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Investigation of the Surface of Charging Materials in the Blast Furnace during Its Shutdown

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New research method and technique of geometrical parameters of the surface of charging material in the shutdown blast furnace with a compact measuring system based on laser rangefinder and digital graphometer are presented. The possibilities of application of methodology for motion trajectories estimation of the charge flow and displacement of the axial funnel on the basis of non-contact measurements of the charge surface parameters in the furnace top space are shown.

Keywords: BLAST FURNACE, RESEARCH, METHODOLOGY, CHARGE SURFACE PARAMETERS, MOTION TRAJECTORIES OF THE FLOW, DISPLACEMENT OF THE AXIAL FUNNEL

Introduction

One of the major components allowing the reasonable calculation and effective choice of charge programs is the organization of prestart studies providing information about the actual trajectories of motion in the furnace top space of charge materials, coming down from the chute, the peculiarities of distribution materials on the cross section of a blast furnace [1, 2]. The Institute of Ferrous Metallurgy has considerable experience in conducting prestart studies on blast furnaces in Ukraine and foreign countries. This allowed to significantly increase the reliability of the results of preliminary calculation of the trajectories of the charge flow, the efficiency of selection of rational parameters of the technological charging equipment settings, including the angles of inclination of the chute [1-4].

Currently many metallurgical enterprises practice blowing-in the furnaces without prestart studies (even during the change charging device), or significantly reduce the time for conducting them (up to 5-10 h instead of the required 24-48 h). Therefore, the Institute of Ferrous Metallurgy constantly develops and improves the research equipment, as well as methods of conducting prestart studies which allow within a limited time getting a sufficient amount of accurate information for make an informed choice of parameters for the charge mode [1-5].

Results and Discussion

The study of motion trajectories of charge materials during loading and their location on the surface of the stockline in the blast furnace with volume 3200 m^3 during its short shutdown were carried out by developed by the authors method [5] on the basis of formation geometrical "combs" when discharging portions of the charge materials from the specified angular positions of the chute with the subsequent measurement of the profile of charge.

In view of the considerable amount of time consuming (about 8 h) on preparatory activities, the production of a measuring bar and special design for its positioning and the lack of feasibility (small size of the site in front of the erection chute did not allow to use a measuring bar of the required length). The method [5] of measuring the stockline surface profile by non-contact means (**Figure 1a**) was improved and adapted to the existing conditions (**Figure 1b**).

In order to determine trajectories of the of charge materials in the working volume of the investigated furnace corresponding paraxial - the third ("3") - and intermediate - sixth ("6") - the angular positions of the chute (**Figure 2**), before the furnace shutdown two test portions weighing 7.4 t (quartzite) and 9.3 t (quartzite + slag), respectively, were unloaded. For determining the position of geometric "combs" a portable electronic protractor installed on the prepared horizontal surface (**Figure 1b**), which, with a laser rangefinder allowed to measure the surface profile of the charge in polar coordinates, was used.

The results of measuring the profile of the charge by furnace diameter, located in the section "erection chute-charge conveying" ("EC-CC"), and calculated trajectory of the flow of materials are shown in **Figure 2**.

