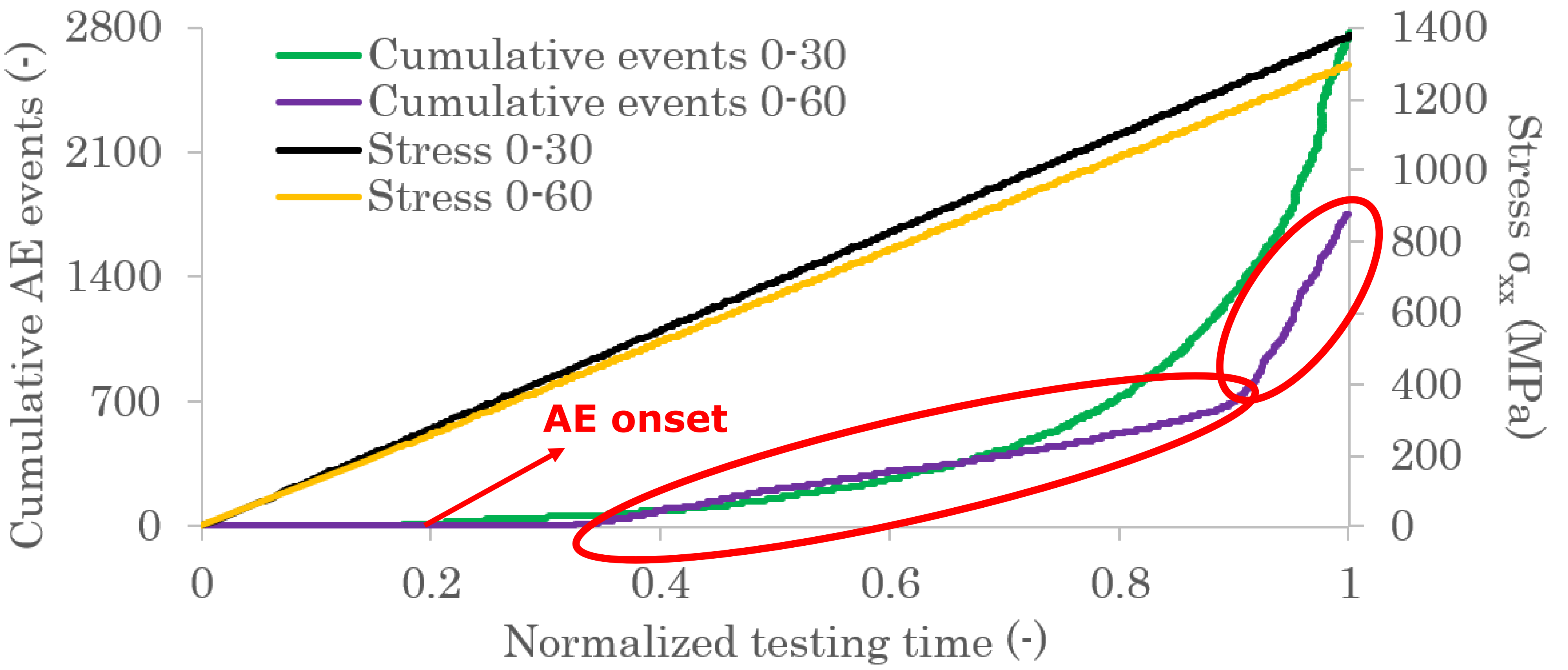

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