Testing Technology of Fire-Resistant Objects using Ultrasonic Low-Frequency Antenna Arrays

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Abstract. Fire-resistant blocks, on which the life of smelting furnace strongly depends are widely used in metallurgic industry. These fire-resistant blocks are produced by specialized industrial enterprises with production volumes of tens thousands items per year of different product types. To solve the problem of such items quality assurance the testing technology was made and special equipment for non-destructive testing of fire-resistant blocks was developed. Quality control is supposed to be held both at technological process and for ready-made products.
The typical defects, reducing the lifetime of fire-resistant blocks, are cracks, holes, friability and foreign inclusions. Through-sounding method was chosen as the most suitable for defect detection, due to its sufficient reliability and productivity of testing. One of the important tasks during researches was to estimate the sensitivity of chosen method for testing fire-resistant block with the form of parallelepiped or more complex. Informative parameter was propagation velocity of longitudinal wave at through-sounding. The results of testing were screened as 2D color image. Researches showed the possibility of detection of stratifications with the diameter starting from 30 mm.
Based on the results of the research the mobile system for technological testing of fire-resistant blocks was developed.
In the paper the principle of operation and structure of the developed equipment are discussed as well as presented results of trials on physical models and on real samples, received during the operation testing.
The developed system can be effectively implemented both for flaw detection of fire-resistant blocks and of other objects.

Introduction

The fire-resistant blocks are widely in use in metallurgy, glass and other industries. The exploitation period of smelting furnace used in these industries is strongly depends on the quality of the fire-resistant blocks they are built from.
One of the biggest industrial complexes, which produces fire-resistant blocks of different types, is JSC "Magnezit" situated in Sadka, Chelyabinsk region, Russia. Under the order of this customer researches in the field of non-destructive testing technology for fire-resistant blocks were made and special equipment for testing was developed. Before that only the destructive methods of testing were available, when the block was destroyed (cut or broken).
The object of testing is the pressed from special compound blocks with thickness of 100-200 mm and side-length of 200-400 mm, the sides of these blocks are not always parallel. (Fig. 1)

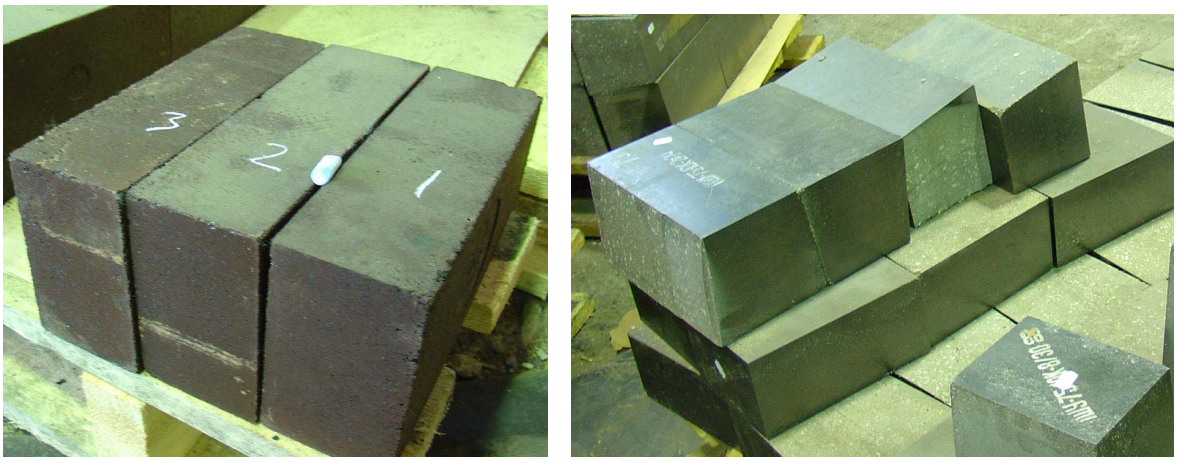


Fig. 1 Fire-resistant blocks, produced by JSC “Magnezit”

The typical defects, reducing the life of fire-resistant blocks, are the defects of internal homogeneity like cracks, stratifications, holes, friability, which are mostly the results of defects in production technology, mainly appearing in pressing mode.

For defects detection the through-sounding method with two matrix antenna arrays was chosen. This method has a high sensibility and provides the necessary efficiency of testing.

The principle of testing is in measuring the time of ultrasound propagation through the whole thickness in each point of the block and in measuring the local ultrasound velocity in each point, which is the informative parameter for this method. If there is a defect, which prevents the direct propagation of ultrasound, the signal will bend the defect and this will reduce the velocity. Also the badly pressed areas inside the block (with low strength of material), appearing due to bad mixture of the source material at production, influence the ultrasound propagation velocity.

Basing on the results of made researches the portable equipment for technological testing of fire-resistant blocks was developed. This equipment is based on two matrix (6x6 elements) antenna arrays. The elements of these arrays are the transducers with dry-point contact with longitudinal vibration of wear pin and operation frequency of 100 kHz. The antenna arrays are mounted to the frame opposite to each other. The frame allows exact positioning and quick pressing of the arrays to the testing block. The system is controlled from the computer (laptop type) with the installed software for data reception and procession. The system was developed as portable equipment, which can be operated by one person, Fig. 2.

