UDC 669.168

New Technique of Blast Furnace Pre-Launch Research

V. I. Bolshakov, V. V. Lebed', A. A. Zherebetskiy

Z.I. Nekrasov Iron & Steel Institute of National Academy of Sciences of Ukraine
1 Academician Starodubov Square, Dnipropetrovsk 49050, Ukraine

The methods of pre-launch experimentations of charge mechanical trajectory in shaft top space and its emplacement on the stock surface during the loading by bell-less top charging system are examined. The methodical bases of pre-launch experimenting with the usage of laser rangefinder are presented.

Keywords: BLAST FURNACE, PRE-LAUNCH RESEARCH, CHARGE MECHANICAL TRAJECTORY, MATERIAL CRESTS EMPLACEMENT ON THE STOCK SURFACE

Introduction

The improvement of charging materials distribution on the shaft top is important for growth of blast furnace operation efficiency [1, 2]. In present time blast-furnace operators have accumulated a large experience and many methods of loading with the help of bell-type feeding mechanisms, however the possibilities of charge distribution control during the furnace loading with the help of bell-type distributors are rather limited [1]. During the charge loading from the bell the trajectory of the charge is nearly constant, thus the change of stock level is practised for crest location shift. The radial distribution of ore loads on the shaft top is defined by the shift of charge materials on the stock profile slope. The usage of bell-less top charging system with chute distributors located over the stock surface led to essential expansion of technological opportunities of the feeding system for forming of reasonable distribution of the materials on the shaft top. During the charge loading by chute distributor the charge mechanical trajectory can be changed by chute slope adjustment.

The knowledge of material flow peculiarities in the shaft top space is required for effective realization of technological capabilities of bell-less top charging system for charge distribution control. The technique of calculation of charge movement from the chute distributor [4] developed in Iron & Steel Institute allows defining charge materials mechanical trajectory and choosing chute slope working angles. However, the complication of accurate values in defining of some initial calculation data (mainly, friction ratio) leads to the necessity of correction of trajectory calculation results according to the data of pre-launch research. The Institute has accumulated the significant experience of pre-launch experimentation and results of their processing. It allowed increasing essentially the estimates reliability of charge flow mechanical trajectory and the effectiveness of choosing the reasonable working angles of chute slope.

In the world practice the active tendency development of equipping the blast furnaces of different capacity with bell-less top charging systems required different constructive solutions. It increased essentially the urgency of thorough pre-launch experimentation and required the improvement of methods and instruments for their accomplishing.

Many years' experience of implementation of new and modernized blast furnace technologies and equipment with the usage of justified estimation of reasonable loading programs based on pre-launch research results confirmed the essential acceleration of furnaces withdrawal of project rates [1, 2]. The research was aimed on the generalization of existing methods of pre-launch investigations, development and testing of new technique using modern measuring tools.

Results and Discussion

The technique of estimating the trajectories of the charge materials flow in furnaces with bell type feeding mechanism consisted in defining of the location range of cross points of charge flow with shaft top protection. The first pre-launch experiments on blast furnaces with bell-less top

charging system (BF-6, Novolipetsk Steel; BF-9, JSC “Kryvorizhstal”) in the USSR done by the scientists of Iron & Steel Institute in 1978-1979 included similar technique with the help of gauging rods which were sunk through gas outlet before the discharge of research samples from definite angle of chute position [5]. The specified method of charge trajectory estimation due to its comparative simplicity and sufficient reliability of the data obtained is used even in present time. However, its disadvantage is impossibility of definition of trajectories which correspond to material load into paraxial and intermediate zones of shaft top radius. There was often lack of the data obtained by traditional researches for valid choice of reasonable parameters of loading mode. Thus, it needed development and usage of principally new research methods and equipment, allowing increasing the volume and reliability of the obtained information.

The research workers of Iron & Steel Institute constructed a special installation for charge materials distribution on the blast furnaces of large capacity equipped with chute bell-less top charging system. It enabled to register the width of charge flow during its moving within the shaft top space and also to select the materials into the cells for their further weighting, screening and analysis of weight distribution and particle granulometry. After the installation of the "P.Wuerthe Company" chute bell-less top charging system, the first investigations with the help of this original system were completed in 1979 on the blast furnace No.9 with the capacity of 5034 m^3 at JSC “Kryvorizhstal”. The results of these investigations have not been published for more than 20 years according to the decision of Ministry of Ferrous Technology.