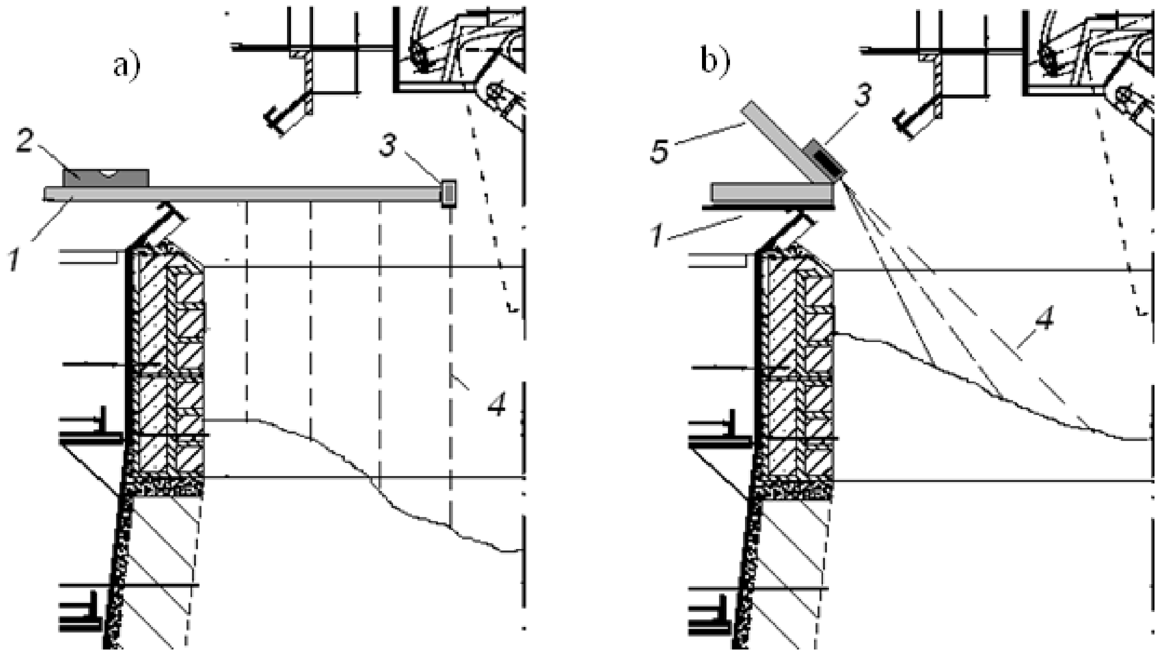

Figure 1. Defining the stockline surface profile of the charge via the laser geometry tool through the erection chute (a) and using a portable device consisting of an electronic protractor and a laser rangefinder (b): 1 - measuring bar; 2 - level; 3 - laser rangefinder; 4 - laser beam; 5 - electronic protractor

In order to determine the most probable surface profile of the charge that existed before the furnace shutdown (**Figure 2**, curve line 3), it has been assumed that the measured profile within 4 h after the furnace shutdown (**Figure 2**, curve line 1) changed insignificantly and can be taken accordingly to the actual stockline 0.65 m, fixed after unloading the test portions. The assumption was based on a comparison of geometrical parameters of surface profiles of the charge, measured after 4 and 25 h after the furnace shutdown, which indicate that the shape of the profiles and arrangement of geometric "combs" did not change significantly.

Figure 2 shows that the calculated motion trajectory of the charge materials in the furnace (the angular position of the chute "3" and "6") are close enough to the actual trajectories (the deviations are within the calculation error associated with different coefficients of friction of combined lining the chute - the ribbed and smooth).

The peculiarity of gas distribution in the investigated furnace is the instability of the parameters of the axial gas flow (under indications of the thermal probe installed above the surface of the charge, and the results of the radial gas extractions with the definition of its chemical composition and temperature), which was shown in the disparity of temperature and CO_2 content in the gas axial sampling points. A significant change in chemical composition and gas temperature in the axial zone was noted in [6] based on the results of studies on a blast furnace with volume of 5,000 m^3.

As can be seen in **Figures 3** and **4**, the points with maximum gas temperature and minimum content of CO_2 in it before the furnace shutdown were shifted toward the selection machine of radial gas PM3-PM4 that corresponds to the iron taphole sector ЧЛ3-ЧЛ4. A similar tendency can be associated with a significant displacement of the axial funnel of the charge surface to the furnace axis.

In order to determine the position of the axial funnel additional measurements were carried out in two vertical cross sections corresponding to the chords that are located parallel to the diameter of the "EC-CC" on both sides at a distance of 700 mm.

