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Automation reinforced concrete structures design models based on the results tomographic ultrasonic

Laith Zeyd Kilani and Valentine Ermakov

Moscow State University of Civil Engineering, Yaroslavskoye Shosse, 26, Moscow, 129337, Russia

E-mail: Lostprojekt@gmail.com

Abstract: In the article the technique of the automated construction of the model of the surveyed building structure using an ultrasonic tomograph. The authors pay attention to the limitations of functionality of the specialized software of the device and offer a variant of their expansion. Describes the purpose and principle of the tomograph. The process of implementing this task with the help of modern computer programs is considered in detail: the graphical programming environment LabVIEW and the CAD system AutoCAD. The technique for processing tomograms and the resulting graphic files, as well as the principles for constructing a three-dimensional model of an existing design with defects and inclusions detected during inspection, is described. Also, options for expanding the functions of the methodology.

1. Introduction

The ultrasonic tomograph A1040 MIRA [1,2,3] is designed to control structures made of concrete, reinforced concrete and stone with unilateral access to them. The tomograph helps to determine the inhomogeneities of the construction material, foreign inclusions, cavities, impurities, delaminations, cracks, and the thickness of objects. The tomograph is a completely autonomous measuring unit that collects and processes data. The image of the internal structure [4,5,6] of the object at the scan location is visualized in the form of an intuitive color map. Each point of the investigated area is displayed on the screen in a certain color, depending on its reflectivity. Advanced data processing is performed in specialized software on the computer. The program allows you to present data in the form of maps and a three-dimensional view. This makes it easier to understand the configuration of the internal structure of the object. For each reflection zone, you can determine the coordinates of the occurrence in the object. The resulting images can be saved in common formats (jpeg, png, etc.).

Damages and flaws may reduce bearing capacity of structure, the effect of the load bearing capacity can be evaluated with the structure analysis

To evaluate the effect of a defect on the load bearing capacity of structures, it is necessary to enter geometry parameters of a flaws and damages_it into the finite element model [7]. At the moment accounting for defects is done manually, which takes a lot of time. Automation of the modeling process will allow you to quickly obtain finite element models of the design that fully describe their work.

2. Methodology

To implement the technique, a high-performance low-frequency ultrasonic tomograph MIRA A1040 was used (figure 1). Matrix antenna consisting of 48 converters [8] (12 blocks of 4 low-frequency elements) allows covering area of 130x380 mm in one measurement. Most of the devices examines only one point in one measurement. High efficiency of work is achieved using_of modern hardware, software and ceramic wear-resistant tips of converters with dry point contact [9]. The use of lubricants is not required. The system of spring-loaded contacts allows to carry out investigations on uneven surfaces without additional processing.

Figure 1. Tomography MIRA A1040

Specialized software is used for a detailed study of the results allowing visualization in the form of a 3D model. You can also select one of the three mutually perpendicular planes (B, C, D scans, figure 2), and change the depth of this plane.

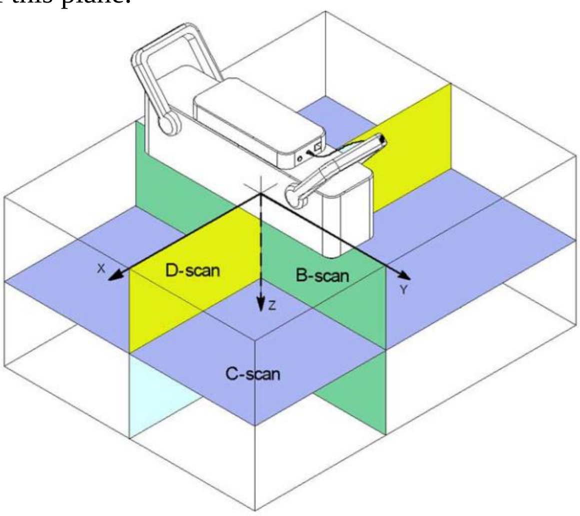

Figure 2. Orientation of B, C, D scans

The quality of the result of the work of a tomograph depends to a large extent on the quality of its setting. It is necessary to establish the exact value of the frequency and speed of the ultrasonic wave for a object. The choice of these parameters was considered by the tomograph manufacturer and other authors.

