Improvement of portable computed tomography system for on-field applications

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Abstract. In 2010, Thailand Institute of Nuclear Technology (TINT) received a portable Computed Tomography (CT) system from the IAEA as part of the Regional Cooperative Agreement (RCA) program. This portable CT system has been used as the prototype for development of portable CT system intended for industrial applications since then. This paper discusses the improvements in the attempt to utilize the CT system for on-field applications. The system is foreseen to visualize the amount of agarwood in the live tree trunk. The experiments adopting Am-241 as the radiation source were conducted. The Am-241 source was selected since it emits low energy gamma which should better distinguish small density differences of wood types. Test specimens made of timbers with different densities were prepared and used in the experiments. The cross sectional views of the test specimens were obtained from the CT system using different scanning parameters. It is found from the experiments that the results are promising as the picture can clearly differentiate wood types according to their densities. Also, the optimum scanning parameters were determined from the experiments. The results from this work encourage the research team to advance into the next phase which is to experiment with the real tree on the field.

1. Introduction
The gamma Computed Tomography (CT) is an area of interest at Thailand Institute of Nuclear Technology (TINT) for analyzing industrial process units and other similar applications. This technique is considered complementary to the other NDT techniques such as radiotracer or gamma scanning and may provide useful information to diagnose the plant problems. Researches in this area have been conducted at TINT and experimental setups have been carried out throughout the years. The ultimate purpose of these researches is to develop a portable CT system which can be deployed easily at the site in the plant process environment. Applications such as analyzing corrosion under insulation or monitoring multiphase flows are anticipated examples of using such portable CT system. However, the portable CT system has a number of challenges to develop due to its complexity of the construction and operation. For example, the portable CT system shall be flexible enough to align with the process unit in different orientations and it shall be light-weighted such that the setup can be done without assistance from lifting equipment which may not be available or accessible in the installation area. This paper discusses the effort to improve and prepare a portable CT system available at TINT to analyze one particular challenging problem – to visualize the amount of resin in agarwood. This portable CT system was received from IAEA as part of the Regional Cooperative Agreement (RCA) program and it is being used for research work. Uses of different radioactive sources for the portable

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CT system were tested in this research. The capability of the portable CT system to differentiate timber densities was also studied. Finally, test of a live tree was conducted to verify the operability of the portable CT in the field which should have environment similar to the actual utilization.

2. Description of Portable Computed Tomography System
TINT received a portable CT system (named “eGorbit”) from IAEA in 2010 as part of the Regional Cooperative Agreement (RCA) program. This eGorbit system has been used as the prototype for development of the portable CT system intended for industrial applications since then. Basically, this portable CT system consists of the mechanical gantry, the controller unit, the measurement unit, the hardware interface software and the image processing software. The portable CT system is operated by a computer running the hardware interface software which controls the rotations and the movements by use of two servo motors. Figure 1 shows the picture of the portable CT system (eGorbit).

![Figure 1. Picture of the portable CT system.](image)

This portable CT system is actually the first generation CT scanner, that is, it performs parallel scanning in which the source, emitting pencil beam of radiation, and the detector are coupled together such that the detector is always facing the source and they both travel in the same direction during the scan [1]. The components and connections among the components in the portable CT system are described in Figure 2.
The portable CT system consists of 2"x2" NaI detector and gamma source holder as shown in figure 2. The radiation source and the NaI detector are collimated by use of lead collimators having the aperture size of approximately 4.5 mm and the thickness of 2 inches. The detector is connected to Ludlum rate meter (measurement unit) which transmits counting data to hardware control unit of the eGorbit system. The hardware control unit controls two servo motors and communicates with the personal computer via RS-232 port. The first servo motor moves the detector and the source along the X direction while the second one rotates the detector and source in radial direction. The typical radiation source used with this eGorbit system is Cs-137.

3. Improvements of the CT system
In this work, various activities have been carried out to optimize and improve the portable CT system. In fact, the following main tasks were performed in this research.

3.1. Stability improvements
After the eGorbit system was received and assembled, it had been tested for operation with some samples in laboratory. It was, however, found that the operation of the eGorbit system had experienced some malfunctions from time to time. The eGorbit system was then examined for its instability. The problem of internal wiring within the hardware control unit was identified as one of the causes for the abnormal operation. This causes unknown electrical noises into the counting data as well. Another problem was found that the cable connectors were not in good contact. The research team rectified this problem by rewiring the internal cables and the cable connectors of the eGorbit hardware control unit.

