This article discusses the significant effect of the profile of blast furnaces on the technical-economic indices that characterize their performance. The working profile may differ appreciably from the design profile and needs to be determined in real time. It is shown that real-time monitoring of the profile of operating blast furnaces can be done by an acoustic method from nondestructive testing. Examples that are given show the results of diagnostic evaluations of furnace profiles. These results are compared to data obtained in the blow-out of furnaces and are correlated with likely explanations of the changes seen in the working profile.

Many years of experience in the operation of blast furnaces have shown that the profile of the furnace has a significant effect on its performance indices. Having an efficient profile helps make the descent of the charge materials more uniform. When the maximum possible pressure gradient is being maintained in the furnace, even descent of the stock in turn increases furnace productivity while keeping fuel consumption low. The main scientific methodologies that have been developed to calculate the profile of a blast furnace all take the following into account:

1) the laws that govern counter-current heat exchange between the gas and the charge;
2) the mechanics of motion of the bulk materials in the charge as they flow in the direction opposite the furnace gases; and
3) the laws that govern the distribution of gases over the furnace radius.

Practical use of the above-mentioned methods has led to the discovery of several techniques which have now been incorporated into the process of designing the profile of blast furnaces:

• designing the shaft with walls inclined at a variable angle (the angle is smaller in the upper region, where heat exchange occurs at higher rates) [1];
• designing the bosh so as to prevent the formation of stagnation zones and, thus, make it less likely that an irregularly shaped crust will form inside this region;
• making the bosh with a variable angle of inclination as well, to decrease the pressure gradient near the tuyeres and thereby reduce the probability of hanging of the charge in the lower part of this region [2];
The use of a fracture-resistant lining made of refractories based on silicon carbide (SiC) and the installation of high-efficiency cooling systems make it possible to form a furnace profile that should be sufficiently resistant to erosion even while it is being formed. However, the working profile of the furnace during its operation may differ appreciably from the design due to the formation of excess crust inside the furnace. Accurate and timely determination of the geometric position and dimensions of slag crusts is an important problem, especially on poor-performing furnaces with low productivity. Timely instrument-aided monitoring of the condition of the furnace’s working profile makes it possible to devise technical modifications and measures that can eliminate undesirable distortions in the profile and restore the contour to efficient dimensions.

The working profile of a blast furnace is evaluated by using different methods to determine the thickness of the refractory lining and the slag crust:

- determination of the amount of heat being removed by the coolers (heat extraction);
- calculation of the temperature fields from the readings of thermocouples installed in the lining [3];
- removal of a core sample (by drilling up to temperatures ≈600°C);
- monitoring of the furnace with the use of embedded radioactive elements;
- the use of different variants of acoustic diagnostics [4].

All the methods listed above have their shortcomings: warping of the coolers, changes in the density of the lining, and encrustation of the tubes of the coolers distort measurements of the thickness of the lining and crust that are made based on heat extraction; carbon buildup on the thermocouples, cracking of these instruments, or the formation of cracks in the lining cause the results of calculation of the temperature fields to not correspond to the actual profile of the furnace; in acoustic diagnostic methods, the presence of numerous sources of interference makes it difficult to identify signals from interfaces in the lining.

Fig. 1. Distortion of the profile of a blast furnace with a cooling system composed of copper slab coolers.