Visualization of dynamic fluid flow processes by means of neutron imaging

Optimized engineering shines through

Introduction

Numerous natural and technical processes are driven by the flow properties of liquids in various environments, in very different guises. These can range, for example, from simple water ingress into concrete up to the sophisticated injection processes of fuel in today's modern combustion engines. These liquid transport processes can occur on very different time scales, from diffusion over hours up to fast and repetitive events of the order of milliseconds, or even shorter.

It is a great challenge to effectively study and trace such processes directly and non-invasively. Because most test assemblies incorporating dynamic flow processes are not transparent to the visible light spectrum, optical inspection is limited to only a few cases. The visualization of dynamic fluid processes in advanced technology requires transmission and high resolution within the same experimental setup, thus enabling dynamic visualization of manifold details over entire assemblies.

Neutron imaging as an inspection tool

In today's non-invasive and non-destructive testing practice, it is very common to use X-rays for structural analysis. This well-known method is not only used for medical diagnosis but also finds increasing technological application in materials sciences and engineering.

However, X-rays have two major drawbacks: their transmission properties for imaging through metals is fairly limited, and hydrogen compounds, such as water, oil or any other aqueous solutions, are not clearly visible and distinguishable inside metallic structures. Both limitations can be overcome when a beam of free neutrons is used instead of X-rays.

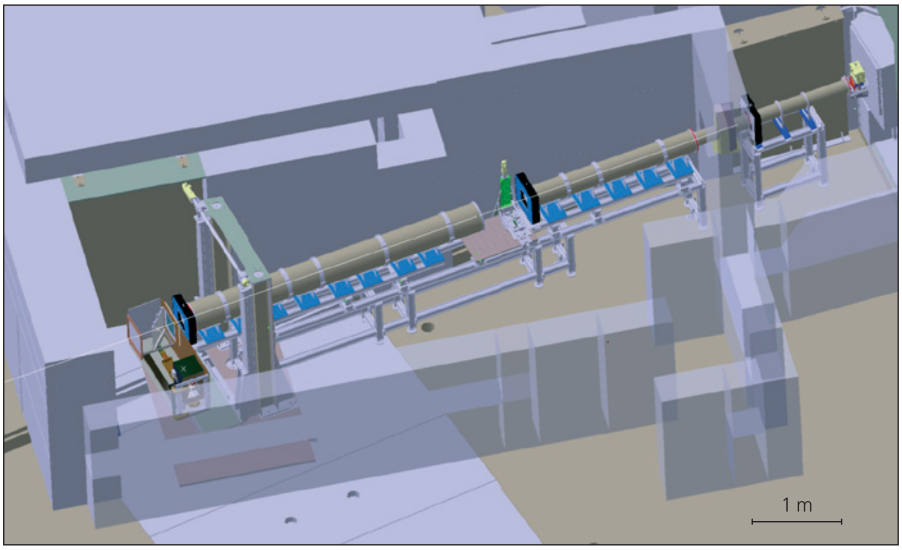

Figure 1: **Layout of the neutron imaging facility ICON at the Spallation Neutron Source, SINQ: two different beam positions offer a wide dimensional range for samples or engineering installations.**

Current and future applications

The new method of Neutron Imaging offers a broad versatility to screen hollow structures made of most engineering metals.

Using the particular physical properties of neutrons, which strongly interact with the light elements, such as hydrogen, a continuous flow of thermal or cold neutrons provides new imaging opportunities to study even very thin films of hydrogenous liquids, such as water, ferrofluids or oil. These liquid media are often encapsulated in diverse metallic assemblies, such as engines, or engine components such as carburettors, flow control meters or electro-hydraulic active damping systems.

The monitoring of liquid behaviour within canulla in medical devices is also

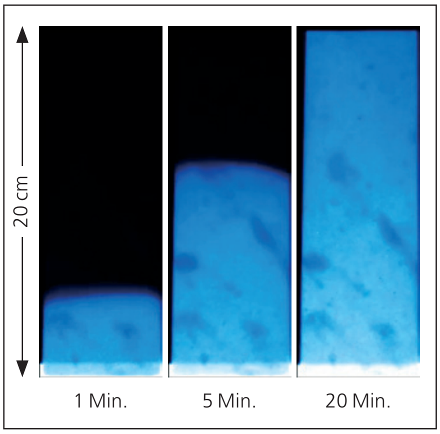

Figure 2: **Study of the water absorption of limestone over a range of 20 minutes and the determination of specific diffusion properties, snapshots of one series of measurements.**