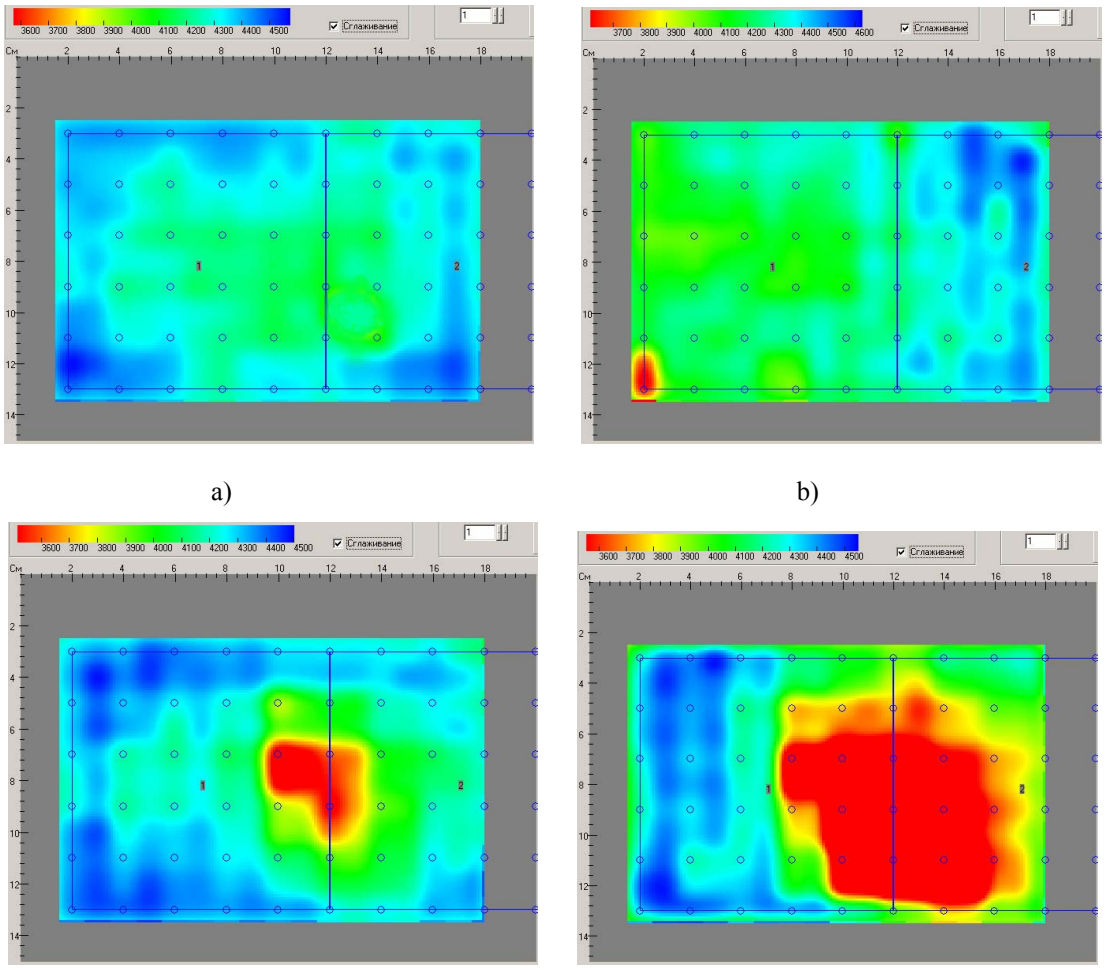
Fig. 2 System in operation.

In one position on the block the arrays test the area of block side with the size of 120 x 120mm. For searching of some technological defects it is enough to control only from one position in the middle of the block.

For the full control the block is divided on the squares 120 x 120 mm on sides and the arrays are positioned on squares in turn. After that all the results are combined in the software and the software shows the full map of the block with the defects.

The signals sent by one element of the array are received not only by the opposite element, but also by the nearest ones. This allows increasing the resolution of testing and sensibility to cracks, especially to the ones, parallel to the surface.

For operational trials special sample blocks were produced with the known sizes of defects inside (20x20, 40x40, 60x60 mm). The results of testing are shown in the fig. 3.



a) b)

c) d)

Fig. 3. a) non-defected block; b) block with a defect 20x20 mm;
c) block with a defect 40x40 mm; d) block with a defect 60x60 mm.

