Peering inside:
3D imaging in materials

Physical Sciences | Prof Dr Elena Jasiūnienė

New strong materials are in demand in many sectors, leading to the development of different hybrid structures. These can be made from dissimilar light materials such as aluminium alloys, which are joined by incorporating reinforcing fillers into the weld, or self-compacting fibre-reinforced concrete, which is reinforced using fibres. However, creating new materials is not without its problems. The process parameters can be imperfect or are affected by different variables or unforeseen circumstances. The quality of the structure can be affected and the performance of the loaded structure could be unexpected. To see how these different reinforcements influence the properties of materials, Prof Dr Elena Jasiūnienė, Ultrasound Research Institute, Kaunas University of Technology, uses X-ray computed tomography, an X-ray imaging technique that can be used on a wide variety of materials, including metals, biological structures and many complex materials, including hybrid structures such as concrete combined with steel or dissimilar metal joints with nanoparticle fillers.

The versatility and non-destructive nature of this approach is why Prof Dr Elena Jasiūnienė, Ultrasound Research Institute, Kaunas University of Technology, Lithuania has been taking advantage of the unique abilities of X-ray computed tomography to examine its contents in full three-dimensional detail. The ability is unique to X-ray computed tomography, an X-ray imaging technique that can be used on objects or tissues inside the patient. This produces a flat image where the densest areas are highlighted in white as they absorb the greatest amount of the incoming X-ray radiation.

Now, using more modern X-ray imaging methods, it is possible to image not just two-dimensional images of the inside of an object, but reconstruct them very difficult to identify with other 2D imaging. The small size of the nanoparticles, with each other in more standard methods and inspire approaches for the design of customised materials for specific applications.

LIGHTWEIGHT AND STRONG
Part of the increasing demand for strong materials that are still lightweight is motivated by attempts to decrease energy consumption. Lighter materials have several benefits as less energy is required to transport them and, if they are being used to make transport vehicles, it reduces their fuel demands too. A common way of achieving high strength while reducing weight is to make alloys, mixtures of two or more different materials. Aluminium alloys are very popular for this purpose but can be very hard to handle during construction as they are difficult to weld into structures using conventional welding techniques.

Some of this difficulty in the welding process results in inconsistencies and imperfections in the final weld on a microscopic scale. To identify such deficiencies, Prof Dr Jasiūnienė and her team used a combination of X-ray computed tomography and acoustic microscopy to investigate the invisible defects inside welds between different alloys. From the reconstructions of the three-dimensional images of the inside of the welds, they could pinpoint exactly where the defects in the weld zones formed. The 3D capabilities of 3D tomography mean all of this can be done in real space and it is possible to resolve defects that would overlap with each other in more standard 2D imaging.

The small size of the nanoparticles, and the defects they can cause, make them very difficult to identify with other non-destructive imaging techniques. The non-destructive nature of the technique also means it is suitable for use on manufactured pieces that require checking and could potentially be done routinely to assess fatigue or accumulating damage.

SELF-COMPACTING CONCRETE
Concrete is a mixture of cement and a binder that is usually liquefied with water. After the mixture is made, it remains in a gel-type form so it can be poured into moulds and manipulated until it sets, as a solid. While it is being poured, the concrete needs to be compacted so that all the air bubbles and voids in the structure are removed to ensure that there are no inhomogeneities in the structure of the concrete and it is as strong as required. This is achieved by using a steel probe to act as a continuous source of vibration while the concrete is being poured.

Self-compacting concrete eliminates the need for continuous vibration and typically has a higher strength for a given water:cement and binder ratio than the traditional form. One way of making self-compacting concrete is to include superplasticizers that help...
Behind the Research

Prof. Dr. Elena Jasiūnienė generates 3D images of the inner structure allows quality evaluation of the different structures non-destructively – making the invisible visible.

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Prof. Dr. Elena Jasiūnienė investigates the properties of various materials, particularly self-compacting concrete, using X-ray computed tomography both alone and in conjunction with other methods.

Research Objectives

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• D.A. Dragatogiannis, E.P. Koumoulos, C.A. Charitidis (Institute of Advanced Composite Materials and Structures, National Technical University of Athens, Athens, Greece)
• Dr Vaidotas Cienas, (Prof. K. Baršauskas Ultrasound Research Institute, Kaunas University of Technology)
• O.A. Dragatogianis, E.P. Kournoulis, C.A. Charitidis (Research Unit of Advanced Composite Materials and Nano Technology, University of Athens, Athens, Greece)
• Jzmantas Rudbionis, Paulius Grigaliunas (Faculty of Civil Engineering and Architecture, Kaunas University of Technology)

Collaborators

• Dr Vaidotas Cienas, (Prof. K. Baršauskas Ultrasound Research Institute, Kaunas University of Technology)
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• Kaunas University of Technology under grant agreement No-MTEPI-P-15010, project BeReTyr “Determination of mechanical properties of concrete in order to assess the harmful consequences of alkali-silica reaction on the composition of the material; investigation of glider longeron, made from CFRP to determine porosity; investigations of very different types of materials/structures have been performed: investigation of the structure of 3D scaffolds for bone tissue regeneration; investigation of titanium pin array structure produced using additive manufacturing technology; human teeth for investigation of root canal transportation and centring ability of rotary endodontics instruments; visualisation of inner structure of microchips; investigation of the integrity of concrete in order to assess the harmful consequences of alkali-silica reaction on the composition of the material; investigation of glider longeron, made from CFRP to determine porosity.

References


Personal Response

What other material and systems have you been investigating with X-ray imaging tomography?

Investigations of very different types of materials/structures have been performed: investigation of the structure of 3D scaffolds for bone tissue regeneration; investigation of titanium pin array structure produced using additive manufacturing technology; human teeth for investigation of root canal transportation and centring ability of rotary endodontics instruments; visualisation of inner structure of microchips; investigation of the integrity of concrete in order to assess the harmful consequences of alkali-silica reaction on the composition of the material; investigation of glider longeron, made from CFRP to determine porosity.