The use of the results of measurements together

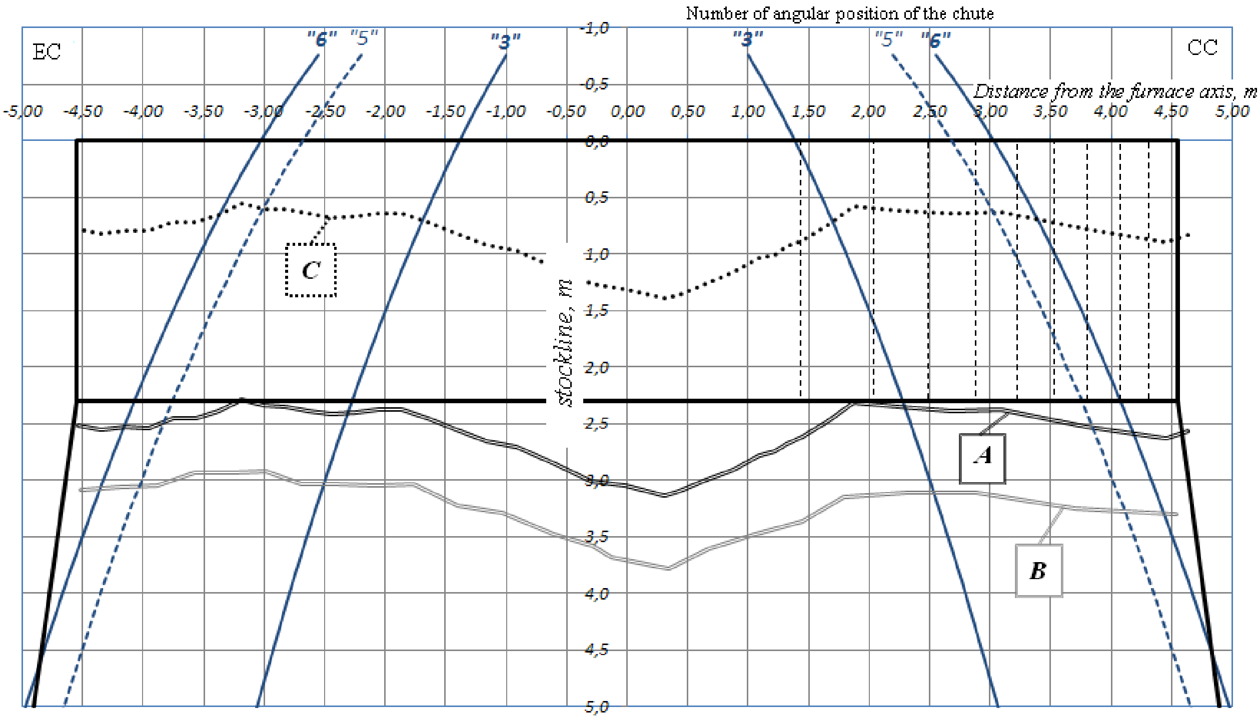

Figure 2. Results of the measurements the profile of the charge in the blast furnace with volume 3200 m^3 after its shutdown for capital repairs of the third category: A - surface profile of the charge 4 h after shutdown B - the surface profile of the charge 25 h after shutdown; C - supposed profile of the charge before shutdown

