

TP83 - MicroCT Data Acquisition, Reconstruction and Analysis Using the ISA MicroCT System

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1. Objectives

The objective of this test plan is to acquire MicroCT small scale data (60 mL) samples using the ISA MicroCT system. The data will be used to acquire x-ray properties of the sample.

2. Summary of Approach

A specimen of interest will be housed inside a 60-mL Low Density Polyethylene (LDPE) container. The sample will be placed on the MicroCT carousel and 3 CT data scans will be acquired. The first scan (exp1) uses a 160 kV bremsstrahlung x-ray source with Aluminum and Copper filtering configured as a fan beam. The second scan (exp2) uses a 100 kV x-ray source with Aluminum filtering with a fan beam configuration. The third scan (exp1_Open) is identical to exp1 but the configuration is a cone beam. Each data set will be reconstructed using LLNL developed software and LLNL developed reconstruction scripts.

System performance will be monitored through analysis of the carousel references and energy dependent copper strip attenuation values. If the references and copper strip are within Quality Assurance (QA) bounds, the scan will be considered acceptable. If they are outside the bounds, the scans will be considered unacceptable and a new data set will be generated.

The reconstructed sample images will be analyzed using LLNL developed segmentation and analysis code. The output of the analysis is an Excel spreadsheet with x-ray properties of the sample.

3. Materials

- a) ISA MicroCT System [Brown]
- b) Specimen
- c) Nalgene 60-mL bottles¹

4. MicroCT System Alignment

For proper reconstruction of the CT data, the MicroCT system must be aligned and the geometry of the system be defined. The system will be aligned by following the alignment procedure [Divin]. An abbreviated alignment acquisition checklist can be found in reference [Pincus]. It is recommended the system be re-aligned whenever there has been preventative maintenance performed on the system, when any of the system components have been replaced, or if there is a potential the x-ray tube head and/or detector may have been disturbed. In addition, it is recommended the alignment procedure be executed and the results recorded on a monthly basis. The monthly recordings can be used to track the stability of the alignment.

¹ www.Fishersci.com, Part Number 02-896-1B, 60 mL capacity

5. Detector Calibration

The flat panel detector requires a calibration to be performed to allow uniformity and linearity of the panel during data acquisition. The operator will acquire the calibration files by following the calibration procedure checklist [Pincus]. The detector shall be calibrated at the energies used for data acquisition and with the slit collimator removed. New calibrations should be acquired on a monthly basis or whenever there has been a realignment of the MicroCt system.

6. MicroCT Data Acquisition Procedure

Three CT Scan will be performed for each sample. The three scans are 160 kV, 2 slit with Aluminum and Copper filtering (exp1), 100 kV, 2 slit with Aluminum filtering (exp2) and 160 kV, 1 slit, with Aluminum and Copper filtering (exp1_Open). Appendix A contains the three techniques for each scan. These techniques contain the scanning parameters. The operator shall follow the data acquisition checklist that provides step-by-step instructions for acquiring each of the 3 data acquisition scans [Pincus].

The three scans should be acquired on the same day and it is recommended the scan order should be:

- Exp1 – 160 kV Al/Cu Filter – 2 Slits
- Exp2 – 100 kV Al Filter – 2 Slits
- Exp1_Open – 160 kV Al/Cu Filter – 1 Slit

Use the applicable technique sheet to setup the scan parameters and the checklist to acquire each data scan.

7. Copper Strip QA Check

To verify the x-ray machine is generating a repeatable spectrum, LLNL developed software to monitor the copper strip. The name of the copper strip analysis software is *Cu Strip GUI*. To run the *Cu Strip GUI* refer to the *Cu Strip GUI* manual [Seetho1]. After the software has completed, the resultant values of the mean lower slit and the ratio of the mean upper slit to mean lower slit will be compared to the copper strip criteria. Appendix B contains the copper strip QA Boundaries and criteria. If the scan fails the criteria requirement, it may be an indication the system has changed and may warrant rescanning the sample. If the copper strip results pass the criteria continue to Section 8.

8. Reconstruction of MicroCT data and Qualitative Review

The MicroCT data will be reconstructed using the LLNL developed software IMGREC [Schneberk]. The reconstructions will be performed on the ISA System reconstruction and analysis computer. Appendix C contains example scripts to execute the reconstruction from IMGREC. The actual scripts may change whenever the system has undergone preventative maintenance or there has been a change in the system hardware. The following tasks will be used to reconstruct the exp1 data:

- a. Place the exp1 reconstruction script in the same directory as the exp1 data.
- b. Double click on the IMGREC Icon to start the program.

