Correction of vertical point of projection images using the correct axis tilt parameter in the Octopus software package

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Abstract. Correction of vertical point of projection images using the correct axis tilt parameter in the Octopus software package. In the acquisition process to get a projection image need sample test stability of vertical point directly to the detector. During the acquisition process, the sample test must be still on coordinate and not take a movement. The problem that appears in some tests caused when both of them haven’t be done, can make projection image not good. This problem can be handled with the correction parameter and without the repeat acquisition process. The correction of the projection image may concern the vertical point movement of the sample test to the detector. It can decide a conclusion for sample test conditions. Correct axis tilt parameter help to change a better projection image result for the reconstruction process. The first correction was obtained tilt angle amount 0.333289˚, the second correction was obtained tilt angel amount -0.463394˚, and the third correction was obtained tilt angle amount 0.4903˚. The correct axis tilt was succeed rotate projection image and change the view transaction of reconstruction better and can be read easily.

1. Introduction

The development of industrial technology has been growing rapidly. Many manufacturing industries produce goods using a variety of materials with large and thick dimensions. The quality of goods produced by industrial must be tested and have guaranteed quality before distributed to the global market. [1] On the final check of the product, the objects must be free from inside damage which condition can not be detected only checking by outside of the object. Object test was through testing without damaging the object test. [2] Therefore, the objects were checked through irradiation using radiation source equipment using an X-ray plane in the acquisition images process. X-ray computed tomography is a method of forming three-dimensional (3D) representations of an object by taking many x-ray images around an axis of rotation and using algorithms to reconstruct a 3D model. [10,11,12]

The image's acquisition process produces the images needed in the reconstruction process. Reconstruction processes using Octopus Software with angular turns to meet 360˚ of projection images. Results of reconstruction object test in the form of a cross-section two-dimensional images. The data are processed by a computer system that performs a reconstruction using the acquired x-ray intensity readings for each of the detector elements. These intensity readings result from the summation of individual linear attenuation coefficients along a vector through the measurand from the x-ray source to the detector element. Using these values, the computer builds up individual slice images,
which can then be stacked into a 3D reconstruction. [9,10] To get the geometric shape of the object defect as a whole, we need an image that can display the object in 3D. The image is a 3D image, which is an image that displays the geometry of the shape of the volume in the coordinates of space. [13] The appearance and shape of objects in cross-section images are influenced by stability or shift the object test during the acquisition process. If there is no shift in the object test, it will produce clear reconstruction results.

The instability correction is performed when there is a shift in the vertical point of object test against the detector. The shift occurs because the object test does not settle on the coordinates of the turn or objects that rotate when the turntable media moves. The parameter used to solve this problem is the correct axis tilt parameter in Octopus software, for correcting vertical point and change projection image to be better than before the correction was applied.

Repetition of correct axis tilt parameter in reconstruction testing is expected to be able to display the results of reconstruction cross-sectional images more clearly so that they are easier to use in analyzing the quality of object test. In other words, a quality image is an image that can provide as much information on the object being examined so that it will assist in the accuracy of the radiographic operator's diagnosis. [3] This can save testing time, because corrections can be made without repeating the acquisition process from the beginning.

2. Theory
The acquisition process is a process when an X-ray device emits light against to test object then obtains an image that will be further observed in the reconstruction process. The acquisition process produces projection images with different angles and elaborating together to build a virtual object test to obtain cross-sectional image data. [4] Rotation to form an angle of 0˚-360˚ can be done by innovating the media on which the object test is placed. The object test used in the test is an ignition coil as shown in the following picture:

![Figure 1. Object test](image)

The acquisition process uses a radioscopy box that is equipped with several components such as a detector, Edmund's mirror, and a camera. Following a brief explanation of these components:

- The detector used is a fluorescent screen detector that serves as a detection medium to capture the image results of the object test that have been exposed to a beam of light emitting from an X-ray device with a certain distance. Because it uses a fluorescent screen, digital cameras are used to take the results of X-ray projections of the object test.
- Edmund's mirror functions as a tool to reflect shadows or images that appear on the fluorescent screen and towards the camera. [5]
- The camera in the radioscopy box is placed in a small box to protect the camera from light exposure and radiation received. [6]
In image reconstructing can use the technique of dividing images into sections or called image sectioning. The impossibility of splitting objects into pieces is one of the reasons for implementing the reconstruction process. [7] Reconstruction with Octopus software uses projected images which in the process there is a correction vertical point obtained tilt angle value. Following steps make corrections: [8]