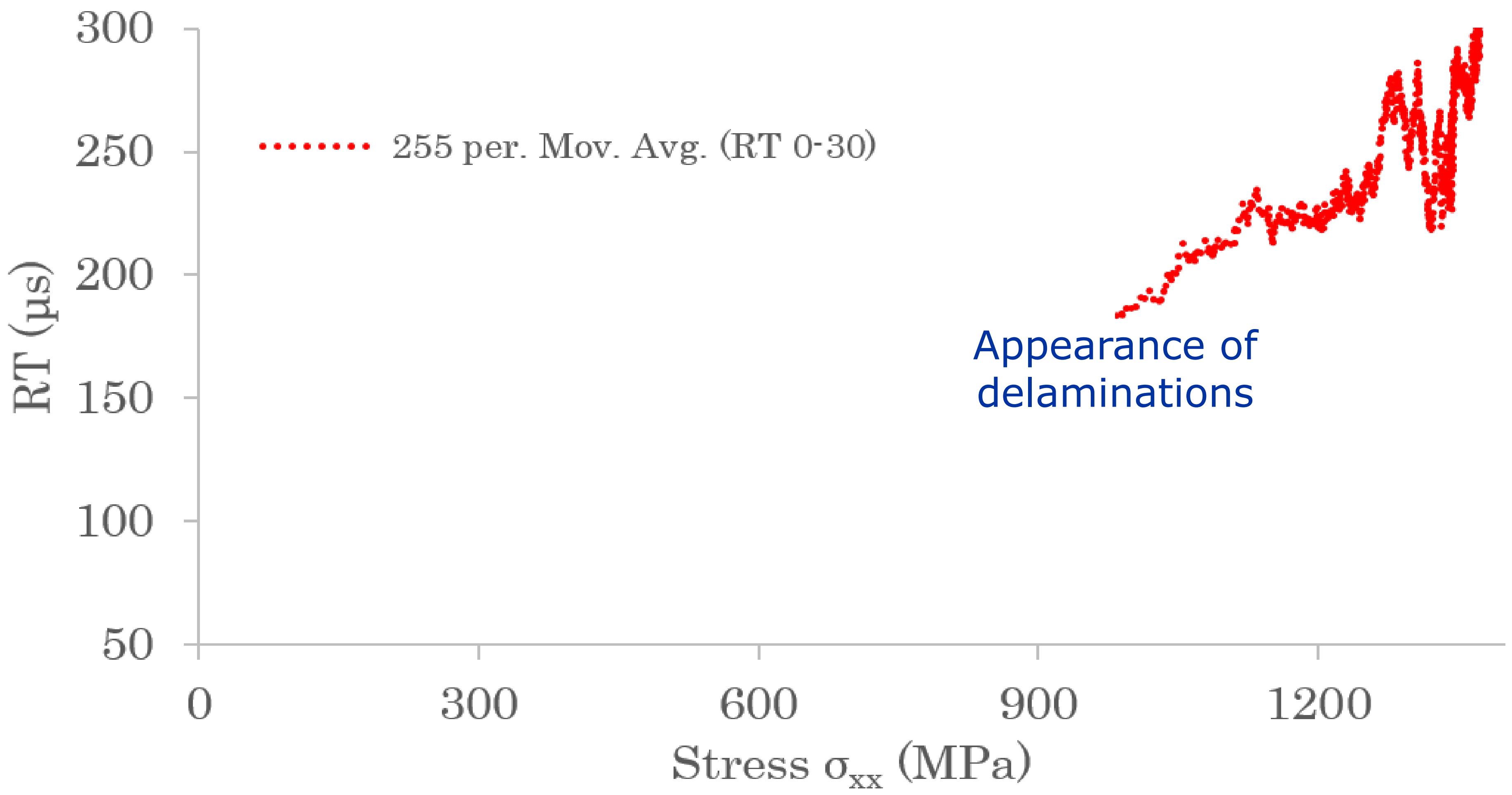
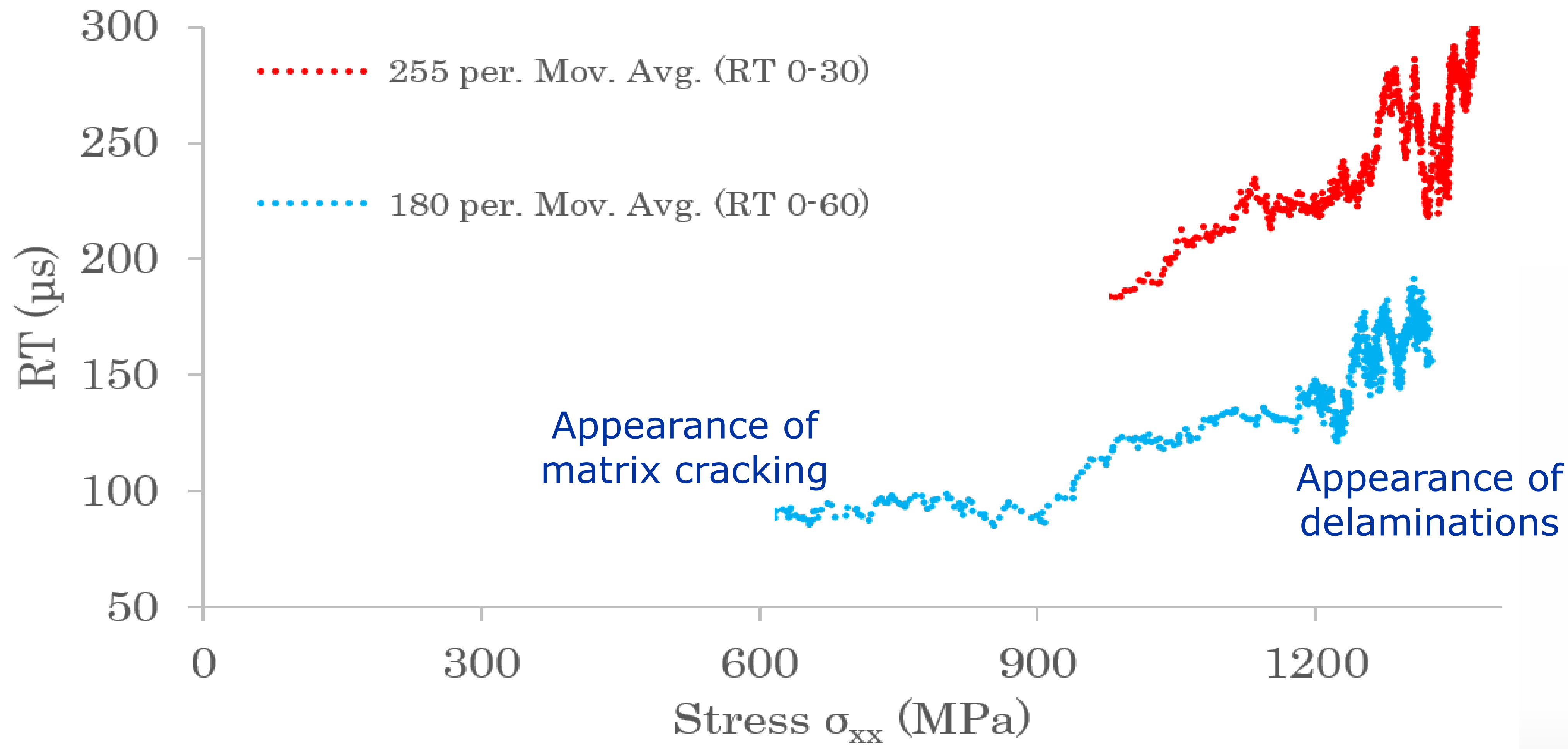


