EXPERIMENTS ON MATERIAL RECOGNITION FOR 8 MEV CUSTOMS INSPECTION SYSTEM FOR TRUCKS AND LARGE-SCALE CONTAINERS

M.F. Vorogushin, S.A. Ogorodnikov, V.I. Petrunin, NPK LUTS NIIEFA, St. Petersburg, Russia

Abstract

Series of experiments on material recognition were carried out on a full-scale prototype of customs inspection system for vehicles and large-scale containers developed by Efremov Research Institute. The 8 MeV linear electron accelerator operating in 4-8 MeV range dual energy mode was used as an X-ray source. Experimental interlaced images of tested samples and real cargo container were processed and visualized by advanced software. The special palettes representing integral absorption and Z-characteristics of cargo material were used for visualization. Some images are given.

1 INTRODUCTION

Until recently the experimental realization of so-called dual energy method of material discrimination could not be performed in 4-8MeV energy range of X-rays due to its low sensitivity.

The radiographic discrimination of materials is achieved when the inspected object is alternately irradiated by X-ray with different (dual) boundary energies. Discrimination is due to the fact that different materials have different attenuations of high and low energy of X-rays.

It has been shown the dual energy method can be realized for aforementioned energy range [1,2] and discrimination of materials according to their atomic numbers irrespective to their thickness can be fulfilled for the limited number of groups of materials. The purpose of this paper is to show the method's practical applicability for the customs inspection systems for trucks and large-scale containers.

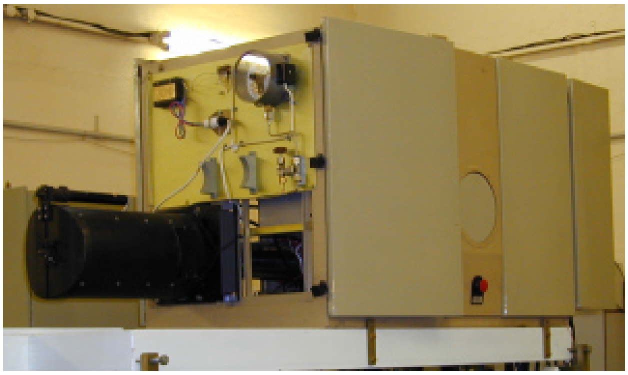
2 EXPERIMENTS

The experiments were fulfilled at the full-scale prototype of customs inspection system for vehicles and large-scale containers developed by Efremov Research Institute. Industrial linear electron accelerator on travelling wave was used as an X-ray source.

The accelerator operates at so-called interlaced mode, when each even pulse generates 8MeV electron beam and odd – 4MeV. Pulse duration - 5μsec, repetition rate – 100Hz, average current - 100μA. In the output target the electron beam is converted into bremsstrahlung. System of slit collimators (picture 1) forms narrow fan-like vertical X-ray beam. Detector line scintillation crystals coupled with p-i-n diodes are used.

Picture 1 Slit collimator, detector line and guide rails of transportation system for examination of container.

During the inspection process the transportation system moves the tested objects across the X-ray beam and penetrated radiation is registered by detector line. Signals from detectors are processed and visualized on the screen of workstation. Experiments were performed for a set of wedge-like tested samples with different atomic numbers and for a large-scale transport container with materials of four Z-groups (table 1).



Picture 2 Industrial linear accelerator with 8MeV at nominal and 4MeV dual operational modes.

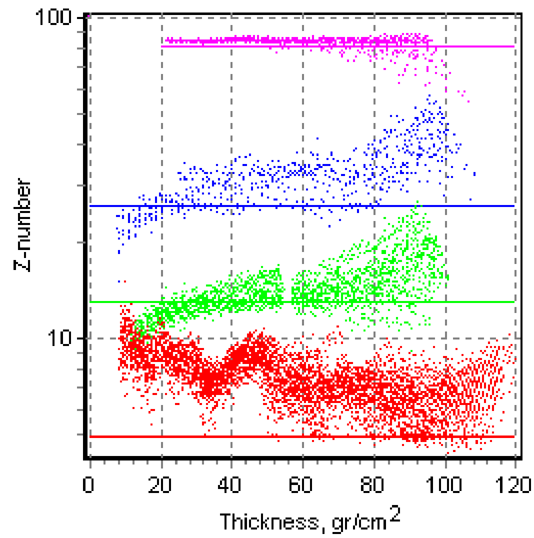
Procedure of interlaced image processing and visualization [3] includes the following steps:

1. Interlaced files are decomposed into high and low energy ones and each image's pixel is characterized by two dual counts.
2. Data counts are converted into physical values of transparencies by means of special non-linear correction procedure.
3. Special denoising and bilateral filtration of both transparency images are performed with experimentally selected domain and range corns.
4. The system of integral equations is solved for each image's pixel. Material's thickness and atomic number are calculated from high and low transparencies.
5. Pixel's color of resulting image is composed from separately evaluated hue, saturation and luminosity values. Color's hue characterizes Z-belonging, luminosity – integral absorption and saturation – degree of Z-discrimination.

Due to the low sensitivity of method in given energy range [1] the atomic number precision totaled ~10 for thicknesses 15gr/cm^2<t<120gr/cm^2 (picture 3). Colorized images demonstrate effectiveness of recognition method (pictures 4, 5). Colorization is chosen according to the following table:

Table 1 Reper points of color encoding:

Media	**Reper material**	**Z**	**Hue**
Organic	Hydrocarbon (CH_2)	~5	Red
Organic-inorganic	Aluminium (Al)	13	Green
Inorganic	Iron (Fe)	26	Blue
Heavy metals	Lead (Pb)	82	Lilac



Picture 3 Calculated Z-number vs. thickness (gr/cm^2) for sample wedge of water (ρ=1gr/cm^3), aluminum (ρ=2.7gr/cm^3), iron (ρ=7.9gr/cm^3) and lead (ρ=13gr/cm^3) (picture 4). Solid horizontal lines are the reper points of Z-number (table 1).

Picture 4 Recognition of tested samples (from left to right): 110cm wedge-like tank with water, 200cm wooden wedge, 35cm aluminum wedge, plexiglas samples, lead sample, 15cm steel wedge, three 50cm plastic wedges, 4.5cm tungsten wedge, 9cm lead wedge, 5cm steel plate. Color encoding is according to table 1 (colored representation is available in electronic version of the paper only).

Picture 5 Colorized image of the transport container filled with sawdust sacks. The following items are included also: suitcase with plastic, truck's wheel, 3cm and 5 cm lead bars, three 20cm plastic tanks with petrol, TV-set, fire extinguisher. Color encoding: organic – red, inorganic – blue, heavy metals – lilac (colored representation is available in electronic version of the paper only).

3 CONCLUSION

Dual energy method of material recognition is proved to be applicable in 4-8MeV X-ray energy range for customs inspection systems for vehicles and large-scale containers.

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