NEUTRON AND SYNCHROTRON X-RAY MEASUREMENTS: UNIQUE TOOLS IN THE NON-DESTRUCTIVE TOOLBOX

Neutron and X-ray beams provide unique, powerful and non-destructive access into the heart of materials and components, over length scales ranging from the centimetre to the atom. The Institut Laue-Langevin ILL – Europe’s leading neutron source - and the ESRF – Europe’s leading synchrotron light source, combine 80 experimental stations providing neutron and X-ray beams with exceptional properties to overcome the limitations of standard laboratory characterisation techniques. Regarding challenges in the aeronautic and space sectors, we will detail some advantages obtained by synchrotron and neutron beams in stress mapping and computed tomography.

The ESRF’s high-energy synchrotron X-rays can map efficiently the strain and stress at the surface and up to several hundreds of microns below to give depth profiling with high spatial resolution. Neutrons give access to the full stress tensor from 60µm below the surface up to the interior of the component (e.g. 30 cm in Al, 6 to 7 cm in Ti, Ni or steel). Both techniques are able to measure in real time and non-destructively the stress distribution during mechanical loading, or during heating/cooling processes. A current exciting development is the investigation of residual stress build-up during additive manufacturing. Here, we will show examples of measurements taken from aircraft and satellite components. Note that a combination of neutron and X-ray datasets can be offered by the institutes.

With regards to computed tomography, synchrotron X-rays and neutrons provide complementary information. Synchrotron X-rays provide remarkable insights into materials up to the nanoscale with a resolution as high as 30 nm. At the microscale, synchrotron X-rays enable vastly more accurate (eg. with phase contrast imaging and lower beam hardening effect) and faster data collection than lab equipment – 2D radiography can be performed at MHz rate for monitoring rapid phenomena and 3D CT can be done at ~Hz speed. With these capabilities, it is possible to monitor dynamic processes in real time (e.g. crack propagation, exploding fuse or bed fusion in additive manufacturing). Neutron tomography makes use of the specific properties of thermal neutrons to penetrate deeply a large majority of materials (e.g. most metals) whilst being highly sensitive to other elements, notably hydrogen and lithium, enabling the imaging of water, polymers or explosive charges embedded in metallic structures, without metal induced image artefacts neither radiation damage.

We will conclude our presentation by briefly showing how further neutron and synchrotron X-rays techniques can address issues in composites, electrical components and radiation.

KEYWORDS
Stress and strain | Tomography | In-operando and in-situ | Advanced techniques |