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Engineering

Rotation axis demultiplexer enabling simultaneous computed tomography of multiple samples

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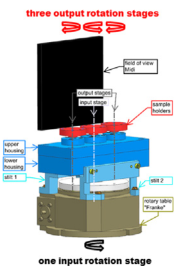
G R A P H I C A L A B S T R A C T



A B S T R A C T

This paper describes a device that allows for simultaneous tomographic imaging of samples on three independent rotational axes. This rotation axis demultiplexer (POLYTOM) is equipped with anti-backlash gears and placed on a standard sample rotation stage thus allowing for the transformation of the input rotation axis onto two additional parallel vertical axes. Consequently, three times the number of samples can be investigated within a given time period, thereby reducing the acquisition time of multiple sample tomographic investigations by a factor of three. The results of our pilot experiments using neutron tomographic imaging are presented. We foresee that the device will be of particular use for tomographic imaging of elongated samples at low-flux (e.g. neutron) sources; however, its use for the more widespread types of imaging techniques (e.g. X-rays) is not ruled out. The highlights of this new device for the purpose of the (neutron) computed tomography are:

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- Anti-backlash transformation of the input rotation onto two additional rotational axes.
- Reduction of the acquisition time of the multiple sample tomographic investigations by a factor of three.
- Low-cost.

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Method details

The temporal resolution of some imaging facilities (e.g. those for neutron imaging) is limited by the relatively low flux of its sources. Even with the most powerful neutron sources it is common that the acquisition time for neutron radiographies is on the order of many seconds to minutes, while the time required for acquisition of entire neutron tomographies is on the order of tens of hours (e.g. [1]). The neutron flux consideration is even less favorable in the case of energy-selective neutron imaging [2] in which only fraction of the incoming polychromatic beam is utilized and thus the times needed for the statistically-relevant investigations might be even more demanding. Such time budgets therefore pose serious obstacles for investigations that require high throughput of samples (e.g. biological studies [3]).

While the size and shape of the field of view depend on a particular test arrangement, the typical field of view in (neutron) full-field imaging is given by the shape of the utilized detector. The routinely used charge-coupled devices (CCDs) or complementary metal-oxide-semiconductor (CMOS) cameras are usually in the shape of a square or low-aspect-ratio rectangle. Likewise, the available neutron beam profile at the detector position usually has similar vertical and horizontal dimensions.

For tomographic imaging, samples are placed on a rotational stage and radiographs are acquired from various angular positions. In the case that the samples are significantly smaller than the field of view, it is possible, and indeed a common practice, to stack the samples above each other and perform the tomography investigation of multiple samples in the same tomographic run. However, even when stacked in the vertical direction, the samples often fill up only a limited part of the available field of view in the horizontal direction [4]. This also holds true for samples with elongated shapes (e.g., swords [5,6], cladding tubes [7], etc.), which intrinsically occupy only a limited part of the view in the horizontal direction. For such sample shapes and sizes, it would be rather advantageous to be able to perform simultaneous tomographic imaging of multiple samples by utilizing more of the detector area and, thus, the (neutron) flux more efficiently.

Tomographic sample stages are routinely equipped with a single rotational stage with its (usually vertical) axis of rotation parallel to the imaging plane (e.g., the scintillator screen). In this paper, we demonstrate that a rotation axis demultiplexer (POLYTOM) can be reliably used to transform the rotation from this single rotational axis onto two adjacent parallel axes. In this way, the field of view is divided into three independent vertical segments in which three tomographies can be run simultaneously. We tested the device using both neutron and X-ray imaging at the NEUTRA beamline, and we demonstrate that the three resulting tomographic datasets show no sign of any instability or irregularity artifacts due to its use.

Methods

The POLYTOM device was designed with three actuated axes. In order to provide the highest possible precision, and hence obtain the highest resolution during tomography, two constraints were applied to the mechanical design: (i) minimization of tolerances, and (ii) no allowable backlash from the gears. It is worth pointing out here that the anti-backlash gears are particularly important for the tomographic experiments, during which the direction of the motion of the rotation stages changes (i.e. time series of tomographic experiments and/or any tomographic experiment using non-sequential

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