The second similar investigation was carried out at JSC “Severstal” on BF-5 with the capacity 5580 m^3 in 1986. According to results, we obtained unique experimental data about the material flow parameters: flow width, distribution of intensity and granulometric composition [6, 7]. The scheme of research equipment installation is shown on **Figure 1**. The research mechanism of original construction was used during the experiments. Before the discharge of the investigation portions the console of mechanism situated on the shaft top platform was injected into the shaft top space along the furnace radius through the fitting hole. The working part of machine 2.6 m long consisting of 13 cells was installed at the angle 45° to the horizon and blocked the charge flow. In the definite moment during the charge the machine cells were opened and after the single passage of the chute above them they were closed. The obtained testing material from each cell were weighted and sown to the fractions. The results of the mentioned researches allowed to obtain new experience about the pattern of the charge materials flow during their loading into the furnace and to improve the mathematical pattern of radial charge distribution.

The third cycle using the described research installation was carried out at JSC “Kryvorizhstal” on BF-9 in 1989. These investigations along with estimation of charge distribution trajectories included the investigation of distribution to the chute positions and stock surface circles of coke mixed with pellets, agglomerate and ore [7].

After it the pre-launch investigations according to the described technique using the installation on **Figure 1** were not done anymore, because each definite case needs constructing new research equipment considering constructional peculiarities of the real object. Unfortunately, in spite of our publications and speeches on congresses and meetings, some Ukrainian and Russian plants still do not accomplish pre-launch investigations before the starting of new or repaired blast furnaces and do not use these experience accumulated by workers of Iron & Steel Institute. It does not enable to achieve quick and efficient insertion of furnaces to target parameters of productivity and energy consumption.

In 2007 after the 1st rate general overhaul with reconstruction the blast furnace with the capacity of 3000 m^3 was equipped with chute bell-less top charging system constructed by “Azovmash”. However, the pre-launch investigations were not done. It resulted in long period of furnace assimilation and its insertion to target parameters [8]. In September 2010, the administration of the enterprise made a decision to stop and blow-down the furnace to the bosh and further pre-launch researches during the loading of charge materials into the furnace before starting. It was related to melting operation degradation and decrease of necessity in cast iron.

According to the regular technique of Iron & Steel Institute the definition of geometric parameters of charge flow was accomplished by gauging rods 3.0 m long installed vertically on stockline wearing plates of the shaft top through the holes of furnace offtakes. The basic results of measurement accomplished when bell-less top charging system is set in the angle position “10” (49.5°) are shown in **Figure 2**. We should note that according to the results of pre-calculation of

