Neutron DR/CT Upgrade at McLellan Nuclear Reactor Center

This is the second year of a two-year project in which LLNL and McLellan Nuclear Reactor Facility (MNRC, at the University of California, Davis) are collaborating on the upgrade of a neutron imaging DR/CT system.

Neutron imaging is a particularly useful nondestructive imaging technique for specimens containing trace amounts of hydrogen. Neutron-based inspections are recommended for evaluating fluid flow in soil and rocks, and in the inspection of high explosives (HE).

Project Goals

The overall goal of this collaborative work is the construction of DR/CT capabilities at MNRC enabling inspections with spatial resolution in the 50 to 100 μm range. The current properties of the scanner are 3 lp/mm (0.2 mm spatial resolution), and 4 % contrast for objects that fit in the field of view.

A number of specific tasks were undertaken:

1. collaborate with UC Davis staff on the fielding of hardware and the use of CT data;
2. perform studies of candidate scintillators;
3. perform DR/CT of soil and selected rock samples;
4. investigate DR/CT of HE samples; and
5. perform comparisons of data from LLNL x-ray systems and MNRC neutron scans.

Relevance to LLNL Mission

Scientists in energetic materials, environmental restoration, and earth sciences have applications for neutron-based inspections. Successful completion of this collaboration provides LLNL robust access to a world-class neutron-based inspection facility.

FY2005 Accomplishments and Results

Neutron DR/CT. The camera-scintillator-based scanner is fully operational at MNRC. A number of studies have been performed and numerous modifications applied to fielded hardware (Fig. 1). Several reference objects and geologic specimens have been scanned. Figure 2 contains slices from the CT scan of a rock sample scanned with a 9-in. field of view.

Figure 1. Neutron DR/CT scanner at MNRC.

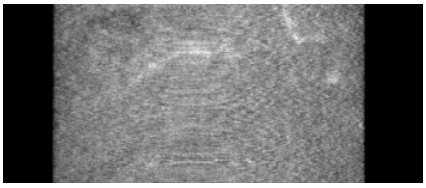

Figure 2. Vertical CT slice of geology sample showing traces of water residue (white voxels).

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Scintillator evaluation studies. We obtained a number of Li-6 and $GdSO_4$ scintillators for evaluation of brightness. Figure 3 is an image from a candidate scintillator. Results showed the Li-6 scintillators provided the best brightness and were able to measure the available resolution for typical object placements. Figure 4 shows an acquired modulation transfer function (MTF) for the best scintillator.

Scans of geologic and aerospace samples. The bulk of the scanning performed at MNRC has focused on geologic samples. We have performed a variety of rock-sample and plant-hydrogen-uptake studies. Two LLNL samples and several commercial objects have also recently been scanned and the results are currently being processed. Figure 5 contains DR and CT images from a Boeing three-position valve, showing the clear way in which the neutron beam images hydrocarbon O-rings in an aluminum matrix.

Inspections. Current inspection work at LLNL for NASA has focused on the inspection of a cartridge explosive bolt, part of the release mechanism that separates the main shuttle rocket engine from the later stage items. We are recommending neutron radiography to determine the presence or absence of the explosive bolt, and CT for inspecting the integrity of the O-ring in the bolt.

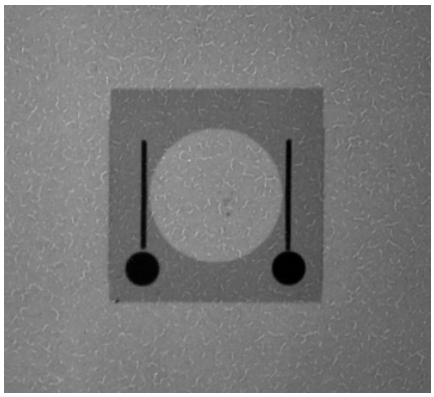

Figure 3. Image from sample scintillator.

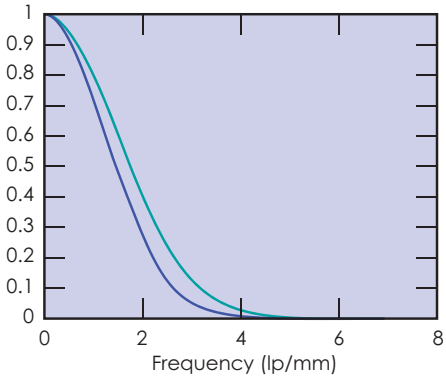

Figure 4. MTFs from the best of the scintillators studied.

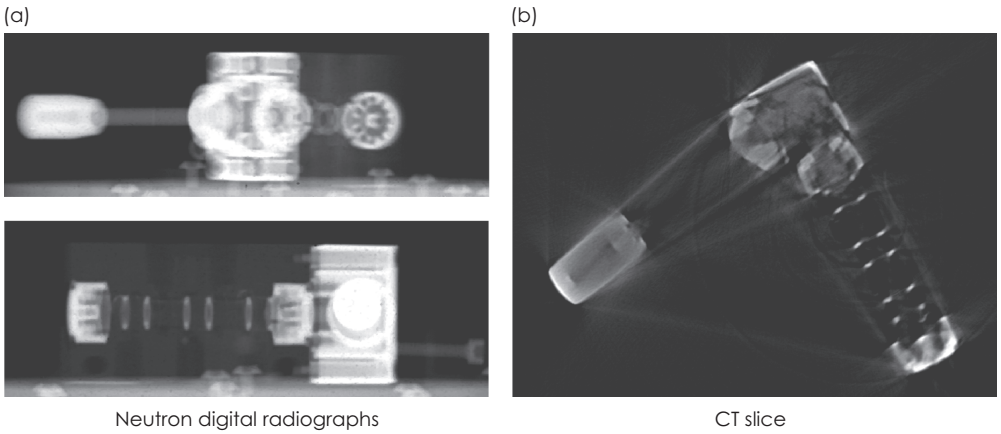

Figure 5. Neutron (a) DR and (b) CT images of Boeing three-position valve.