Appearance of delaminations

EXPERIMENTAL RESULTS: QUASI-STATIC TESTS



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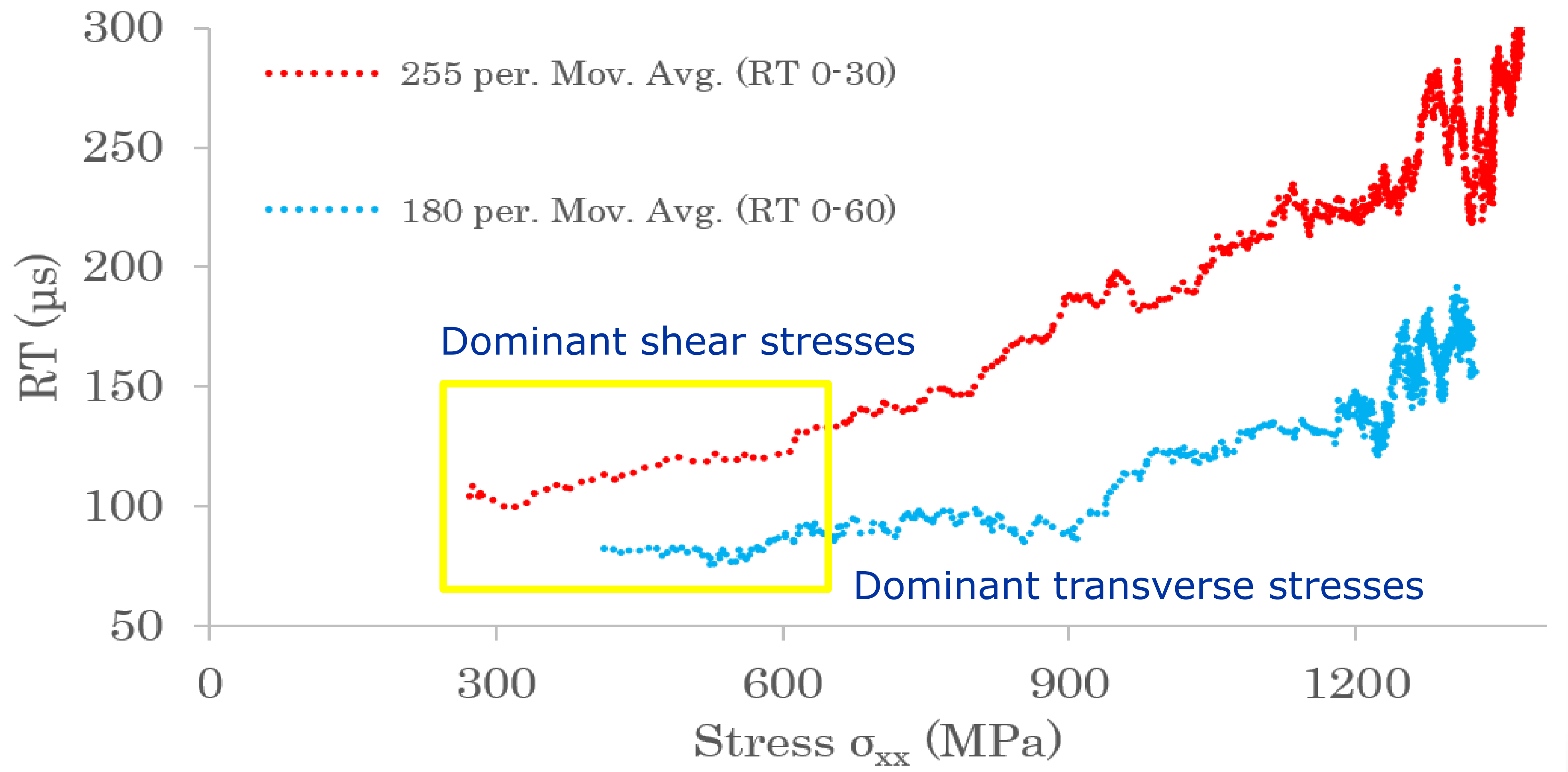