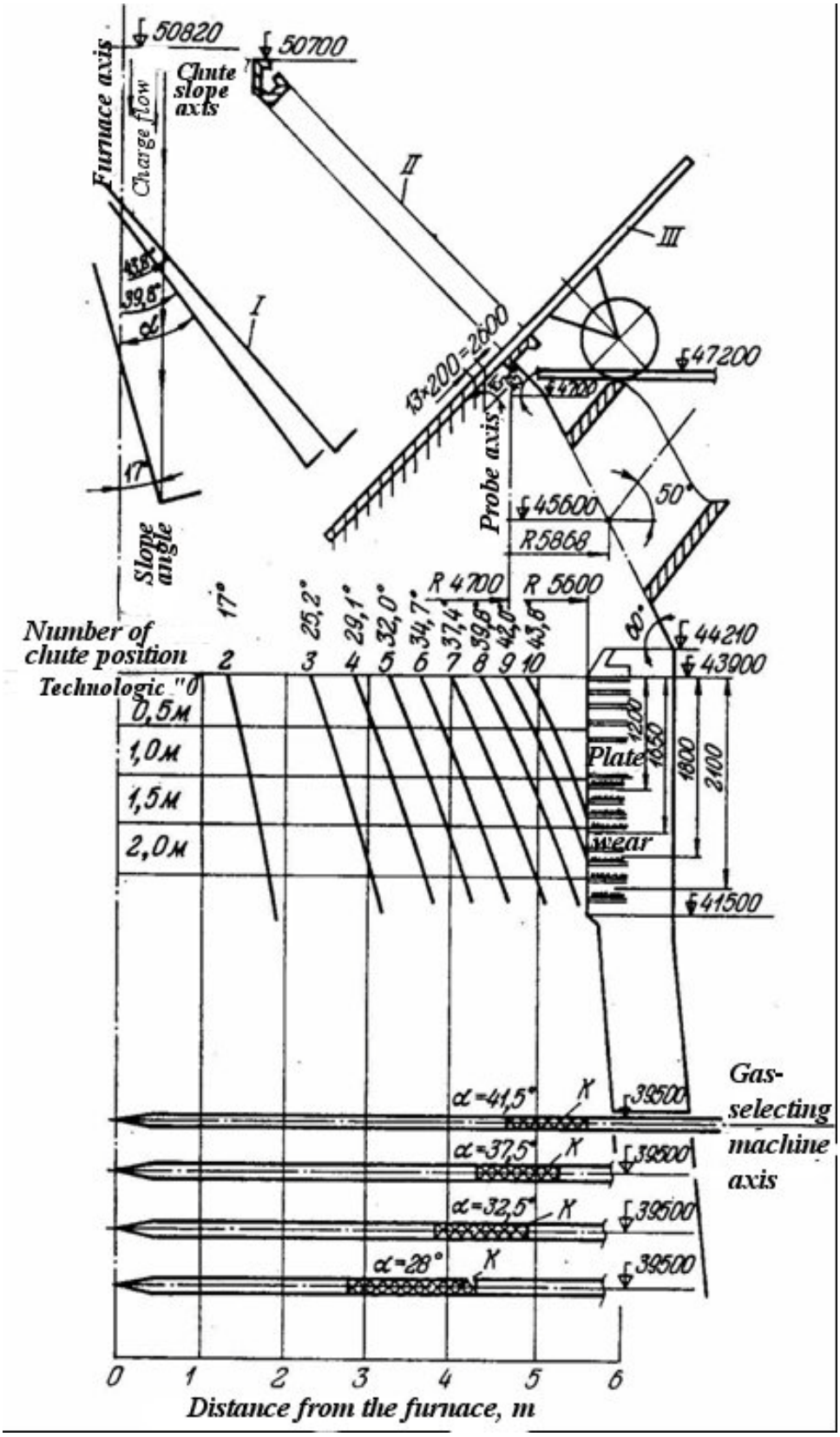

Figure 1. Installation scheme of research equipment on BF-5, JSC "Severstal'" in 1986 [6]: I - bell-less top charging system chute, II - loading chute, III - research unit

charge trajectory we set 50.4° (**Figure 2**) for the 10th angle position of chute, which is corrected under the results of measurement of actual angles of distributor and accepted as equal to 49.8°.

As follows from **Figure 2** during the charging of the material with chute slope angle equal to 49.5° the adjustment of middles of intensive part of charge flow and marginal 10th circle of shaft top is provided. During the coke and iron-ore materials charging we observed not significant difference in averaged distances from the cross points of flow middles to the furnace axis. This difference means that iron-ore materials are closer to furnace walls than coke. However, the charge of materials on the shaft top was done under fully opened choke valve of storage hoppers of bell-less top charging system. It can lead to some mistakes in measurement results. Except it, the small value of average deviation (~100 mm) does not require special correction during the development of reasonable programs for furnace charging.

During the charge of iron-ore materials into the furnace we noticed a significant change of flow trajectory along the shaft top radius (**Figure 3c**, **d**). We think that it is a result of the iron-ore mixture shift in the central pipe of bell-less top charging system in the side which is opposite to charging hopper. It leads to different initial conditions of the material flow through the chute distributor depending on circumferential chute position. The shown peculiarities of iron-containing material charging confirm the reasonability of using special charging modes with changing of material kind in the hoppers of bell-less top charging system in order to provide the compensation of circumferential inequality of charge distribution. The acceptable variant of such charge mode is the usage of special programs of bell-less top charging system for the furnace, which can vary depending on the material in the hoppers with the help of periodical charge of two adjacent portions of coke from different hoppers.

The special peculiarity of investigated furnace equipping is absence of radial gas-selecting machines, probes of which were usually used for definition of material flow trajectories by the marks of this material, left on their whitened surface (**Figure 1**), and for measuring of charge stock in the furnace shaft with mechanical profilometer on the basis of radial probes.

