INDUSTRIAL PILOT PROJECT

In-situ X-ray scattering for understanding failure of paper-based packaging due to moisture induced creep

THE INDUSTRIAL CHALLENGE

The static loads on corrugated boxes during transportation and storage induce material creep and may lead to box failure. The creep phenomenon is especially important in conditions of high and varying humidity (mechano-sorptive creep, MSC) and is a major drawback of corrugated box packaging. It causes significant loss of packaged goods, like for example fresh fruit and vegetables.

WHY USING A LARGE SCALE FACILITY

The deformation mechanism behind MSC is not yet fully understood. However, previous work suggests that the origin of the phenomenon relates to an interplay between moisture and the structure of the paper fibres at the macromolecular level. Changes in the paper at this scale can be probed using small- and wide-angle X-ray scattering (SAXS and WAXS). Due to the role played by moisture, it is important that the measurements are done in a humidity-controlled atmosphere, which precludes using vacuum-based laboratory SAXS/WAXS equipment. As the material creep is a dynamic process, fast data collection is also necessary. For both reasons, synchrotron-based measurements are required.

HOW THE WORK WAS DONE

An experimental setup was designed by RISE in which a tensile tester was enclosed in a climate-controlled chamber. This enabled paper samples to be subjected to a specified load in an environment with controlled temperature and relative humidity (RH).

Simultaneous measurements of SAXS, WAXS, mechanical stress-strain as well as creep and MSC were performed at two separate occasions, using the P03/MiNaXS beamline of the Petra III-synchrotron (DESY) in Hamburg. The data obtained in the first round of measurements gave important learnings regarding the setup and beamline parameters that allowed improved data collection during a second set of measurements.

Assistance from the beamline staff was required during the setup of the experiment, but the team from BillerudKorsnäs and RISE was able to operate largely independently due to RISE beamline expertise.

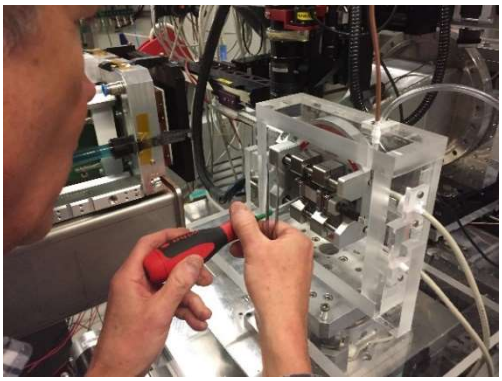

Figure. L. Salmén, RISE, mounting a sample.

THE RESULTS AND EXPECTED IMPACT

The WAXS analysis showed changes in the cellulose unit crystal dimensions as a reaction to changes in the relative humidity in the sample chamber. Also, sheering of the cellulose unit crystal was observed during creep tests. The SAXS analysis indicated change in orientation of the cellulose fibrils with load and time during straining and MSC tests. For the time being, no substantially new conclusion has been possible to make regarding the ordinary creep and MSC deformation mechanisms. Nevertheless, the results were sufficiently encouraging to warrant continued and improved synchrotron-based investigations of the phenomenon, with a suggestion to then use a more pure highly oriented cellulose material in order to better reveal deformation mechanisms, as well as involving artificial-intelligence-assisted analyses.

"Synchrotron-based investigations give a glimpse of the future challenges to improve sustainable packaging" ***/Robert Nilsson, Project Manager at BillerudKorsnäs***

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