The processing technique is implemented using LabView [7] programming environment (figure 3), the AutoCAD software and a Visual Basic [8] programming language. The programming procedure in LabView is not to write commands, but to create links between the blocks of the program. The blocks of the program are sets of various functions: mathematical functions, logical functions, output / input functions, signal generation and processing functions, working with arrays, etc. Each block has input and output channels after the function.

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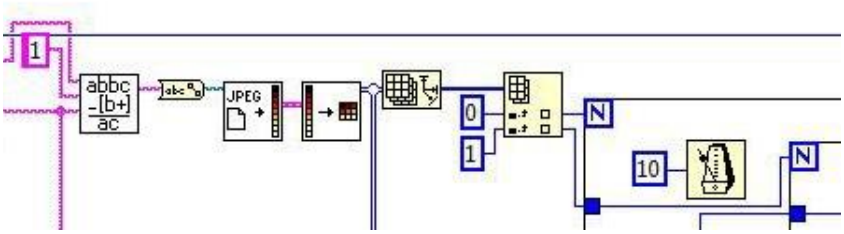


Figure 3. LabView programming environment

The programming language Visual Basic that can be used in AutoCAD allows to automate the process of graphical building / changing objects. Most of the basic functions of AutoCAD are available in programming. The program code is universal and suitable for work with different source data.

3. Implementation of the method

The developed technique allows to automate the process of build a finite element model of a design based on the tomograms. Thus, the finite element model contains defects and inclusions detected during scanning. For the successful operation of the method, additional computer programs have been developed. The methodology is presented in the flowchart (figure 4).

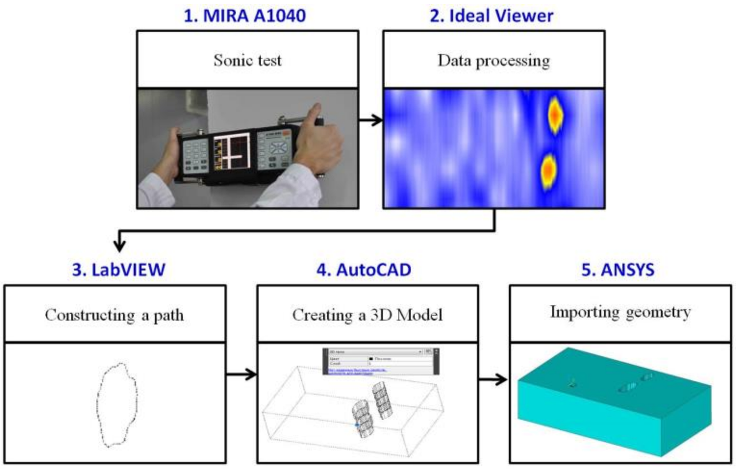


Figure 4. Flowchart of method operation

The method consists of the following steps:

1. Scanning with an ultrasonic tomograph.
2. Processing of results using specialized software Ideal Viewer. Image analysis, determining the size and position of defects and structural elements
3. Converting received graphics files to pixel maps using the LabVIEW software.
4. Automatic construction of a 3D model with defects in the AutoCAD system based on pixel maps.
5. Export model in ANSYS for the calculation stress strain state of building structures.

Let's consider each stage in more detail.

First step. The tomograph works in two modes (VIEW and MAP). The VIEW mode allows you to select the correct ultrasonic parameters (frequency and speed of ultrasonic), knowing some parameters of the object. For example, the thickness or dimensions of an initially designed defect. The MAP mode allows you to create arrays consisting of several single ultrasonic tests.

When working in a MAP mode, you must enter the amount of horizontal and vertical steps.