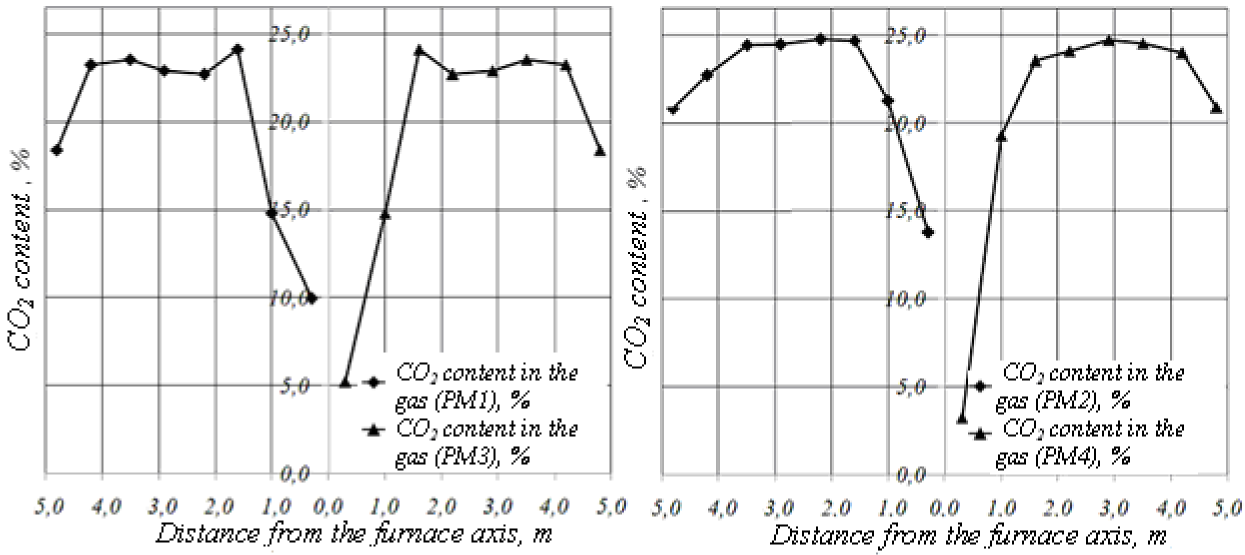

Figure 3. The typical distribution of the CO_2 content in the gas along the radius of the studied furnace

with application software allowed us to obtain two-dimensional and three-dimensional projection of the surface profile of the charge (**Figure 5**), as well as determine the actual axial displacement of the funnel on the surface of the charge (**Figure 6**).

According to the results of measurements the axial funnel displacement by diameter of "EC-CC" was 339 mm in the direction of charge conveying (**Figure 5a**), while by the perpendicular diameter about 278 mm in the direction of the iron taphole sector ЧЛ3-ЧЛ4 (**Figure 5b**).

The current displacement of the axial funnel on the surface of the charge relative to the studied furnace axis is fully consistent with the direction of displacement of the axial gas flow according to the monitoring of gas distribution before the furnace shutdown (**Figure 3, 4**). The causes of displacement of the funnel on the surface of materials can be the following factors: the distribution of the blast to the circumference of the furnace, the operation mode of iron tapholes, the parameters of charging mode, the state of loading device and the stock distributor, as well as uneven wear of the masonry of the furnace in height and circumference. Identification of specific factors and their influence on displacement of the axial funnel requires further research.