3.2. Adopting Am-241 source
The typical radiation source for use in the eGorbit system is Cs-137. However, Cs-137 which has single gamma energy of 661 keV may not be suitable for all applications. One of the current applications of interest is to use the eGorbit system for scanning live agarwood. It was hypothesized that Cs-137 is not best for using in this application since the gamma energy is relatively high which does not have good attenuation property in agarwood. Therefore, a new radiation source was adopted in this work. The Am-241 was selected because it has low gamma energy (main gamma energy of 59.7 keV) [2] and it is considered to have good attenuation property in wood. Comparison of using the eGorbit system with Am-241, Cs-137 and Co-60 was conducted. The activities of the Am-241, Cs-137 and Co-60 sources used in this experiment are approximately 200 mCi, 25 mCi and 14 mCi respectively.

Figure 2. Components and Connections in the eGorbit system.
3.3. Experiments in preparation for on-field application

It is expected that the eGorbit system will be used for scanning objects on-field. Laboratory experiments as described in the followings were designed and conducted to test the feasibility prior to such on-field work:

3.3.1. Test specimen. A test specimen was prepared for testing with the eGorbit system. The test specimen was made of timbers with different densities (approximately 20% difference). The purpose of this test was to observe whether the eGorbit system can differentiate the pattern of wood types in the specimen. The scanning test was conducted with different scanning views to observe the effects of the scanning views to the picture quality as well.

3.3.2. Live tree. Another test performed in preparation to use of the eGorbit system for on-field application was to scan a live tree. The tree was actually located near the laboratory building in TINT. The tree with diameter of approximately 13 cm. was selected for the test. The purpose of this test was to observe the overall performance of the eGorbit system under on-field environments where test conditions were not controlled (i.e., close to the real use). Figure 3 shows the setup of the portable CT system for scanning a live tree.

![Figure 3. Setup of the portable CT system for live tree.](image)

4. Experiment results

4.1. Adopting Am-241 source

The tests of using the eGorbit system with Am-241, Cs-137 and Co-60 for scanning a tree trunk were conducted. It shall be noted that the collimator of 4" thickness in total has the transmission factor of approximately 0.001% for Cs-137 while that of Co-60 is approximately 0.4%. These transmission factors show that only small fraction (less than 1%) of uncollimated radiation beam can enter the detector. Therefore, the collimator shall be sufficiently thick enough for all sources used in this experiment. The pictures from the tests are shown in comparison in figure 4.
As it can be clearly seen from the comparison in Figure 4, the picture quality scanned by use of different radiation sources varies. For tree trunk which is made of wood, radiation source with high gamma energy would not interact very well with the material. Therefore, the picture quality is not as good as that of using lower gamma energy. Thus, the Am-241 source produces best picture quality of all and the Co-60 source produces the worst picture quality of all.

4.2. Test specimen
The results from scanning the test specimen using the eGorbit system are shown in Figure 5.
It can be seen from the pictures shown in figure 5 that the eGorbit system using Am-241 source is able to clearly differentiate the types of wood which have different densities. Moreover, the effect of picture quality when increasing the number of scanning views is compared. It can be observed that using 64 scanning views provides better picture quality compared to using 32 scanning views. However, the scanning time is proportional to the number of scanning views. In this test specimen, the scanning time of approximately 7 hours is typical when using 32 scanning views. This scanning time doubles when using 64 scanning views. Thus, the nominal scanning view of 32 is selected to compromise between practical scanning time and the picture quality.

4.3. Live tree
The scanning of the live tree takes approximately 6 hours. The test of the eGorbit system in the environment similar to the actual one was completed successfully without malfunctions of the hardware and hence it fulfils the purpose of the test. However, since the tree was not cut down to compare with the scanned picture. There is no picture comparison for this test.
5. Conclusion

This research has been conducted to realize the use of the portable CT system available at TINT for on-field applications. It was found at the beginning of the research that the hardware of the portable CT system had some problems and it was rectified by rewiring the cables within the hardware control unit. Moreover, laboratory experiments were conducted to evaluate the feasibility to use the portable CT system for visualizing the amount of resin in agarwood. In order to do that, Am-241 source was adopted to replace the typical Cs-137 source in the portable CT system. The experiment showed that Am-241 source provides better picture quality for wood than Cs-137 or Co-60. Additionally, the use of the portable CT system for differentiating wood densities was performed. It was found that the portable CT system with Am-241 source is able to clearly differentiate the wood density difference of 20%. Finally, the portable CT system was tested with a live tree in order to observe the overall performance under on-field environments and the test was completed successfully. The results from this work encourage the research team to advance into the next phase which is to experiment with the real agarwood.

References

[1] Goldman L W (2007) Principles of CT and CT Technology J. Nucl. Med. Technol. 35 115-28
[2] Strain J E and Leddicottee G W 1962 The preparation, properties, and uses of Americium 241, alpha-, gamma- and neutron sources ORNL-3335 (Oak Ridge: Oak Ridge National Laboratory)