The software detected also the following defects, appeared due to the incorrect pressing and other breaches of production technology:

Block 1 Defect type: over pressed crack

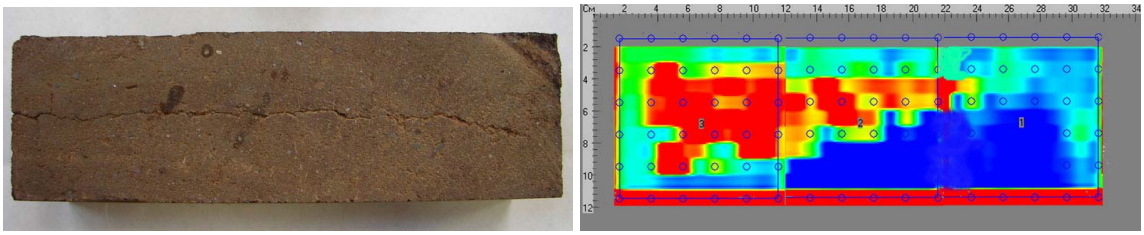


Fig. 4. Photo of block with crack and software processed image.

Block 2. Over pressed cracks (the velocity in areas with cracks is 1390-2500 m/sec, the velocity in non-defected area is up to 4000 m/sec)

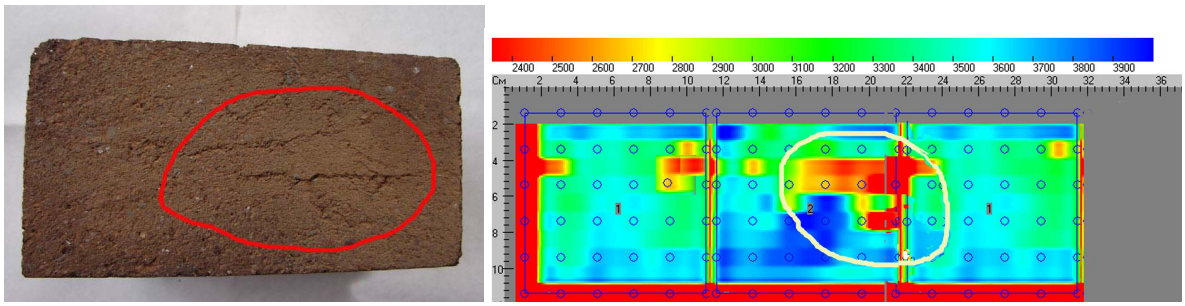


Fig. 5. Photos of block with crack and software processed image.

Block 3 Defect type: underburning due to bad compound mix and smelting due to foreign inclusion

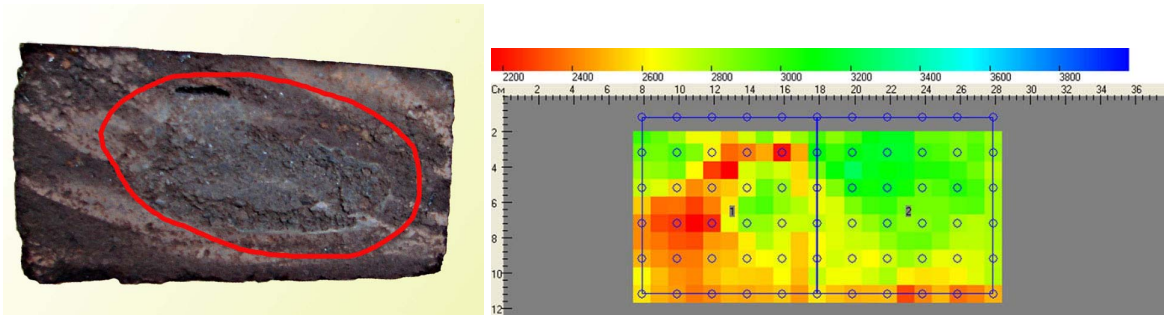


Fig. 6. Photo of block with underburning and software processed image.

Conclusions

Based on the testing results the following conclusions can be made:

1. The equipment provides detection of stratifications with the diameter starting from 30 mm (Fig. 7).

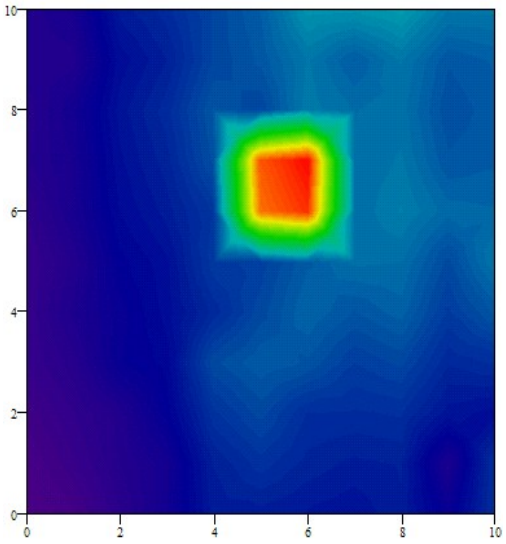


Fig.7 Image of fire-resistant block with stratification 40 x 40 mm

2. The developed equipment allows testing the ready-made fire-resistant blocks to confirm the quality of the products and to reduce the number defective products.
3. The equipment allows quick testing and improving the technology process, by the estimation of the product quality right after each technological stage of production.
4. The equipment allows detection of faulty products on the early stage of production to reduce costs for the further intensive and expensive production cycles.