UDC 004.93, 535.317,548.732

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OBJECT BOUNDARIES DETECTION USING DIFFERENCE IMAGE METHOD

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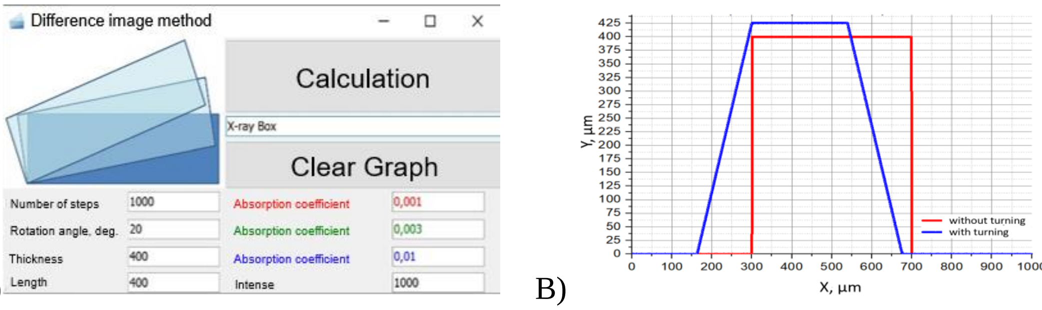
Developed the program "X-ray Box", which calculates the intensity distribution of X-ray emission on the detector depending on the rotation angle of the object. Calculated the intensity distribution based on the rotation angle of the object and calculated new coordinates of the projective form of the object on the basis of the rotation operator. Performed numerical experiments for rectangular plates. The result of the difference survey contains positive and negative parts of the graph, which allows to determine the boundaries of the object.

For obtaining images of low absorbing X-ray objects the differential imaging method is used [1]. Principal of method is capture of two images of object at variation of angular position, and generation of differential image This method of differential imaging focused on the detection of object boundaries, which significantly change the transmittance during angular rotation of the object. This principle was laid down to the "X-ray Box" program.

"X-ray Box" program was developed in the Rad Studio 11 Alexandria Delphi programming environment. The program "X-ray Box" simulates the process of X-rays transmission through the object at a preset rotation angle and calculates the distribution of intensity on the detector. Figure 1 demonstrates the main window of the "X-ray Box" program. To run the program, we need to choose in the main window several parameters: number of steps, which are used to locate the object; rotation angle (in degrees), that shows how the object will be rotated from the initial position; object thickness and length; the intensity of emission; the linear absorption coefficient, which is determined according to the material of which the object is made and the energy of X-ray photons; log file name for saving the results of the work.



A) B)

Figure 1 – Main window of the «X-ray Box» program (a) and the dependence of the thickness of the square object in rotation from the coordinate (b)

The intensity distribution of the X-ray emission on the detector, depending on the rotation angle of the object, calculated by the formula:

$$I(x,y) = I_0\, e^{-\mu(\lambda)\cdot D(a_x,a_y,a_z,x_0,y_0,z_0,\alpha,\beta,\gamma)}, \qquad (1)$$

where I_0 – the emission intensity of the source, $\mu(\lambda)$ – the linear absorption coefficient of the object material in dependence on the emission wavelength λ, $D(a_x,a_y,a_z, x_0,y_0,z_0,\alpha,\beta,\gamma)$ – the thickness of the object across the vector direction (a_x,a_y,a_z) at rotation about the axis (x_0,y_0,z_0) by the angle (α,β,γ).

$D(a_x,a_y,a_z, x_0,y_0,z_0,\alpha,\beta,\gamma)$ – the object thickness in direction of vector (a_x,a_y,a_z) that defines the projective form of the object, which is calculated by the object coordinates $F(x,y,z)$ from the set of points belongs to the boundary $F\{\{x_i,y_i,z_i\}\}$. Rotation of the object provides to calculate new coordinates of the projective form of the object $F\{X_j,Y_j,Z_j\}$ based on the rotation operator $R(x_0,y_0,z_0,\alpha,\beta,\gamma)$:

$$F\{X_j,Y_j,Z_j\} = F\{\{x_i,y_i,z_i\}\}\cdot R(x_0,y_0,z_0,\alpha,\beta,\gamma). \qquad (2)$$

Results of calculations by formulas 1 and 2 in the program "X-ray box" are shown in Figure 2. Numerical experiments were performed for rectangular plates of size 20-1000 μm, for rotation angles from 1 to 90 degrees. By rotating the object, the thickness of the object changes, and the projective shape of the object will be presented as a trapezoid (Figure 1b, 2a). The "trapezoid" effect by rotation of the object, leads to a modification of the effective length of the object, which also results in a change of the intensity distribution.