- Open Octopus software
- Application of filter spots on the projected image as a spotting filter image.
- Select a folder contains the projection images and create a new folder for the filtered image.
- It provides a normalized image by running the parameter normalize images.
- Select a folder contains the image of the spotted filter and create a new folder for normalizing results.
- Make corrections vertical point in the projected image using the correct axis tilt parameter to get a better image to be reconstructed.
- Select a folder contains the normalized image. Next step, measure the value of the tilt angle that used as the angle of rotation object. This rotation will improve the cross-section image reconstruction result. Also, create a new folder for the corrected image.

In the correction phase, the projection image is needed at an angle of 0˚ and 180˚ as a comparison of the occurrence of vertical point shifts in the image of the detector and also using the ROI selection to determine object boundaries.

In the cone-beam geometry method described in Figure 3, the optical axis is a line along with the X-ray source that is perpendicular to the detector surface. This point is the center of rotation or the midpoint of the detector. The detector line leading to the midpoint of the detector is defined as a vertical point. Perfect alignment occurs when the optical axis intersects at the center of the detector, the rotation axis intersects with the optical axis, and the axis of rotation is parallel to the midpoint of the detector line.
The center of rotation is the axis of rotation when projection on the detector. The number of columns in the detector defines the axis of rotation position in the reconstruction module. The fractional value will be obtained, when the rotation of projection does not shift from the center of the detector column.

![Figure 4. Vertical point shift](image_url)

Figure 4. Vertical point shift

Figure 4 explains the vertical shifts that occur in the detector (or shifts that occur in X-ray sources in different directions). All values remain the same except the vertical point. The optical axis will intersect the detector at a certain height.

![Figure 5. ROI (Region of Interest)](image_url)

Figure 5. ROI (Region of Interest)

Region of interest parameter uses to cut region of the projection image in accordance with the desired coverage. This parameter is executed before applying the parameter Correct Axis Tilt. With the application of ROI, the value of the vertical point and rotation axis will change position. [8]

3. Method
Reconstruction requires a projection image to be processed into several images generated therein. Following are images needed for reconstruction process:

- Projection images 0° to 360°.
- Spot filter images.
- Normalize images.
- Correction images result.
- Reconstruction images.

Following steps to obtain reconstruction image with the addition of tilt correction:
Figure 6. First correction of the vertical point flow chart

The correct axis tilt parameter can be used more than once to get a clearer image cross-section. Following flow charts of second and third correction:
4. Result

Based on the test results of the correction process carried out on the test objects, the results obtained below:

- There was a shift vertical point of the test object to the detector, resulting in a cross-sectional view of reconstruction results that seem unclear.
- Rotation of the object test is caused by the vibration of the turntable. This occurs when the acquisition process of the projection image running.

(a) Figure 7. Second correction tilt flow chart (a) Third correction tilt flow chart (b)
In the first correction after determining the ROI selection, proceed measured tilt angle with detect axis tilt parameter. The first correction obtained a tilt angle amount of 0.333289°.

Figure 8. Tilt angle value of detect exist tilt

Image rotated by 0.333289° can be seen in Figure 9. Following correction tilt at an angle of 45° and 360° projection:

Figure 9. Correct tilt on projection image 45°

Figure 10. Correct tilt on projection image 360°
Rotated images are stored in a folder to be used as a directory file for creating sinograms and reconstruction process. Image correction carried out in three stages. The measured tilt angle values of second and third correction are shown in the following figure:

(a) Tilt angle value of second correction (a) Tilt angle value of second correction (b)

The second correction using image rotated first step and the measured tilt angle value amount -0.463394°. The third correction using image rotated the second step and the measured tilt angle value amount 0.4903°. Overall correction results on slices 150, 250, 480, and 620 are compared in the following figure:

Figure 12. Comparison of reconstruction without and with tilt correction

The difference in the correction results can be seen from the reading of the grey value. These results make it easier to read the quality of the two-dimensional cross-section the reconstruction results. Following explain in the grey value profiler graph:
Figure 13. Reconstruction image slice 155 (a) Correction step 1 slice 155 (b) Correction step 2 slice 155 (c) Correction step 3 slice 155 (d)

Figure 13 (a) is a cross-sectional image reconstruction without correction tilt with a tight line ripple. It is influenced by a large or small of grey values along a line that shows the quality of the reconstruction. Several correction steps carried out on the projected image made the reconstruction image clearer, characterized by reduction ripple on the profiler graph of cross-section image. The projected image that has been successfully corrected makes the outline of the object test sharper and the object detail boundaries clearer. And also, visual graphics become smoother or reduced ripple on the graph.