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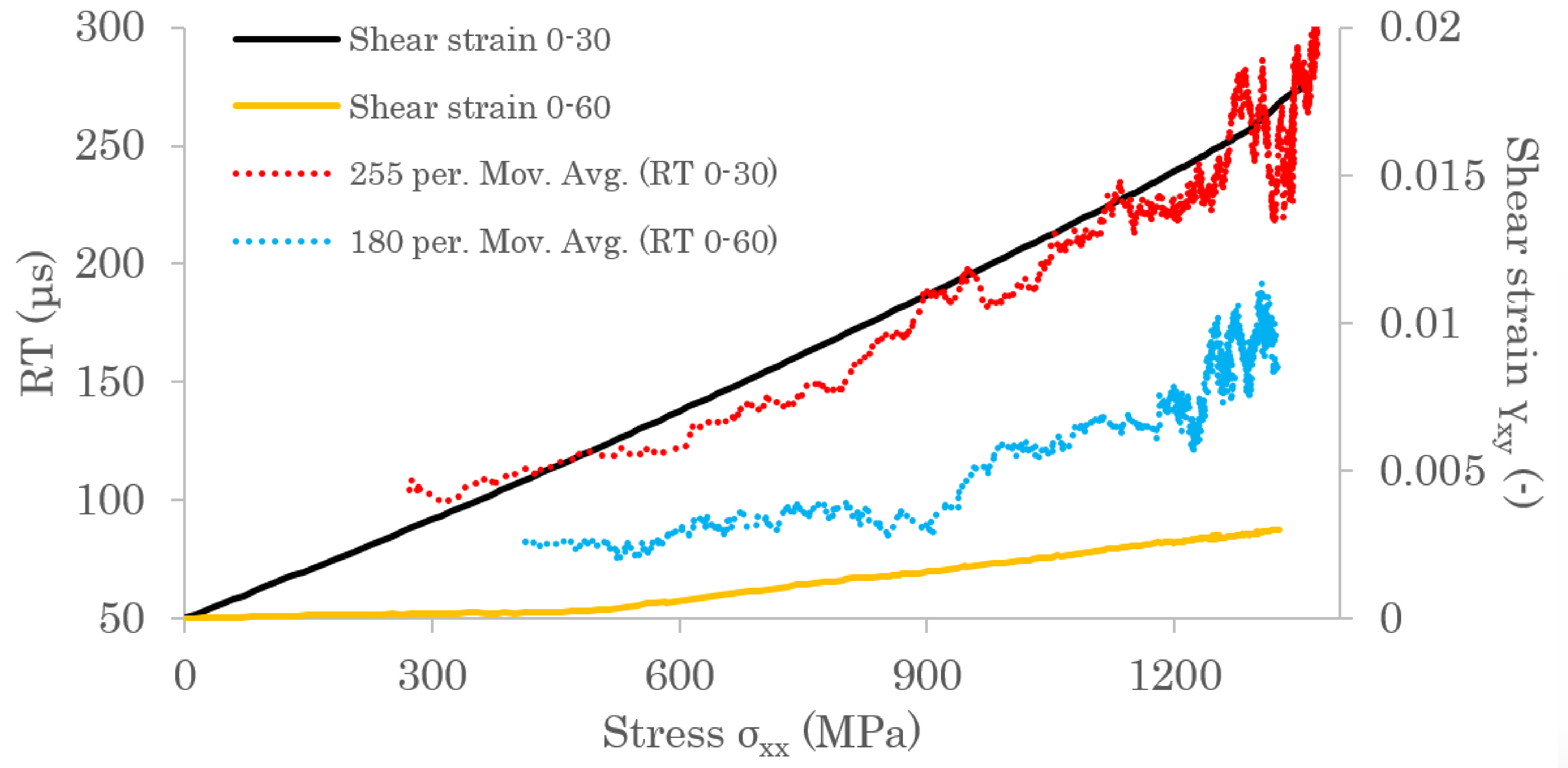

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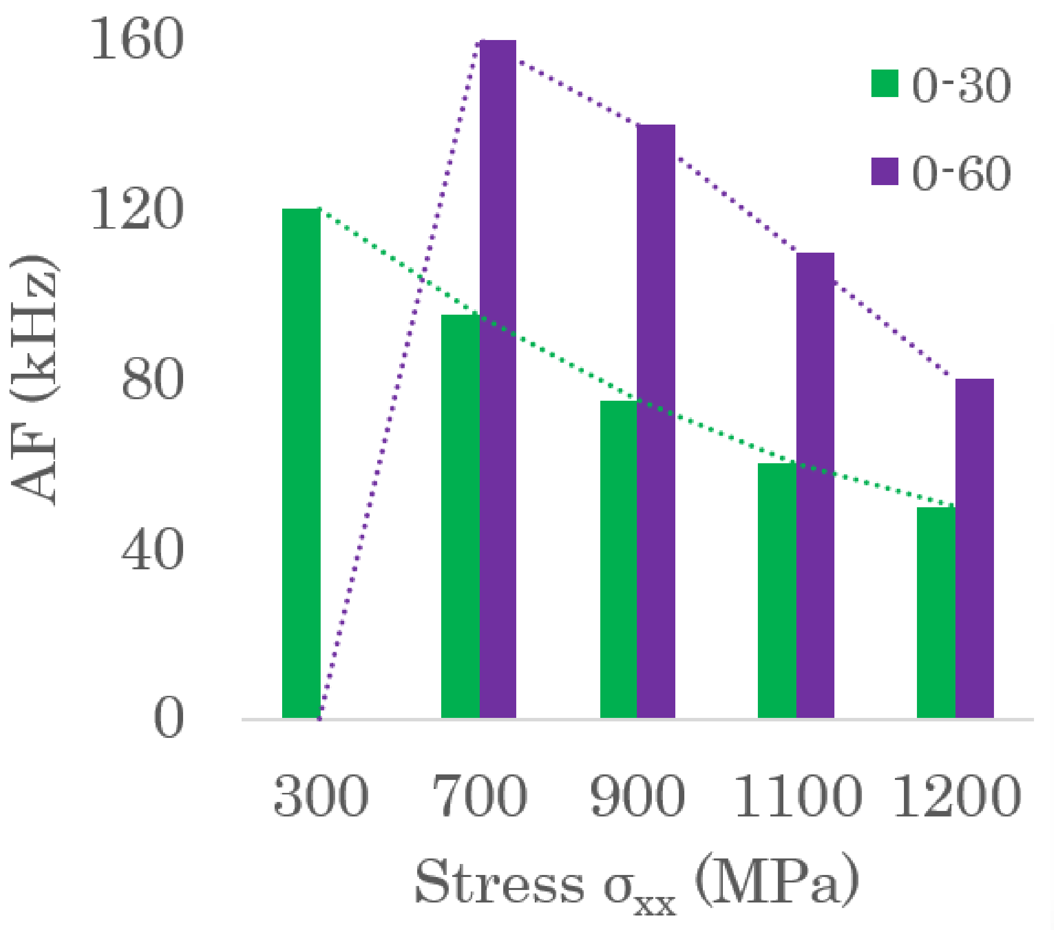