- c. Using the *Set Current Dir* window, set the directory to the exp1 data set.
- d. Click *File IO => ReadComFile* and click on the exp1 script file.
- e. In the *Command File Processing* window, click the *Do-Com-File* button to start the reconstruction.
- f. When the reconstruction is complete the *Current Command* in the *Command File Processing Window* will state "*Reconstructions Complete*".

Repeat steps a. thru f. for the exp2 and exp1_Open data sets. After the reconstructions are complete, the data will be qualitatively reviewed to check for centering artifacts or a bad beam hardening correction in exp2. Review all reconstructed images in each data set. If the data shows horseshoe artifacts the centering of the data set will be changed, the scripts modified to include the new centering value and the reconstruction re-run with the modified scripts. LLNL will be notified if the scripts change and a copy of the modified scripts will be sent to LLNL. Refer to the IMGREC manual [Schneberk] to change the centering parameter. For the exp2 data set, the aluminum reference will be checked for beam hardening correction [Schneberk]. If there is evidence of cupping in the aluminum reference, LLNL should be consulted for correction.

9. MicroCT Reference Analysis

The MicroCT exp1 and exp2 data set references will be analyzed using the LLNL developed software *Automated MicroCT Analysis GUI* (AMAG). To run AMAG refer to the AMAG Standard Operating Procedure (SOP) [Seetho2]. After the software has completed, open the resultant spreadsheet and compare each reference value to the reference QA Boundaries and reference criteria. The reference boundaries and reference criteria can be found in Appendix B. If the references meet the criterion, the scans are considered acceptable. If the criterion is not met, it may be an indication the system has changed and may warrant rescanning the sample.

References

- Brown Brown, W.D., *Documentation of the ISA Micro Computed Tomography System*, Lawrence Livermore National Laboratory, LLNL-TR-XXXXXX, December 18, 2013
- Divin Divin, C., *MicroCT: Procedure for Alignment*, Lawrence Livermore National Laboratory, LEDP-MCT-SOP-010, Lawrence Livermore National Laboratory, December 11, 2012
- Pincus Pincus, C, *MicroCT Data Acquisition Checklist*, Lawrence Livermore National Laboratory, LLNL-TR-XXXXXX, May 1, 2013
- Seetho1 Seetho, I., J. S. Kallman, W. T. White, H.E. Martz, *MicroCT: X-Ray Radiograph Quality Assurance Through the Analysis of Copper Strip Data Using the Matlab CuStrip Analysis GUI*, LLNL-TR-588852, October, 8, 2012
- Schneberk Schneberk, D., *Imgrec User Guide: CT Pre-processing, Reconstruction, and Image Processing and Image Inspection Tools*, Version 10, Lawrence Livermore National Laboratory, March 1, 2010
- Seetho2 Seetho, Isaac, *MicroCT: Automated Analysis of CT Reconstructed Data of Home Made Explosive Materials Using the Matlab MicroCT Analysis GUI*, Lawrence Livermore National Lab, LLNL-TR-503291, October 6, 2011

Appendix A

Data Acquisition Technique Sheets

| | |
|---------------------------------------|------------------------------------|
| Title | 160 kV 2 Slit Al/Cu Filter - exp1 |
| System Information | |
| Data Acquisition Date | Monday, January 13, 2014 |
| System | ISA 450kV |
| Archive Directory | C:\ISA System\CT Data\2014_Jan_SAT |
| Source | |
| X-ray Source | Yxlon 450kV D11 |
| Effective Spot Size (mm) | Small 0.4 |
| Energy (kV) | 160 |
| Tube Current (mA) | 4.35 |
| Geometric Unsharpness (mm) | 0.112 |
| Filter (Type/Thickness mm) | Al/2.0 Cu/2.0 |
| Detector | |
| Detector Type | Amorphous Silicon Perkin Elmer |
| Source-Detector-Distance (SDD) (mm) | 1413.4 |
| Source-Object-Distance (SOD) (mm) | 1103.8 |
| Object-Detector-Distance (ODD) (mm) | 309.6 |
| X-Offset (Pixels) | 309 |
| X-Size (Pixels) | 1694 |
| Y-Offset (Pixels) | 995 |
| Y-Size (Pixels) | 255 |
| Magnification | 1.280 |
| Frame Average(s) | 6 |
| Integration Knob-Thales Only | N/A |
| Integration Time per Frame(sec) | 1.15 |
| Raw Pixel Size (mm) | 0.2 |
| Global Resampling | 1 |
| Effective Pixel size at Detector (mm) | 0.2 |
| Effective Pixel size at Object (mm) | 0.156 |
| CT Parameters | |
| Numbers of Views | 401 |
| Angular Range | 200.5 |
| Angular Step (Degrees) | 0.5 |
| Estimated PxCenterFull Panel (Pixel) | 1023.1 |
| Estimated PzCenterFull Panel (Pixel) | 1027.8 |