The definition of charge materials trajectories in the working space of the investigated furnace corresponding to axile (2nd) and intermediate (4th) angle positions of chute was completed by new technique developed by the authors. It is based on the formation of geometrical crests by directed charging of charge material portions from the mentioned angle positions of chute with further measuring of charge stock profile through the fitting hole (**Figure 4**).

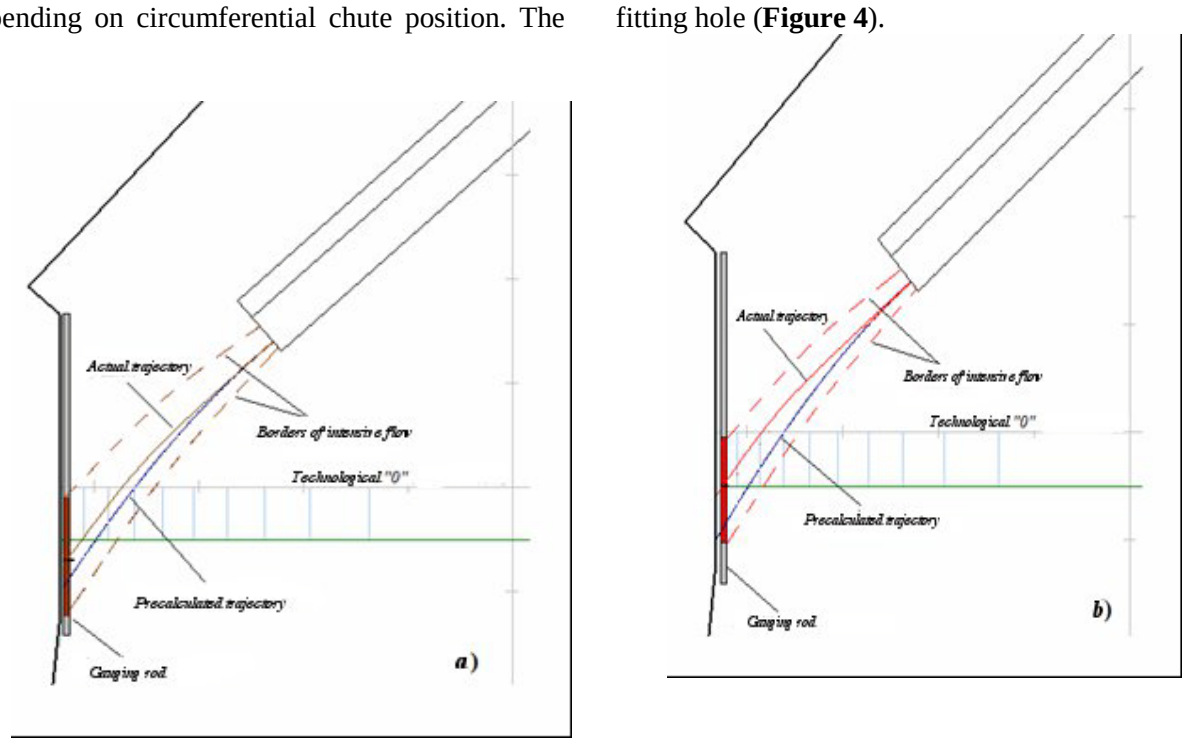

Figure 2. Pre-calculated and actual trajectories of coke (a) and iron-ore (b) flow in the working space of BF with capacity 3 000 m^3 during the charge of portions from 10th angle position of chute of bell-less top charging system (49.5°)