Figure 14. Reconstruction image slice 620 (a) Correction step 1 slice 620 (b) Correction step 2 slice 620 (c) Correction step 3 slice 620 (d)
Corrections slice 620 also displays the same graphic detail. Ripple reduces along with the line indicator on reconstruction result. The projected image has been successfully corrected.

5. Conclusion
The results of the cross-section image with correction using the correct axis tilt parameter can show better results. The first correction produces a tilt angle of 0.333289°. The second correction produces a tilt angle of -0.463394°. The third correction produces a tilt angle of 0.4903°. The correction parameter using Octopus software can be applied in the reconstruction process. Reconstruction results are affected by the arrangement of vertical point and axis of rotation object during the acquisition process. A better projection image will be obtained by applying the correct axis tilt parameter and do without repeating the acquisition process.

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Reference
[1] Suryaningsih F, Kurnianto K, Susanto A T 2015 Pengujian Hasil Rekonstruksi Citra Radiografi Digital Menggunakan Program Labview (Indonesia: Center for Nuclear Facility Engineering - National Nuclear Energy Agency) p 20 ISSN No.1978-3515
[2] Susanto A T, Kurnianto K, Handoyo D, Suryaningsih F 2017 Modul Perangkat Lunak Akuisisi Citra Dan Kendali Meja Putar Prototype Perangkat Radioskopi Untuk Industri Manufaktur (Indonesia: Center for Nuclear Facility Engineering - National Nuclear Energy Agency) p 10 ISSN : 1411-0296
[3] Suryaningsih F and Susanto A T 2015 Kalibrasi Akuisisi Citra Pesawat Sinar-X Portable Dig 1100 (Indonesia: Center for Nuclear Facility Engineering - National Nuclear Energy Agency) ISSN : 1411-0296
[4] Carmignato S 2012 Computed Tomography As A Promising Solution For Industrial Quality Control And Inspection Of Castings (Italy: University of Padova) Vol 30-1 p 6
[5] Suryaningsih F, Handoyo D, Susanto A T 2018 Development Of Image Acquisition Software for Digital Radiograph and X-Ray CT (Indonesia: Center for Nuclear Facility Engineering - National Nuclear Energy Agency) p 1 doi: 10.1088/1742-6596/1198/4/042007
[6] Suryaningsih F, Handoyo D, Khasan N, Susanto A T 2016 Modifikasi Kotak Penangkap Citra NDE Radioskopi Digital Desain Bam-Jerman (Indonesia: Center for Nuclear Facility Engineering - National Nuclear Energy Agency) p 232 ISSN : 2540 - 8062
[7] Zvolský M, Garutti E, Grüner F 2013 Tomographic Image Reconstruction (German: University Of Hamburg) p 3
[8] Octopus Reconstruction User Manual 2016 Version: 8.9.2 pp 29-31 pp 45-50
[9] Hsieh J 2009 Computed tomography: principles, design, artifacts, and recent advances (Bellingham, WA, USA: SPIE Press)
[10] Thompson A, Maskery I, Leach R K 2016 X-ray computed tomography for additive manufacturing: a review (UK: University of Nottingham) p 2-3
[11] Kruth J-P, Bartscher M, Carmignato S, Schmitt R, De Chiffre L and Weckenmann A 2011 Computed tomography for dimensional metrology CIRP Ann. Manuf. Techn. 60 821-42
[12] De Chiffre L, Carmignato S, Kruth J-P, Schmitt R and Weckenmann A 2014 Industrial applications of computed tomography CIRP Ann. Manuf. Techn. 63 655-77
[13] Amin M, Suryaningsih F, Imran W Z, Handoyo D 2015 Perancangan Perangkat Lunak Rekonstruksi Citra 3 Dimensi Dari Lembaran Citra Hasil Rekonstruksi 2 Dimensi (Indonesia: Center for Nuclear Facility Engineering - National Nuclear Energy Agency) Prosiding Pertemuan Ilmiah Perekayasaan Fasilitas Nuklir p 156-157