| | |
|---------------------------------------|------------------------------------|
| Title | 100 kV 2 Slit Al Filter - exp2 |
| System Information | |
| Data Acquisition Date | Monday, January 13, 2014 |
| System | ISA 450kV |
| Archive Directory | C:\ISA System\CT Data\2014_Jan_SAT |
| Source | |
| X-ray Source | Yxlon 450kV D11 |
| Effective Spot Size (mm) | Small 0.4 |
| Energy (kV) | 100 |
| Tube Current (mA) | 7 |
| Geometric Unsharpness (mm) | 0.112 |
| Filter (Type/Thickness mm) | Al/2.0 |
| Detector | |
| Detector Type | Amorphous Silicon Perkin Elmer |
| Source-Detector-Distance (SDD) (mm) | 1413.4 |
| Source-Object-Distance (SOD) (mm) | 1103.8 |
| Object-Detector-Distance (ODD) (mm) | 309.6 |
| X-Offset (Pixels) | 309 |
| X-Size (Pixels) | 1694 |
| Y-Offset (Pixels) | 995 |
| Y-Size (Pixels) | 255 |
| Magnification | 1.280 |
| Frame Average(s) | 6 |
| Integration Knob-Thales Only | N/A |
| Integration Time per Frame(sec) | 0.267 |
| Raw Pixel Size (mm) | 0.2 |
| Global Resampling | 1 |
| Effective Pixel size at Detector (mm) | 0.2 |
| Effective Pixel size at Object (mm) | 0.156 |
| CT Parameters | |
| Numbers of Views | 401 |
| Angular Range | 200.5 |
| Angular Step (Degrees) | 0.5 |
| Estimated PxCenterFull Panel (Pixel) | 1023.1 |
| Estimated PzCenterFull Panel (Pixel) | 1027.8 |

| | |
|---------------------------------------|--|
| Title | 160 kV 1 Slit Al/Cu Filter - exp1_Open |
| System Information | |
| Data Acquisition Date | Monday, January 13, 2014 |
| System | ISA 450kV |
| Archive Directory | C:\ISA System\CT Data\2014_Jan_SAT |
| Source | |
| X-ray Source | Yxlon 450kV D11 |
| Effective Spot Size (mm) | Small 0.4 |
| Energy (kV) | 160 |
| Tube Current (mA) | 4.35 |
| Geometric Unsharpness (mm) | 0.112 |
| Filter (Type/Thickness mm) | Al/2.0 Cu/2.0 |
| Detector | |
| Detector Type | Amorphous Silicon Perkin Elmer |
| Source-Detector-Distance (SDD) (mm) | 1413.4 |
| Source-Object-Distance (SOD) (mm) | 1103.8 |
| Object-Detector-Distance (ODD) (mm) | 309.6 |
| X-Offset (Pixels) | 309 |
| X-Size (Pixels) | 1694 |
| Y-Offset (Pixels) | 495 |
| Y-Size (Pixels) | 755 |
| Magnification | 1.280 |
| Frame Average(s) | 6 |
| Integration Knob-Thales Only | N/A |
| Integration Time per Projection(sec) | 0.267 |
| Raw Pixel Size (mm) | 0.2 |
| Global Resampling | 1 |
| Effective Pixel size at Detector (mm) | 0.2 |
| Effective Pixel size at Object (mm) | 0.156 |
| CT Parameters | |
| Numbers of Views | 401 |
| Angular Range | 200.5 |
| Angular Step (Degrees) | 0.5 |
| Estimated PxCenterFull Panel (Pixel) | 1023.1 |
| Estimated PzCenterFull Panel (Pixel) | 1027.8 |

Appendix B Copper Strip QA Boundaries and Criteria

| | Mean Lower Slit | | Lower Slit/Upper Slit | |
|-------------|-----------------|--------|-----------------------|--------|
| | Attenuation | | Ratio | |
| | Min | Max | Min | Max |
| 160 kV AlCu | 0.6833 | 0.6919 | 1.0016 | 1.0117 |
| 100 kV Al | 1.9725 | 1.9926 | 1.0062 | 1.0086 |

