POSSIBILITY OF USING BETATRONS FOR CHECKING DEFECTS IN REFRACTORY STRUCTURES

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Normal operation of units built from refractory brick prevents reductions in the thickness of the structure, and also makes it very difficult to detect cracks and breaks in such structures. Visual examination of the internal surfaces of the lining is impossible in many furnaces without stopping the production process. Checking the burning-out of the internal layers of the structure by inserting ampules containing radioactive isotopes, and checking the resulting product for radioactivity, does not guarantee the detection of cracks and local burnouts in the structure. It is impossible with these methods to detect cracks and scaling of the structure without opening up its surface.

The shadow method of radiation defectoscopy using industrial x-ray units as the source of radiation, as well as radioactive isotopes, only enables us to control or to check layers of refractory brick of not more than 40-50 cm thick, which limits the extensive introduction of radiation methods of controlling refractory brick constructions. This disadvantage can be eliminated by increasing the energy of the electro-magnetic radiation, in particular, by using electrons accelerated in a betatron, which is widely used for detecting defects [1-4].

This article deals with an investigation of the possibility of using electron irradiation with the maximum energy in the range 10–30 MeV for controlling the external continuity of fireclay, silica, and magnesite brick. For the investigation we used artificial defects which consisted of exaggerated standards, specified in GOST 7512-55 for illuminating welded joints. Standards were prepared from brick with gaps of rectangular cross section cut in them.

The standards were placed on the side of the radiation source and separated from the x-ray film on which the results of the illuminations were fixed by a compound specimen of bricks. In addition, the standards were placed in the middle of the specimen, and were separated in this way from the film by a layer of brick the size of which equalled half the thickness of the compound specimen. The specimens were prepared by building refractory bricks into a rectangular block, so that there were no straight-through cracks. The courses were made with alternating and covered joints. The cross section of the block at first was made in the form of a square with a side consisting of two and a half bricks, then reduced to two bricks in order to reduce the laying time. There were no marked changes in the control sensitivity with this reduction in the block’s cross section. The bricks were placed in the block without mortar to facilitate and speed up the work. In order to check the soundness of this method of making the blocks, we investigated the appearance of defects with different joint fillings. When the joints were filled uniformly with mortar we obtained regular absorption, and there was no marked influence on the development of the defects in the brick used in the structure [4, 5]. Therefore, data obtained for the use of blocks can be extended to real constructions made from refractory bricks.

Investigations showed that using the betatron with a maximum energy of up to 30 MeV [5] it is possible to illuminate structures of refractory brick more than 2 m thick. The necessary exposures enabled us to carry out control techniques in production conditions;

<table>
<thead>
<tr>
<th>Thickness* of the layer of the structure, tons/m²</th>
<th>Exposure time, min</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.5</td>
<td>0.2-0.3</td>
</tr>
<tr>
<td>1.0</td>
<td>1.2</td>
</tr>
<tr>
<td>1.5</td>
<td>6.0</td>
</tr>
<tr>
<td>2.5</td>
<td>25.0</td>
</tr>
<tr>
<td>3.5</td>
<td>128.0</td>
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* Thickness of the layer is obtained by multiplying the density, tons/m³, by the actual thickness, m (t/m³, m=t/m³).

The betatron was designed and produced at the Tomsk Polytechnical Institute. We used RT-2 x-ray film loaded into a R-74 cassette, and also lead reinforcing baffles; the front thickness was 2 mm, the back thickness 3 mm.

The results of the investigation into the appearance of standard defects in relation to the thickness of the illuminated block are shown in the diagram. The relative development of the defects consists of the magnitude of the least defect discovered, applied to the total thickness of the illuminated layer. For fireclay, silica, and magnesite refractories, if their thickness was measured in tons/m², there is no marked difference in the sensitivity for equivalent thicknesses. Therefore, the data obtained can be used for all three types of brick. Curve 2 shows the relationship between the illumination of the standard defects and the thickness of the concrete. In the experiments we used building concrete, but the aggregate was selected in terms of the grain-size composition of large or coarse aggregate used in refractory concretes [6].

Replacing the bonds used in refractory concretes by bond used in structural concretes (porcelain cement, type 400) was due to the difficulty of preparing blocks of refractory concrete in the investigational conditions. To justify this substitution we measured the mass coefficients of absorption of the retarded radiation for respective energies in the specimens of refractory concrete, and the concretes made using cement. The differences in the mass coefficients for both cases, using one and the same size of aggregate having the same grain size composition, did not exceed 5%, and came within the limits of experimental error; they did not have a marked influence on detection. Therefore, the results obtained can be used for operation with refractory concretes.

To obtain the results shown in the diagram, the standards were fitted in the center of the block under investigation.

The relationship between the relative detectability and the thickness of the illuminated block takes the form of a curve, the minimum of which (indicating the region of greatest illuminability) refers to the blocks of thickness 1-1.5 ton/m². Deterioration in the relative detectability with smaller thickness is explained by the fact that a reduction in the dimensions of the least detectable defect occurs more slowly than the absolute reduction in the block's thickness [2,5]. A deterioration in the detectability with greater thickness is explained by the scattering of the stream of radiation in the material in the path from the defect to the film, and the supplementary fogging of the image by the radiation which does not supply information about the defect.

The impaired detectability of defects in the concrete compared with brick is explained by the granular structure of the concrete, and consequently the supplementary irregularities in the stream of radiation passing through the concrete. This phenomenon is especially typical for concrete whose thickness is lower than the region of the best detectability.

The results obtained from the study of the possibility of using betatrons for detecting defects in constructions of refractory brick and concretes, shows that radiation defectoscopy can be successfully used in this sphere. The betatron as a source of high-energy radiation makes it possible to substantially increase the thickness subjected to checks, compared with isotope sources.

The speed of the control method can be increased by using x-ray films in combination with scintillation counters [2,5]. Those sites in the construction which give the least absorption of radiation, compared with the absorption typical for a given thickness of material, should be illuminated repeatedly, using x-ray films. From the shaded image on the film it is possible to determine the shape and type of defect, which is important for assessing its influence on the quality of the construction. Such a combination of two methods of registering information on the defect gives the optimum combination of the speed of the scintillation method [2,7,8] with the graphic nature and sensitivity of the radio-graphic method [2,3,8].

Betatrons can be used in metallurgical concerns for detecting defects in refractory structures of furnace units.