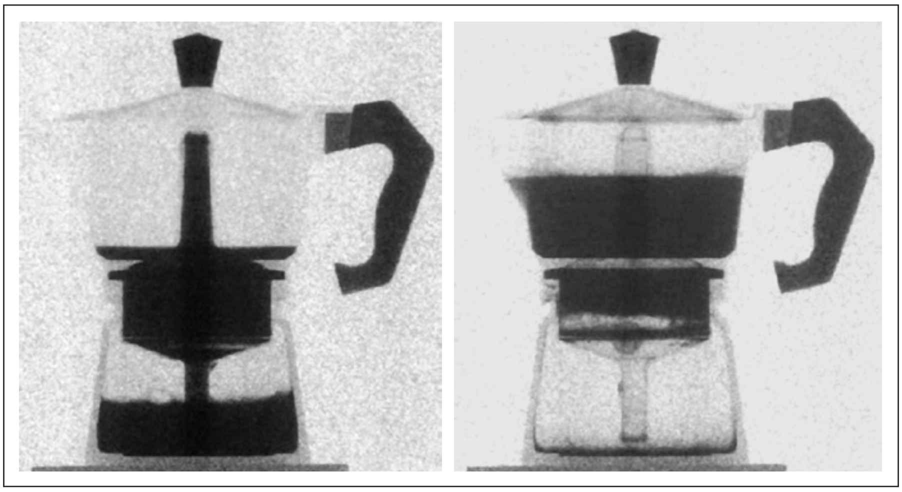

Figure 3: **Coffee pot and boiler, two-phase flow of water and vapour inside the metallic structure, frame rate of 25 pictures/sec, “real time” flow monitoring.**

Figure 4: **Technische Universität (TU) München, Institut Laue-Langevin (ILL) Grenoble and PSI: sequence of oil lubricant distributions inside a running 4-stroke combustion engine.**

possible thanks to the advanced resolution properties of the imaging system at PSI.

Facilities for neutron imaging at PSI

One of the large-scale facilities at PSI is the Spallation Neutron Source, SINQ, hosting about 20 different installations for research using neutron beams. Among these are two beamlines specifically designed for neutron imaging purposes. Figure 1 provides an overview ofone of these, the ICON facility, where investigations can be carried out with cold neutrons.

ICON offers a high degree of flexibility in terms of the field of view available, covering up to 40 cm^2, and allows large samples to be investigated. In addition, the spatial resolution of this imaging technique can be optimized down to a resolution in the range of about 10 µm.

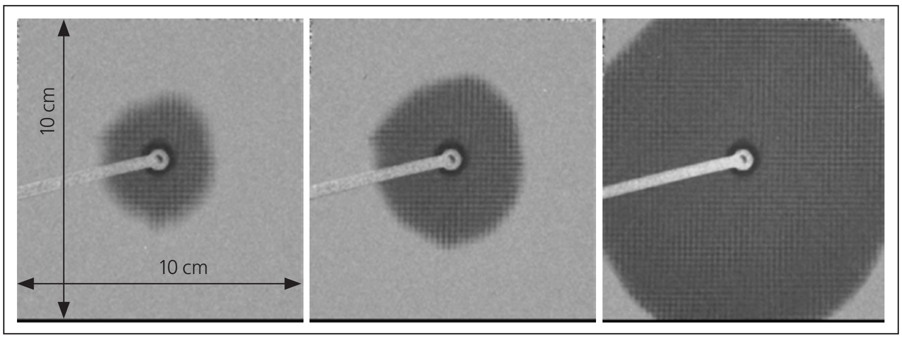

Figure 5: **Time-dependent sequence of the penetration of liquid polymer resin in woven glass fibre fabric over a range of a few seconds, 2D recording of the impregnation process and visualization of the anisotropy of the textile structure.**

Examples of previous studies

Figures 2–5 show selected images taken from investigations on liquid flow processes performed with the help of neutrons. In all cases, hydrogenous liquids (such as water, oil or even resins) become visible with high contrast, whereas encapsulation of solid materials such as stone, metal or wood appears almost transparent in this imaging technique. In Figure 4, the die-cast Al/Mg alloy is almost transparent to neutrons but shows the resolution of oil-jet cooling. The piston crown is visible as a vertical line in the centre. Imaging was carried dout with single frame exposures of the order of few milliseconds, with subsequent superpositioning of identical cycle positions.

Services at PSI

On demand, PSI offers the usage of neutron imaging beamlines on a subscription or partnership basis for services dealing with similar applications to those shown above.

PSI welcomes your proposals for joint cooperation in new technological fields for the visualization of fluid dynamics.

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