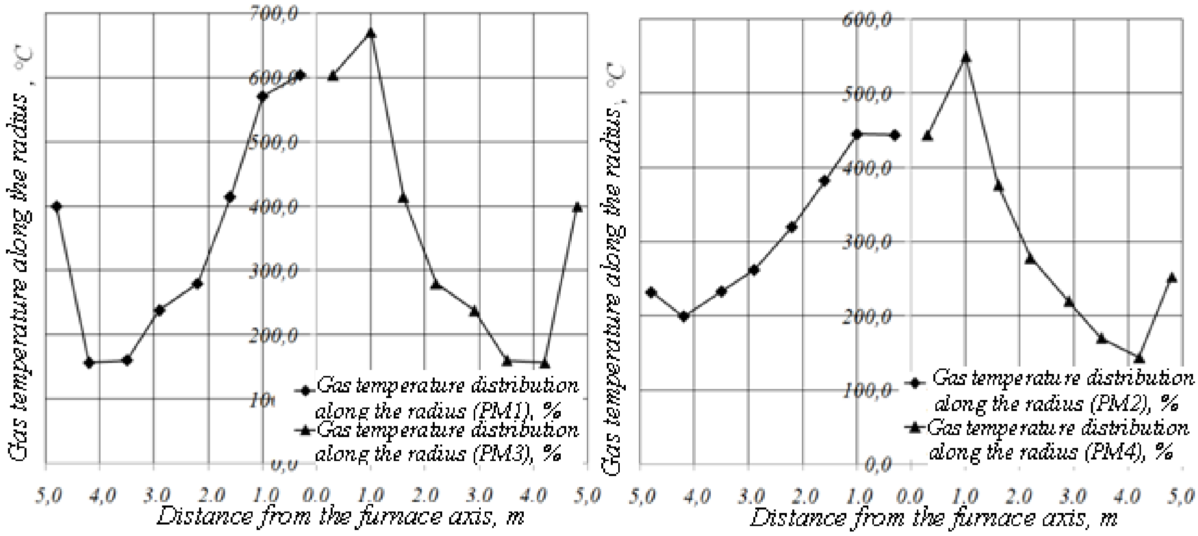

Figure 4. The typical gas temperature distribution along the radius of the studied furnace

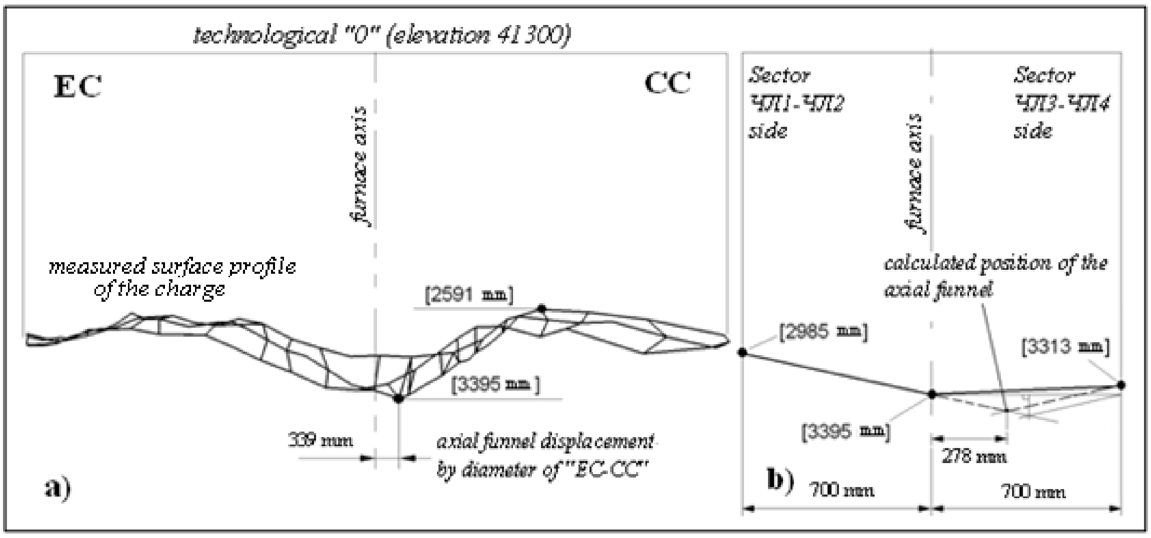

Figure 5. The results of measured surface profile of the charge (a) and position of the axial funnel (b) in the blast furnace with volume 3200 m^3 4 h after its shutdown (the numerical values in square brackets denote the distance from the indicated point to the technological "0")

It should be noted that the use of a new methodology for assessing motion trajectories of charge materials [5] together with the described method for determining the surface profile of the charge can significantly reduce the time required to perform measurements (up to 15 minutes for one measured diameter), increase their accuracy (as all measurements are carried out with fixed platforms, and electronic measuring device has high accuracy class), and secure the work of researchers from the effects of high temperatures and gas concentration.

Thus, the presented method of measuring the surface parameters of the charge and a new research technique during a short furnace shutdown can accurately and quickly enough determine the profile of the charge, the axial displacement of the funnel on the surface of the charge, the motion trajectory of materials in the furnace top.