With the same step, you need to explore the object.

So, if the tomograph is set up correctly, we can analyze the construction to a depth of up to two meters. We can detect cavities, delaminations and cracks, the minimum size of which is 10 mm.

Second step. The instrument software presents scan results in the form of tomograms. Tomogram - the section of the object in the form of an intuitive color scheme of the internal object structure. Each point is displayed in a specific color, depending on its reflectivity. For example, concrete is displayed in blue, steel in orange (figure 5).

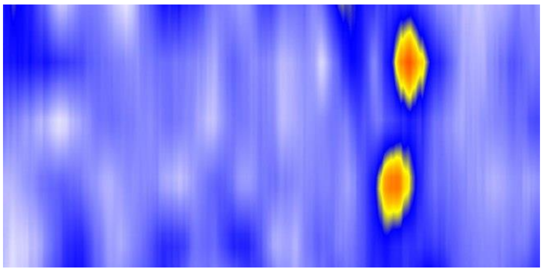


Figure 5. Example of a tomogram

At different depths, the tomogram can change, describing the geometry of the defect. With a certain step to save sections in graphic formats (JPEG, PNG, etc.). The smaller the step size, the greater the accuracy of the model. However, it should not be too small.

The entire volume can be represented in the form shown in figure 6. The size of the vertical step is specially increased to make the procedure work more clearly.

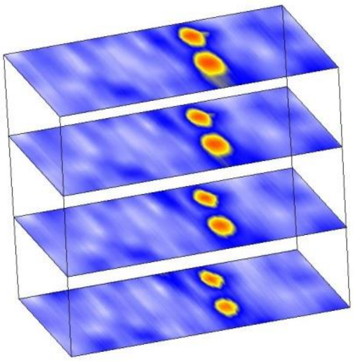


Figure 6. 3D model consisting of sections

Third step. In LabVIEW, the image is converted to a pixmap. A map is a matrix where the sequence number on a line corresponds to the pixel coordinate along the vertical axis, the column ordinal number corresponds to the horizontal coordinate, and the matrix value is the hexadecimal color code according to the RGB model. Minor elements of the matrix are deleted. These include shades of white and blue (corresponding to the reflectivity of concrete). Thus, in the matrix there are only pixels, meaning defects or inclusions (armature, embedded parts, etc.).

Further processing consists in finding boundary points of defect in concrete, inclusion-concrete and defect-inclusion. If all points are significant around the point with the coordinates (i, j) (i.e., points from $(i-1; j-1)$ to $(i+1; j+1)$ with step $i = 1, j = 1$), then it is not located on the boundary of material. The coordinates of the remaining pixels must be arranged in the order of the contour traversal sequence. Any of the points is assumed to be zero with coordinates (i_0, j_0).

For each next point in the list, the sum of the differences of its coordinates with zero is calculated as in equation (1).

$$\Delta = (i - i_0) + (j - j_0) \quad (1)$$

The point at which the resulting value is minimally the next bypass path. The operations are repeated until the area closes. If the next point in the test gives $\Delta > 2$, the second contour will be constructed. The coordinates of points are written to a text file (txt) in the established sequence.

Fourth step. To build a 3D design model using macros for Visual Basic in the graphical programming environment of AutoCAD. According to the text file in the workspace contours of defects and inclusions are built.

After triangulation, the contours are transformed into plane triangular objects.

Further, triangles are combined and subtracted from the plane. The dimensions of the plane correspond to the dimensions of the section of the surveyed structure. The plane is extruded by an amount equal to the cross-sectional height. After extending all planes, the elements are combined into a 3D model of the structure (figure 7).

