SECTION 6. Metallurgy and energy.

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REVIEW OF NON-DESTRUCTIVE CONTROL METHODS OF THE BLAST FURNACE LINING WEAR

Abstract: *The article deals with the analysis of non-destructive monitoring methods of the blast furnace lining wear. The ways of further development with the use of multi-parameter sensors are given.*

Key words: *blast furnace, non-destructive monitoring methods, the lining wear, the generalized model.*

The purpose of a blast furnace is to chemically reduce and physically convert iron oxides into liquid iron called "hot metal". The blast furnace is a huge, steel stack lined with refractory brick, where iron ore, coke and limestone are dumped into the top, and preheated air is blown into the bottom. The raw materials require 6 to 8 hours to descend to the bottom of the furnace where they become the final product of liquid slag and liquid iron. These liquid products are drained from the furnace at regular intervals. The hot air that was blown into the bottom of the furnace ascends to the top in 6 to 8 seconds after going through numerous chemical reactions. Once a blast furnace is started it will continuously run for four to ten years with only short stops to perform planned maintenance [1].

The blast furnace lining is intended for heat losses decrease, for the blast furnace jacket protection from high temperature impact and besides, it protects the blast furnace jacket from contact with hot metal and slag. The lining condition determines the duration of the blast furnace operating period. It also influences the formation of the furnace working lines [2].

The blast furnace lines (Fig. 1), limiting its working space, the so-called "useful volume ", is the most important part of the furnace design. Creating effective lines allows achieve the blast furnace sustainable operation (smooth operation) [3]. Smooth conditions are achieved by the strictly regulated production schedule - from charge materials warehousing and loading them into the oven up to the tapping of the melted products, precise equipment work in accordance with the rules of technical maintenance, safety and organization of production [4]. .Failure to comply with technology leads to significant changes in the lines of the blast furnace: the emergence of dints, lining erosion and the formation of accretions. Dints and uneven lining erosion lead to the development of the peripheral speed, which affects the stability of the blast furnace. Emergence of accretions has a particularly negative impact on the evenness of stroke [5]. Since the reconstruction of the furnace lines is practically impossible by technological methods [6], the role of the visual control of the furnace or by the control devices is growing.

The control method of the refractory lining thickness of blast furnace units by means of elastic shock waves with the registration of the wave reflected from the boundary of the refractory block is well known. The thickness of the refractory lining block is calculated by the delay time of the reflected signal and the known velocity of elastic waves propagation in the material [7].

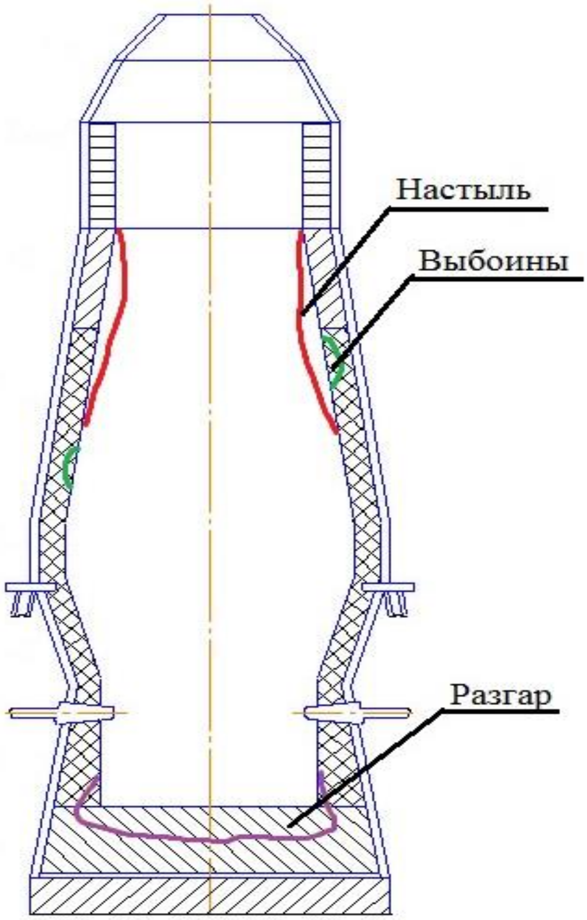

Figure1 - Lines of the blast furnace.

However, in practice this method is difficult to use because during the blast furnace operation elastic waves of different types (longitudinal, transverse, surface, and Lamb waves, etc.) in the furnace jacket are excited propagating in all directions on the surface and inside the structure, whereby, upon reflected signals reception it is necessary to determine the wave type and the possible direction from which the signal has come. The analysis of this type for complex objects such as a blast furnace is very problematic.

The ultrasonic method of a shaft furnace lining wear monitoring by means of waveguides embedded in the lining is also known [8].

The disadvantage of this method is the connection of lining wear diagnosis to the place of waveguide laying and the inability to determine the topography of the refractory lining of the hearth and bottom, and the inability to determine the presence of accretion.

The mirror - shadow method of ultrasonic location is known as the means for determining the lining erosion of the furnace hearth and bottom. According to this method, ultrasonic vibrations (USV) are radiated into the blast furnace from eight points at different angles in the horizontal plane and reflected ultrasonic vibrations are received by one of the receivers located near the transmitter. The thickness of furnace masonry is determined by the propagation time of ultrasonic testing processed by means of the mathematical model [9].

From the standpoint of physics, this method does not differ from the first, since with the used frequencies the converter pattern has the opening angle 180 °. That's why, it is impossible to talk about blast furnace sounding from one point at different angles. Besides the ultrasonic vibrations that are excited in the blast furnace jacket in which configured ultrasonic converters have been installed there emerge different types of waves, such as Lamb waves. Therefore, the receiving transducer will record the signals of all the waves excited by the signal source, as well as all acoustic noise from the furnace operation. It is practically impossible to determine the impulse which is a reflection of the longitudinal ultrasonic wave transmitted in a straight line from the source to the receiver against the background of these signals.

There is an acoustic method of the lining diagnosis based on registering resonance oscillations in the layers [10]. Vibro - acoustic sensors installed on the blast furnace jacket are used during the operation. The layers thickness is determined by resonance frequencies taking into account physical properties of the lining materials in accordance with the mathematical model. Since the layers coordinates are not determined the final lining topography is chosen subject to the technical information.

Further development of non-destructive monitoring methods of the blast furnace lining is possible with the use of the complex approach. One of the modifications [11] is based on the use of acoustic, thermal models and the model of tensile stresses. Model mutual correction is performed with the use of correlation on the basis of which a generalized model of lining is built. To receive the initial information multi – parameter sensors are used. Acoustic, temperature, tensimetric sensors are installed on the blast furnace jacket. The lining layers topography is determined on the basis of the generalized model.

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