The intensity distribution on the detector depending on the absorption coefficient of the object is shown in Figure 2. Absorption coefficients correspond to different materials: C_3H_6 (polypropylene) – blue line, Cu (copper) – green line, $C_5O_2H_8$(plexiglass) – red line. Increasing of the linear absorption coefficient leads to the increase of the contrast of the object boundaries in the image (Figure 2b, 2c). In the rotation of the plate, the intensity decreases, which can be characterized by some blurring of the image on the detector.

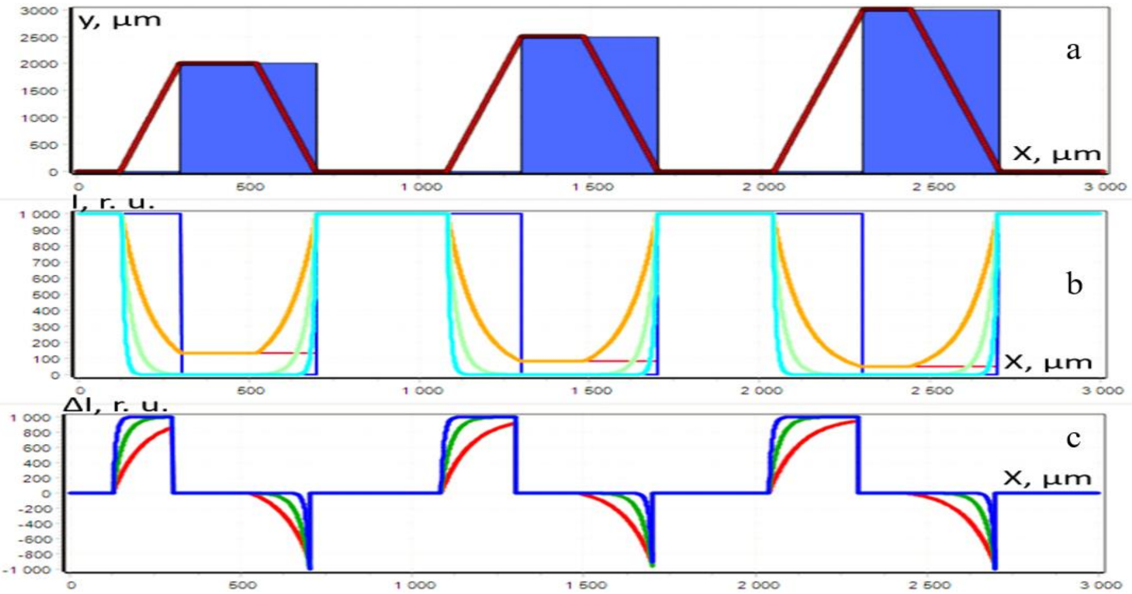


Figure 2 – Results of calculations the program "X-ray box" for the thikness 3000 mkm
Dependence of the thickness from the coordinate(A), Distribution of X-ray intensity on the detector (B)
Result of difference imaging (C).

Simulations were performed with number of steps were 1000, rotation angle – 5 degrees, length – 400 mkm, intense – 1000, and three absorption coefficients: 0,001; 0,003; 0,01. Thickness was from 10 to 4000 mkm. Results of program "X-ray box" calculations are shown in Figure 2. Result of difference imaging ΔI with peaks that determine object boundaries is shown in Figure 2c, where green line – copper, red line – plexiglass, blue line – polypropylene. As you can see, the result of difference imaging will appear at the 150-300 μm and 550-700 μm areas, on rotation of the object, and the dependence of image brightness will have a non-linear character. As increasing the linear absorption coefficient, the difference contrast increases (Figure 2). The result of the difference imaging contains a positive and a negative part of the graph. The positive part of ΔI corresponds to the light elements of the image, and the negative part to the dark elements. Presence of dark and light elements increases the contrast of the image and characterizes the boundaries of the object.

The work is partly supported by the Ministry of Education of the Republic of Belarus within the framework of task 3.07 GPNI "Mechanics, metallurgy, diagnostics in mechanical engineering", subprogram "Technical diagnostics".

Reference

1. Dudchik, Yu. I. Digital X-ray radiography of low-absorbing X-ray objects / Yu. I. Dudchik, A. A. Subach // Instrumentation-2022 : materials of the 15th International Scientific and Technical Conference, 16-18 November 2022, Minsk, Republic of Belarus / editor: O. K. Gusev (Chairman) [and others]. - Minsk : BNTU, 2022. - C. 22-23.