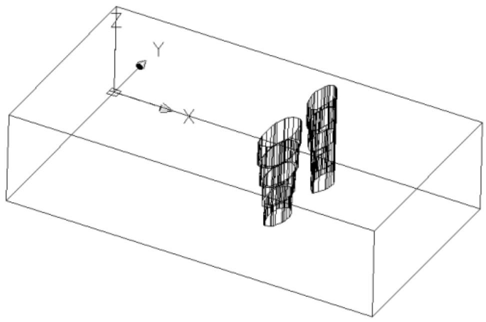
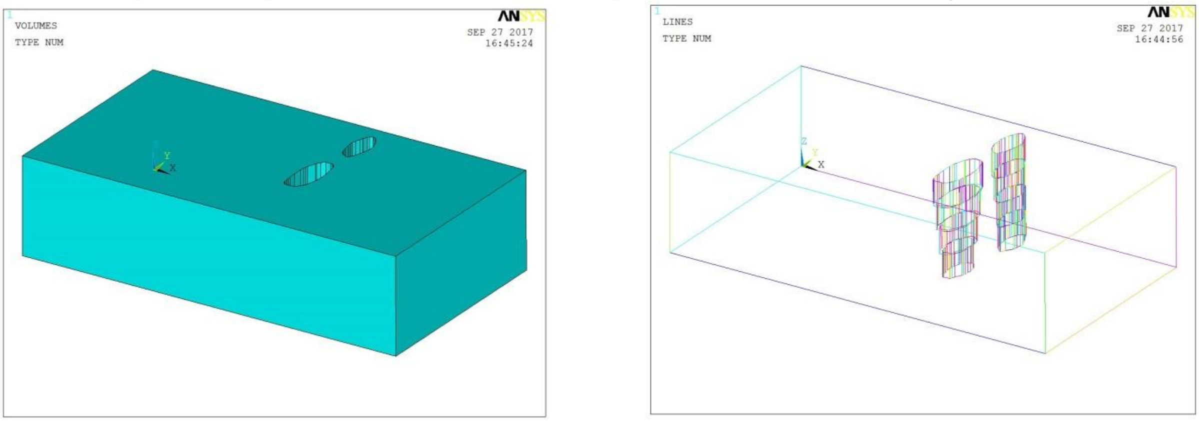


Figure 7. 3D model of a fragment of an object with a defects

For export to ANSYS, the model is saved in IGES format.

Fifth step. After import into ANSYS we have a spatial block with a defect (figure 8).



(a) (b)

Figure 8. 3D model in ANSYS: (a) the volumes, (b) the lines

4. Results and discussion

The ultrasound tomograph is a modern tool that solves the problem of finding defects. Using a tomograph with the technique makes it better. Defects in the finite-element model have geometric characteristics similar to their real geometry. With increasing accuracy of the tests conducted, the application of the methodology will become even more urgent. To implement the methodology, popular software products such as AutoCAD, LabView are used, which underlines their multifunctionality.

Code for the technique is developed in the Visual Basic for AutoCAD environment. Calling subroutines in AutoCAD and running the LabView application does not require much knowledge. In the future, the developed algorithms can be implemented in a special tomography software to immediately obtain the final result in the desired format for export to ANSYS or another finite element complex. The developed technique is universal and suitable for any volumes of tomograph designs.

To get the final result, you need to place the model in ANSYS, assign the parameters of the finite elements, the mesh, the material, associate it with the original model and start the calculation. As a result of simple operations, we quickly obtain a spatial model of a fragment of structures with defects. In the future, it is planned to expand the functions of the methodology:

1. Add the analysis function of extended inhomogeneities to automatically inscribe reinforcing bars of large diameter, taking into account their curvature.
2. Add the ability to combine several sound cards into a single unit, in the case of turning the structure. For example, when examining a column, one can sound from four sides and create a single model.

5. Conclusions
The developed technique allows the most complete use of the results of ultrasonic studies, evaluate the impact of specific defects on the bearing capacity of structures, extends the functions of a tomograph. Also technique allows to significantly reduce the simulation time. Different models in AutoCAD can be combined and edited if required, which is much faster and easier than editing the model in ANSYS. The resulting model most fully describes the actual technical state of structures.

Acknowledgments
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