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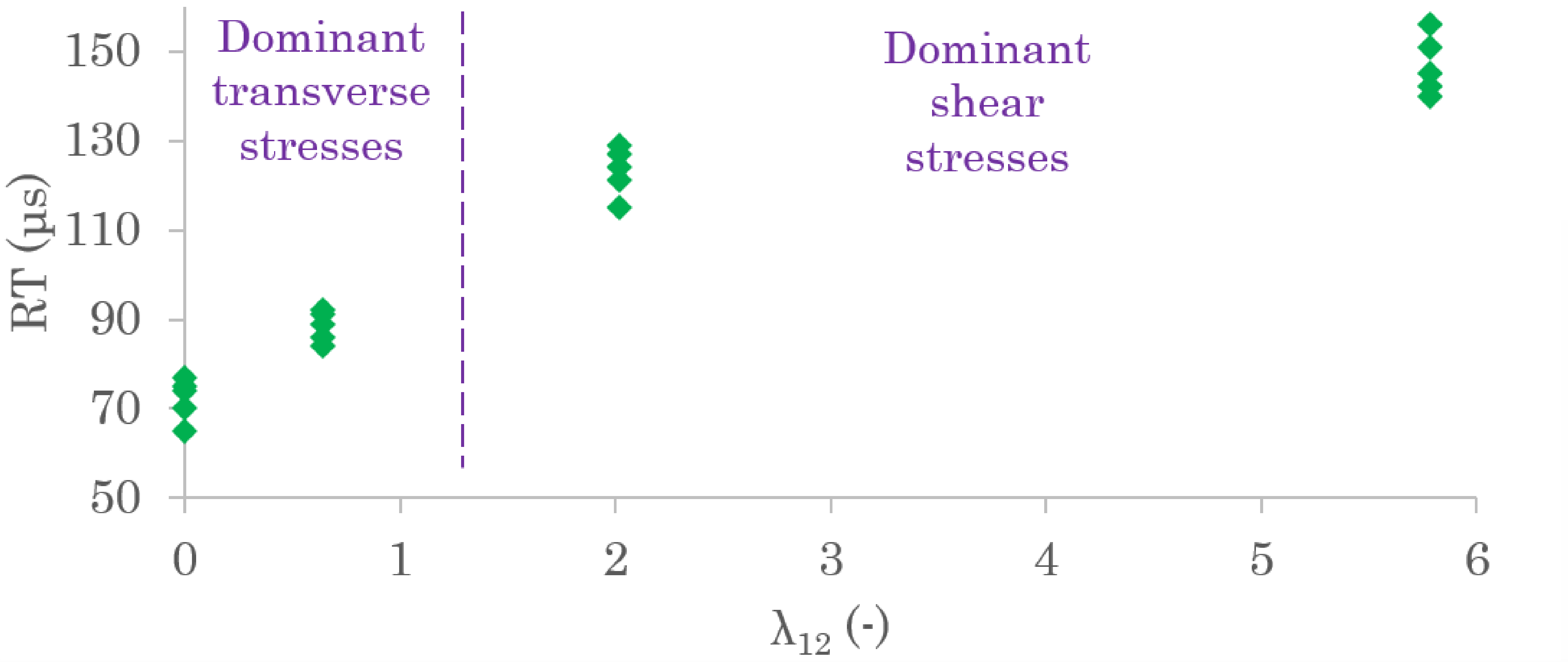
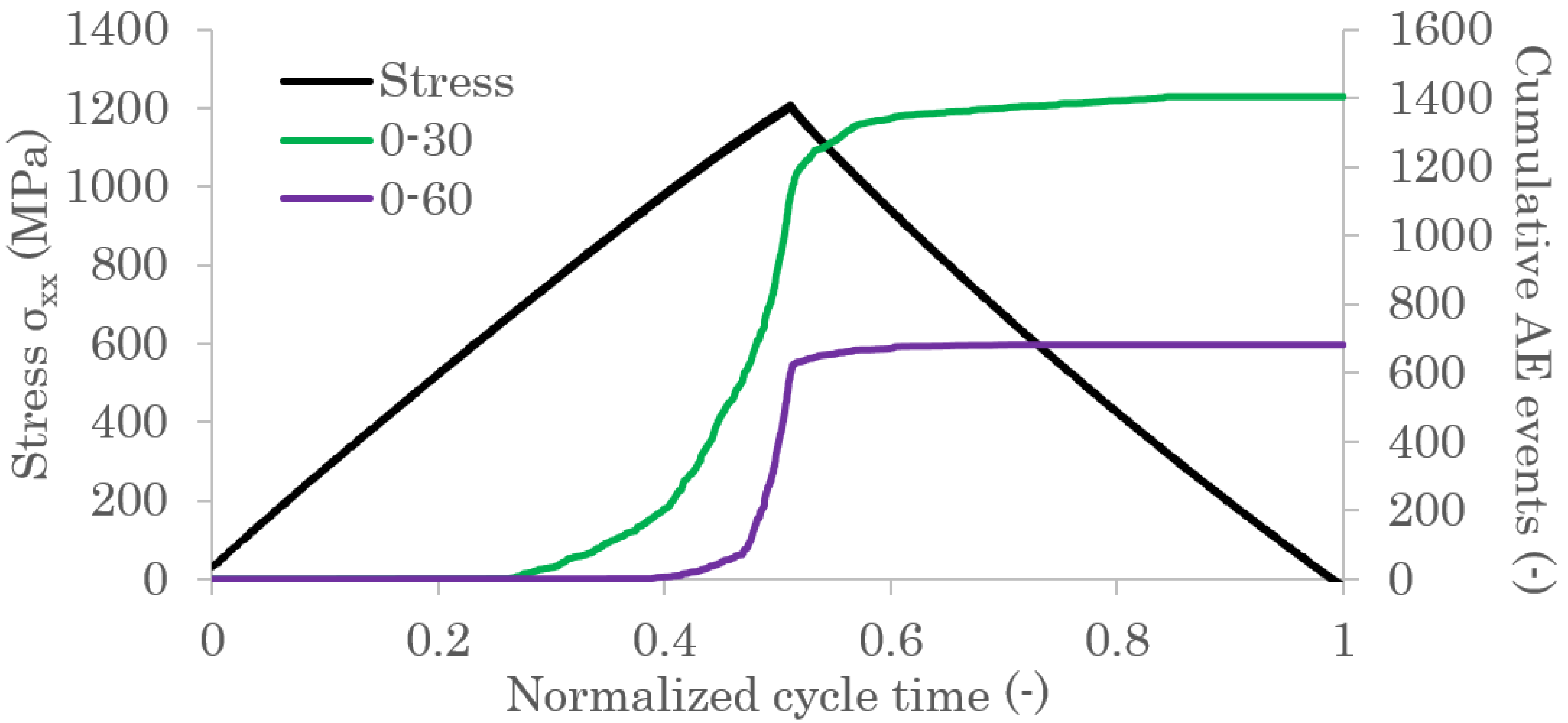