Conclusions

Institute of Ferrous Metallurgy performs improving research equipment, broadening the base of the software used and the methodology for

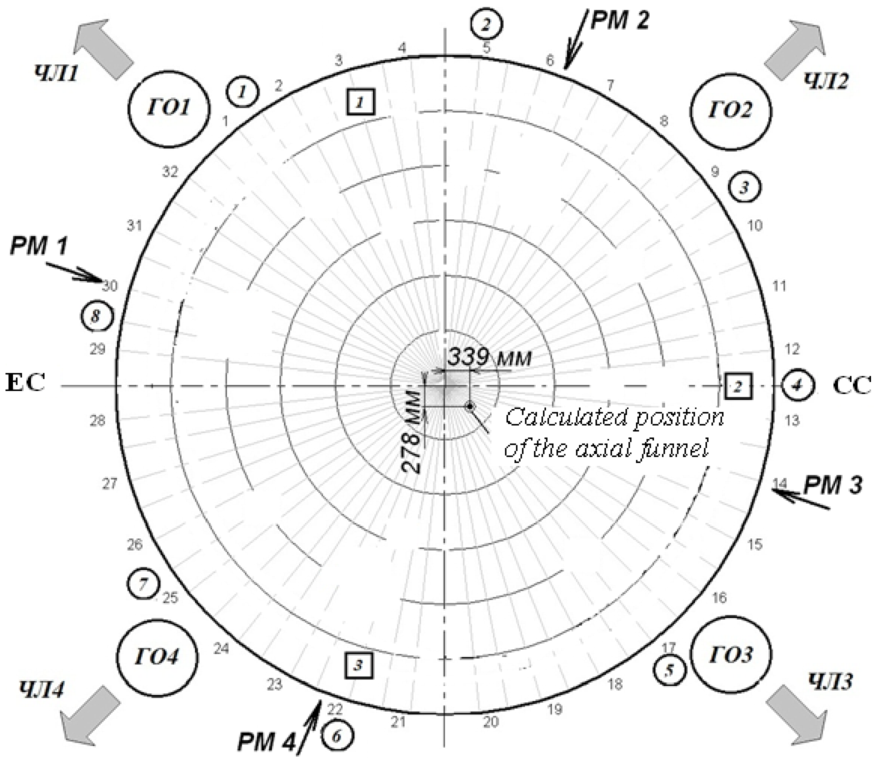

Figure 6. The displacement of the geometric axial funnel on the surface of the charge in the blast furnace with volume 3200 m3 : 1-32 - tuyeres; 1 - peripheral thermal couples; ГО1-ГО4 - gas offtakes; 1 - mechanical level gauges; PM1-PM4 - radial gas extraction machines; ЧЛ1-ЧЛ4 - iron tapholes

conducting pre-launch studies which allow within a limited time to get sufficient amount of accurate information to make informed choices of the surface parameters of the charging mode.

The calculation of the motion trajectories charge materials within a the working space of the studied furnace with volume 3200 m^3 was carried out by the new method [5] on the basis of formation geometrical "combs" by discharging portions of charge materials from the specified angular positions of the chute, followed by measurement of the profile of the charge in the furnace with the help of a device consisting of a laser rangefinder and electronic protractor. The position of the axial funnel relative to the furnace axis was determined.

Non-contact measurement of the surface parameters of the charge and a new research technique during a short furnace shutdown can accurately and quickly enough determine the profile of the charge, the axial displacement of the funnel on the surface of the charge, the motion trajectory of materials within a the working space of the furnace, while ensuring the safety of investigators.

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Исследование поверхности засыпи шихтовых материалов в доменной печи во время ее остановки

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Представлены новые способ и методика исследований геометрических параметров поверхности засыпи шихты на остановленной доменной печи с использованием компактной измерительной установки на основе лазерного дальномера и цифрового угломера. Показаны возможности применения методики оценки траекторий движения потока шихты и смещения осевой воронки на основе результатов бесконтактных измерений параметров поверхности шихты в колошниковом пространстве печи.