Computational Feasibility Study of Dual Photon/Neutron Imaging Technique

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Introduction
- Non-destructive testing (NDT) is crucial for industrial applications, particularly when imaging of internal components or structures is desired.
- Current NDT imaging techniques, such as x-rays, focus primarily on isolating unique shapes. Rarely are these methods capable of distinguishing materials or material composition.
- Potential application in the car industry for testing and examining the functional durability of materials or material composition are these methods capable of distinguishing low-z and high-z materials with significant variation in density.
- Vehicle engines are composed of a combination of low-z and high-z materials
- Being able to determine the location of material during operation eliminates the need to disassemble an engine during study.

Background
- Current imaging techniques make use of dual photon sources. This does not provide significant variation between materials.
- Dual photon/neutron imaging focuses on the inherent differences between particle interactions, making identification of materials more efficient.
  - Photons interact with the atomic shell, making them more sensitive to low-z
  - Neutrons interact with the nucleus, making them more sensitive to high-z
- The ratio of particle transmission through material of a given thickness and density
  \[ \frac{\psi_R}{\psi_N} = e^{-\mu_R d} \]
  \[ \frac{\psi_N}{\psi_N} = e^{-\mu_N d} \]
- Noticeable differences in ratios of solid aluminum material, and the presence of foreign gasoline, water, and polyethylene bodies.

Computational Model
- Complex 3D geometry modeling using the Monte Carlo Neutron Particle Transport Code (MCNP).
- Aluminum engine block with additional water, gasoline, and polyethylene bodies hidden in the voids.
- Isotropic, mono-energetic point source used to develop data.
- MCNP5 FIR Tally used to generate the flux image radiograph on a planar surface.

Radiography Results
- There are noticeable differences in the ratios of particle transmission through materials more efficient.

Transmission Ratios (TR)
- Often, the presence of foreign gasoline, water, and polyethylene bodies are these methods capable of distinguishing low-z and high-z materials with significant variation in density.
- The ratio of particle transmission through material of a given thickness and density \[ \frac{\psi_R}{\psi_N} = e^{-\mu_R d} \]
  \[ \frac{\psi_N}{\psi_N} = e^{-\mu_N d} \]
- Noticeable differences in ratios of solid aluminum material, and the presence of foreign gasoline, water, and polyethylene bodies.

Detector Array
- Multi-pixel detector to measure photons and neutrons simultaneously.
  - EJ-299-33A Scintillator
    - Solid State Plastic
    - Pulse Shape Discrimination
    - Enable event separation
  - Optical Readout
    - PMT, SiPM
  - eMorpho
    - Signal > Digital Waveform > Image

Conclusion
- Computational study of the dual photon/neutron radiography technique was carried out.
- Unique photon/neutron transmission ratios for analysis of shapes and material composition.
- Viable for analysis of 3D objects.
- This technique is feasible for industrial applications.

Future Work
- Development of a dual radiation detector is underway.
- Experimental verification of the dual photon/neutron radiography technique is planned.