MicroCT Copper Strip QA Boundaries

| Material | 160 kV Mean Min | 160 kV Mean Max | Ratio Min | Ratio Max |
|-----------|--------------------|--------------------|--------------|--------------|
| Silicon | 2569.04 | 2605.76 | 2.082 | 2.101 |
| Delrin | 1321.65 | 1336.65 | 1.328 | 1.342 |
| Graphite | 1568.26 | 1588.85 | 1.252 | 1.263 |
| Magnesium | 1807.78 | 1822.03 | 1.911 | 1.920 |
| Water | 999.00 | 1001.00 | 1.372 | 1.388 |
| Teflon | 1896.67 | 1937.53 | 1.468 | 1.484 |

MicroCT Reference QA Bounds

Appendix C

Reconstruction Scripts

```
! Recon Script for ISA Exp 1, 160kV 2-Slits
! For data acquired after January 12, 2014,
!
! start with clean signal stack
!
delete 99
!
rdscat exp1
set exstart 50
set eystart 26
set exsize 40
set eysize 10
mkatrad
rdsq atenrad 0
sqext 78 0 1270 255 atenrad
!
rdscat atenrad
set nrays 1270
set nslices 255
set rxelements 1270
set ryelements 1270
set rzelements 255
wrsct atenrad
!
rdscat atenrad
!
makesino 26 36
set pord 5
set npreord 60
set prthresh 0.003
set rngnorm 0
set rth1 0.03
set ord1 7
set dor1 1
set rth2 0.57
set ord2 21
set dor2 1
!set bmcorsfile
!set dobm 1
!
ringo
Set pxcenter 636.25
```

```
cbp
!  
rdset atenrad  
makesino 215 225  
set pord 5  
set npreord 60  
set prthresh 0.003  
set rngnorm 0  
set rth1 0.03  
set ord1 7  
set dor1 1  
set rth2 0.57  
set ord2 21  
set dor2 1  
!set bmcorfile  
!set dobm 1  
!  
ringo  
Set pxcenter 636.25  
cbp  
!  
!Reconstruction Complete !!!
```

```
! Recon Script for ISA Exp 2, 160kV 2-Slits
! For data acquired after January 12, 2014,
!
! start with clean signal stack
!
delete 99
!
rdsct exp2
set exstart 50
set eystart 26
set exsize 40
set eysize 10
mkatrad
rdsq atenrad 0
sqext 78 0 1270 255 atenrad
!
rdsct atenrad
set nrays 1270
set nslices 255
set rxelements 1270
set ryelements 1270
set rzelements 255
wrsct atenrad
!
rdsct atenrad
!
makesino 26 36
set pord 5
set npreord 60
set prthresh 0.003
set rngnorm 0
set rth1 0.03
set ord1 7
set dor1 1
set rth2 0.57
set ord2 21
set dor2 1
set bmcorsfile C:\CT\bmcorsfiles\131203_ISA_BHC_Coeffs.txt
set dobm 1
!
ringo
Set pxcenter 636.25
cbp
!
rdsct atenrad
makesino 215 225
```

```
set pord 5
set npreord 60
set prthresh 0.003
set rngnorm 0
set rth1 0.03
set ord1 7
set dor1 1
set rth2 0.57
set ord2 21
set dor2 1
set bmcorfile C:\CT\bmcorfiles\131203_ISA_BHC_Coeffs.txt
set dobm 1
!
ringo
Set pxcenter 636.25
cbp
!
!Reconstruction Complete !!!
```

```
! Recon Script for ISA Exp 1_open, 160kV 1-Slit
! For data acquired after January 12, 2014
!
! start with clean signal stack
!
delete 99
!
rdset Exp1_Open
set exstart 50
set eystart 50
set exsize 50
set eysize 50
mkatrad
rdsq atenrad 0
sqext 78 0 1270 755 atenrad
!
rdset atenrad
set nrays 1270
set nslices 755
set rxelements 1270
set ryelements 1270
set rzelements 755
wrsct atenrad
!
rdset atenrad
set pord 5
set npreord 60
set prthresh 0.003
set rngnorm 0
set rth1 0.03
set ord1 7
set dor1 1
set rth2 0.57
set ord2 21
set dor2 1
!
ringo
!
makesino 715 725
rdset sinos
Set pxcenter 636.25
cbp
!
rdset atenrad
fltrads
!
```

```
set ryelements 50
set rzoffset 0
set rzelements 400
set pxcenter 636.25
set pzcenter 532.0
set ryoffset 700
feldkamp
set ryoffset 750
feldkamp
set ryoffset 800
feldkamp
set ryoffset 850
feldkamp
set ryoffset 900
feldkamp
set ryoffset 950
feldkamp
set ryoffset 1000
feldkamp
rdsq recry 700
sqgty 0 400 rz
!
! Reconstruction Complete
```