# Detection of sub-micron damage in thin-ply polymer composites

PREPARATORY INDUSTRIAL PROJECT

## THE INDUSTRIAL CHALLENGE

It is known that the initiation of damage (transverse cracks) in thin-ply laminates is delayed, but the failure process on the micro-scale is not fully understood. This information would give Oxeon capability to design more advanced thin-ply materials. However, to obtain such knowledge there is need for in-depth analysis with use of wide expertise (materials, mechanics, imaging) and advanced equipment. It is a challenge that cannot be dealt with by the industrial partner alone and it requires collaboration with experts from academia.

## WHY USING A LARGE SCALE FACILITY?

Normally, studies of micro-structure and damage in composites are carried out by use of optical microscopy, SEM and micro-tomography (µCT). Most of the lab scale devices are not sufficient to capture all the details related to the defects and failure events occurring in the vicinity of fibers at the scale of microns (or even sub-micron level). Besides, microscopy offers only 2D view from the edge of the specimen with through-the-width information absent. Thus, it is not possible with certainty to conclude what defects are present in the material, how/when they are generated and what failure sequence is triggered because of them. Even most promising method available in the lab, µCT, is often lacking required resolution, not to mention that it is slow and thus extremely time consuming. In order to understand the mechanisms governing the damage initiation and propagation in thin-plies, in-situ mapping of defects during the application of thermo-mechanical loading is required. Due to the limited field of view it is not possible to correlate the location of the defects with internal structure of the material (e.g. fiber orientation). Thus, the large-scale facilities with much faster mapping as well as larger field of view have to be employed. In particular, large-scale facilities which are capable of high resolution and high-speed imaging should be used. In-situ 3D characterization of the microscopic damage mechanisms is a valuable insight to the failure process of thin-ply laminates required by manufacturers for advanced design of new, high performance reinforcement.

## THE RESULTS AND EXPECTED IMPACT

The main objective was to lay the foundations for in-situ measurements of sub-micron defects and micro-damage. Own preliminary lab-scale µCT results as well as data from literature was used as baseline to evaluate the lab-based limitations and to define test parameters and requirements for the design of future experiments at large scale facilities.

The following large scale facilities were considered: 1) The P21 Swedish Materials Science Beamline (SMS) at Petra III in Hamburg, which allows in-situ observations as it is designed for the combination of WAXS, SAXS, and Imaging techniques; 2) The DanMAX beamline at MAX IV in Lund to study the microstructure using full field imaging which will enable multi-modal, multi-scale analysis of the internal structures of bulk materials; 3) The TOMCAT beamline of Swiss Light Source (SLS), Villigen, which allows fast, non-destructive, high resolution (0.2-1 microns 3D spatial resolution), quantitative investigations on a large variety of samples; 4) The ID19 of ESRF in Grenoble, allowing full-field imaging beamline with various in-situ furnaces and mechanical loading stages (spatial resolution 1-100 microns).
Based on the test requirements the following assessment was done: 1) The P21 at Petra III has capabilities of high energy scanning and it may be used to study composites however, it remains to be seen if it is the most suitable for the thin-ply laminates. 2) In the future DanMAX may be well suited for in-situ experiments on thin-ply composites; 3) The micro-tomography beamline TOMCAT at SLS is well suited for the type of tests (rapid scanning during in-situ experiments) that have to be performed to detect damage initiation and propagation in composites (application of this beamline to study fiber/matrix interface has been already demonstrated in literature); 4) The ID19 at ESRF should be considered as one of the main candidates for in-situ observations, as it is already equipped with devices for thermo-mechanical loading.

**Contacts:** Florence Moreau – Oxeon AB, Florence.Moreau@textreme.com
Roberts Joffe – Luleå University of Technology, Roberts.Joffe@ltu.se

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