EXPERIMENTAL RESULTS: INCREMENTAL LOADING TESTS



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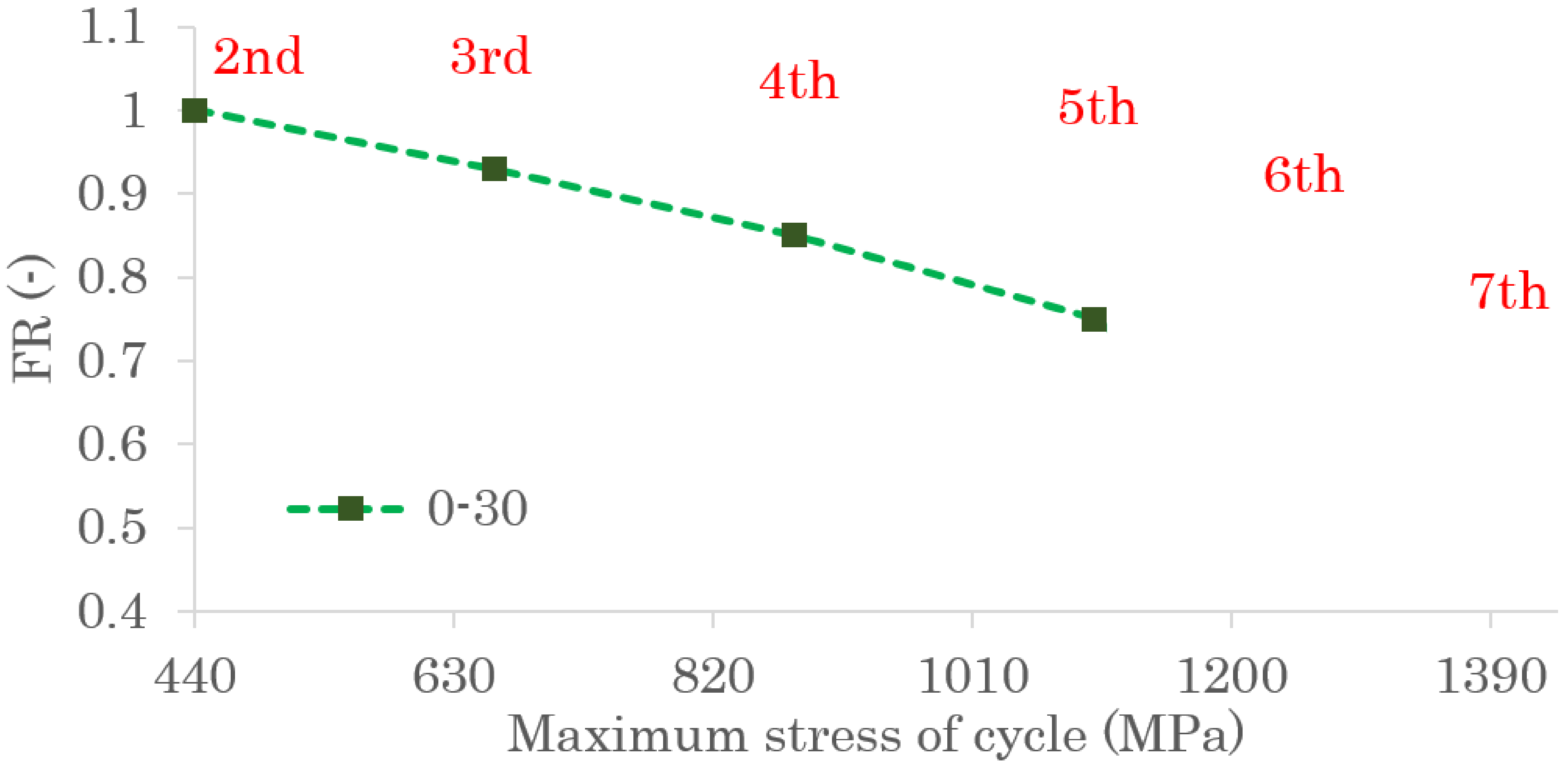

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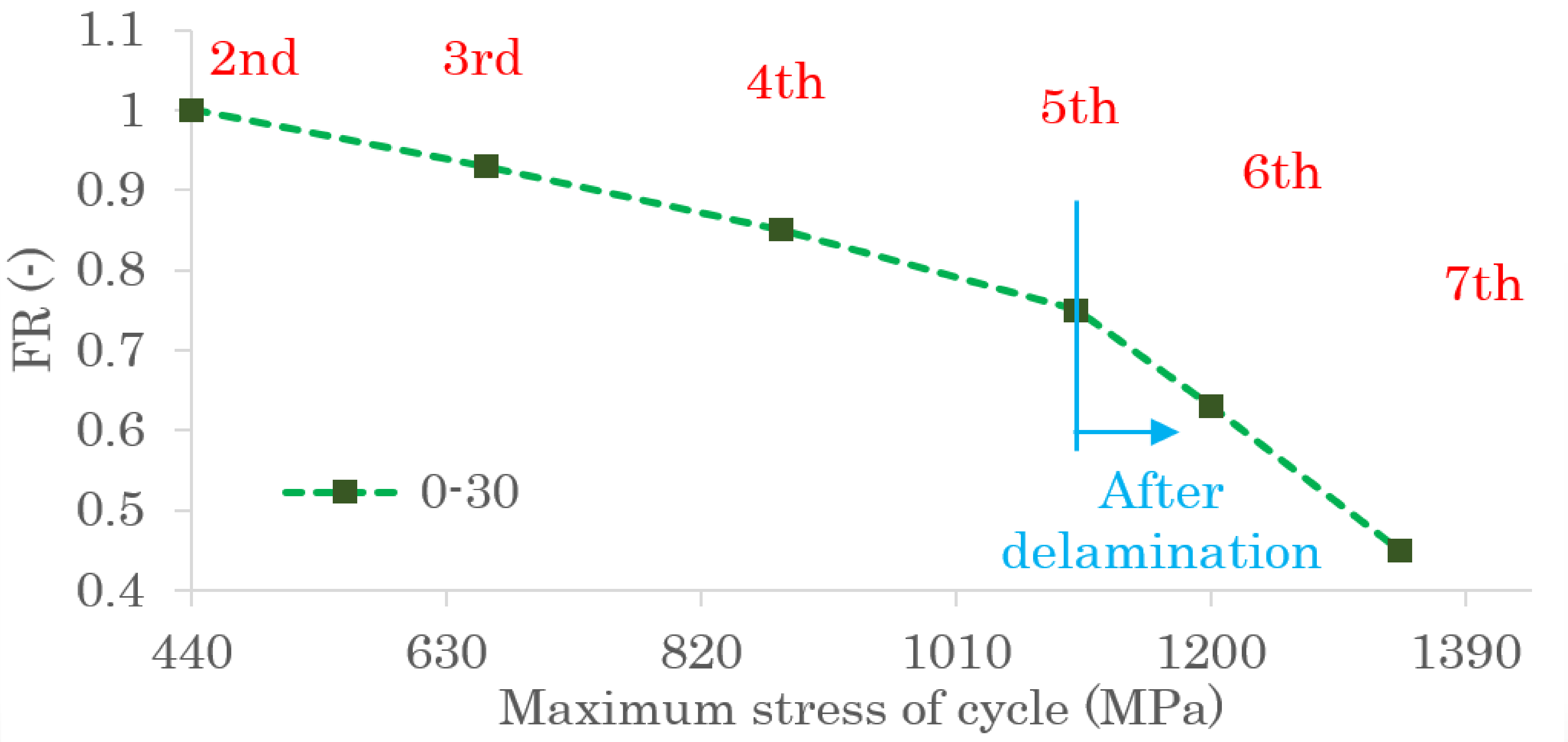

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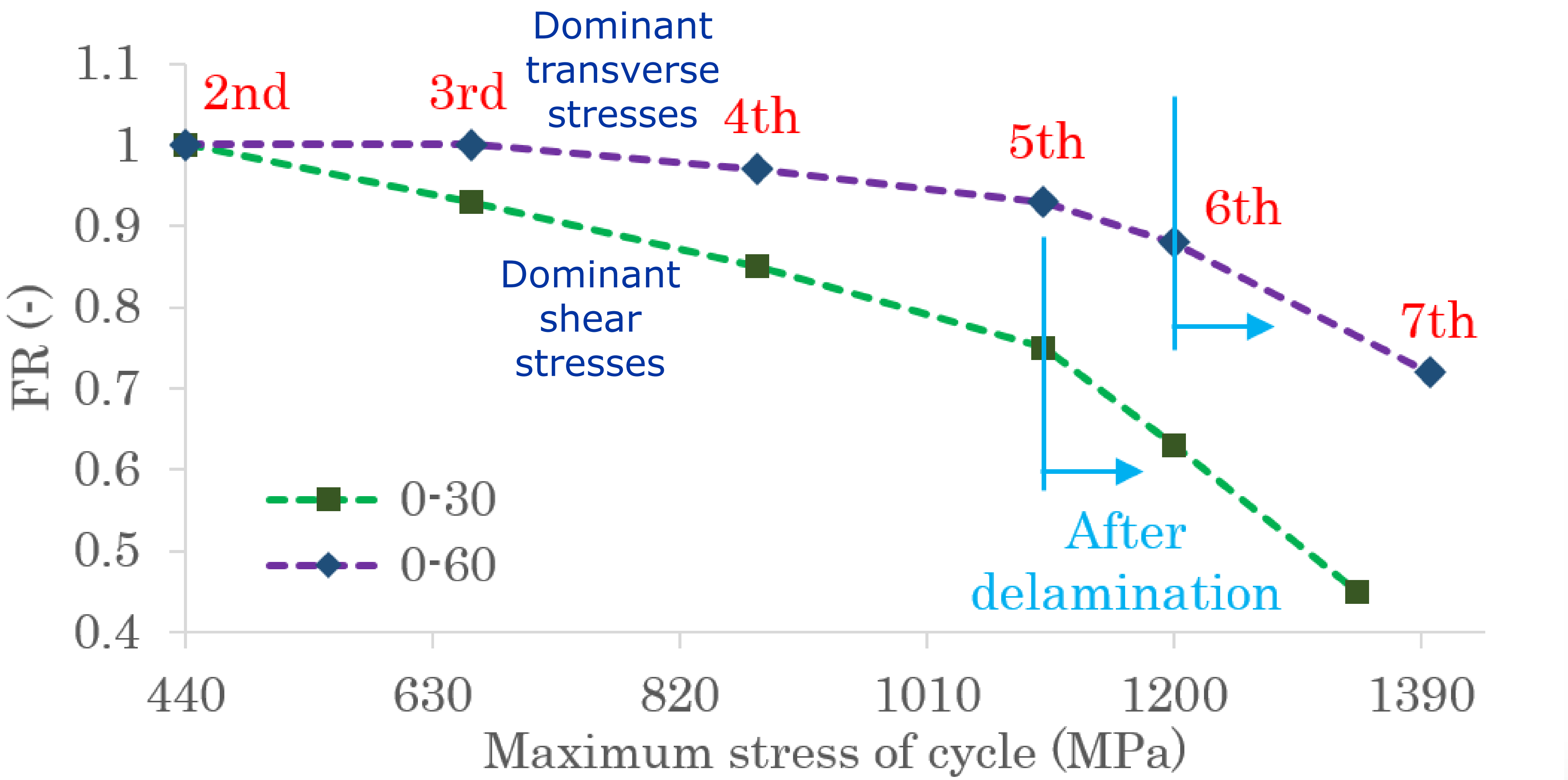

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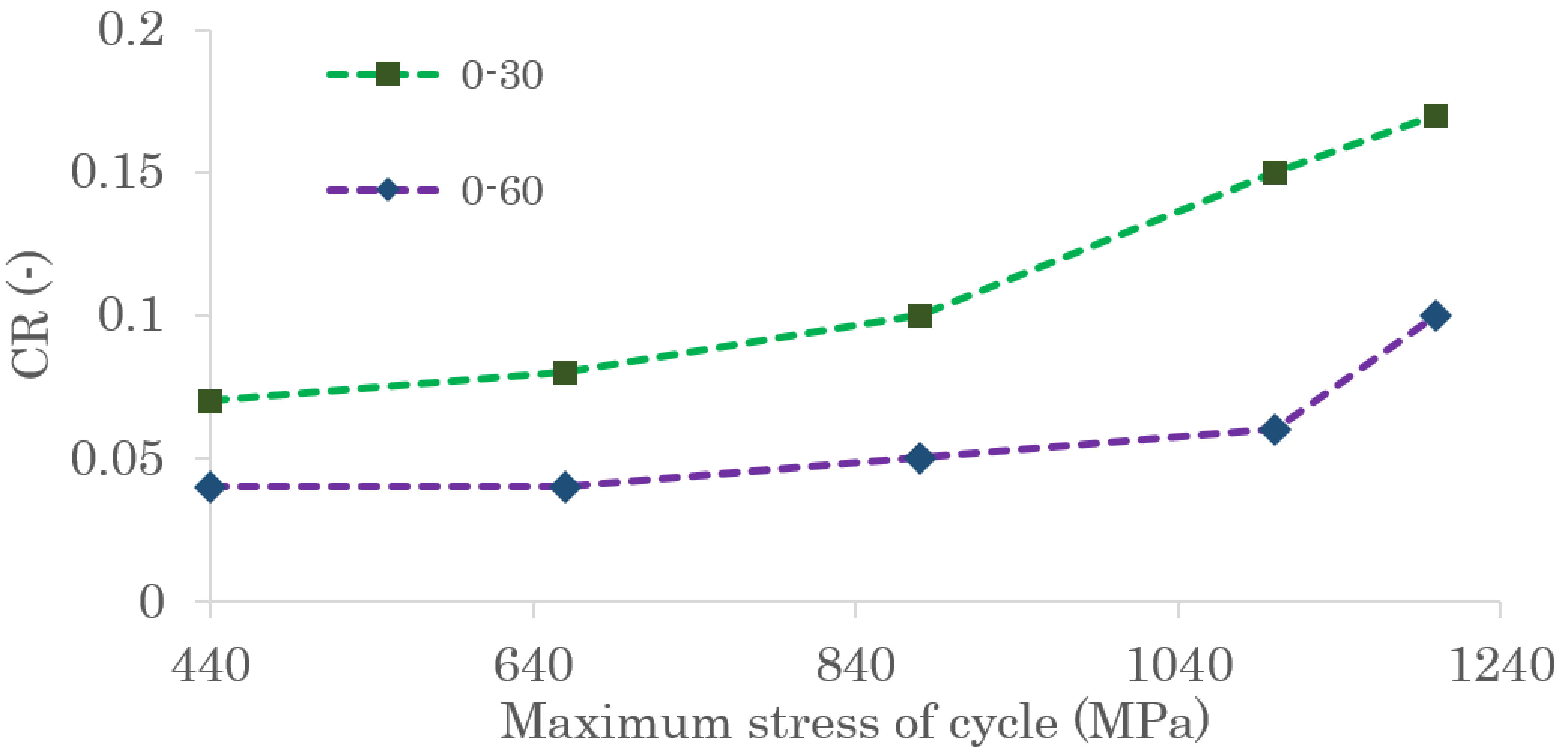

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CONCLUSIONS

- AE can be effectively used for the identification of damage in polymer composites
- Significant differences from early loading stages allowing ***indications of the dominant stress component***
- RT good indicator for the identification of damage modes and the transition between modes
- Low RT linked to tensile related phenomena and high RT to shear related phenomena
- Continuous increase of RT when shear is dominant
- FR is characterised by reduction when delaminations occur → can be used as ***damage mode transition indicator***
- FR appears lower values when shear is dominant → FR is not only material dependent, but also stress state dependent → can be used as ***stress state indicator***
- Higher CR values for shear dominated laminates even from early loads → can indicate the dominant stress component and the consequent deterioration

THANK YOU

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