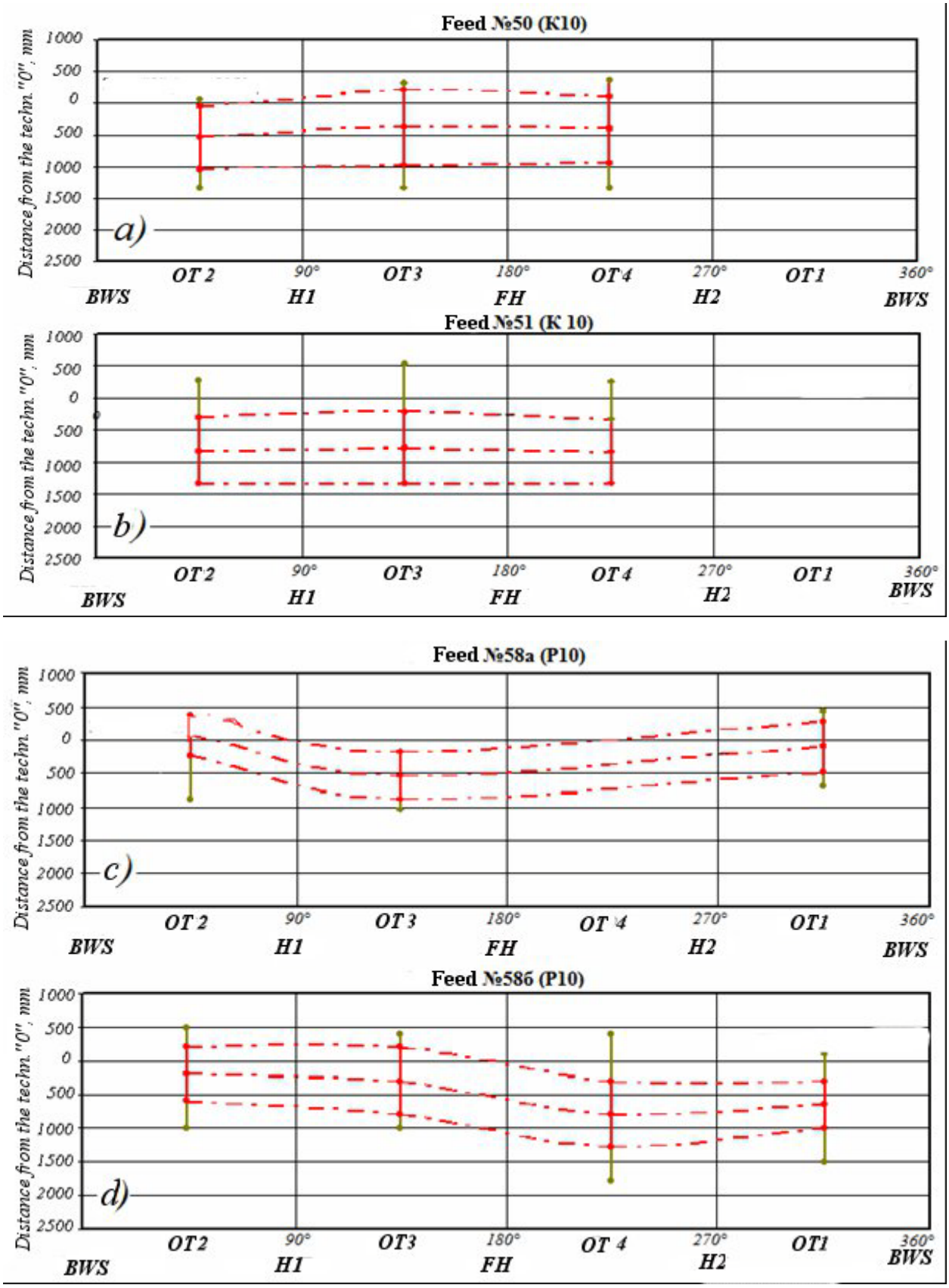

Figure 3. The location of crossing points of charge materials flow with stockline wearing plates during the loading of blast furnace with capacity 3000 m^3: *H1*, *H2* – hoppers of bell-less top charging system; ***FH*** – fitting hole; △ *0˚...300˚* – stations of bell-less top charging system chute; ***OT1…OT4*** – offtakes; ***BWS*** – bridge wall slope

The results of charge stock profile and calculated trajectory of material flow are shown on **Figure 5.** It shows that precalculated trajectories of charge materials flow in the furnace are rather close to actual trajectories. The chosen working angles of chute slope correspond to their reasonable values. The results of measurements shown on the **Figures 2** and **5c** are of the greatest practical as they are accomplished in the closest conditions to furnace charging ones in its working regime. We should notify that the mentioned research technique of material flow trajectories with usage of laser equipment has a certain range of advantages: great accuracy and less duration of investigations, the possibility of metering along the entire altitude of furnace working space. Charge stock profile measuring according to the new technique enables its application in the conditions of high temperatures and gas contamination. In other words, it enables using this technique during short stops of furnace with opening of fitting hole and furnace top gas ignition. Measurements can be also completed through any other holes and recesses of the furnace shaft and shaft top. The disadvantages of the investigated technique are the sensibility of laser equipment to steam and dust and limited opportunities for metering of charge circular distribution.

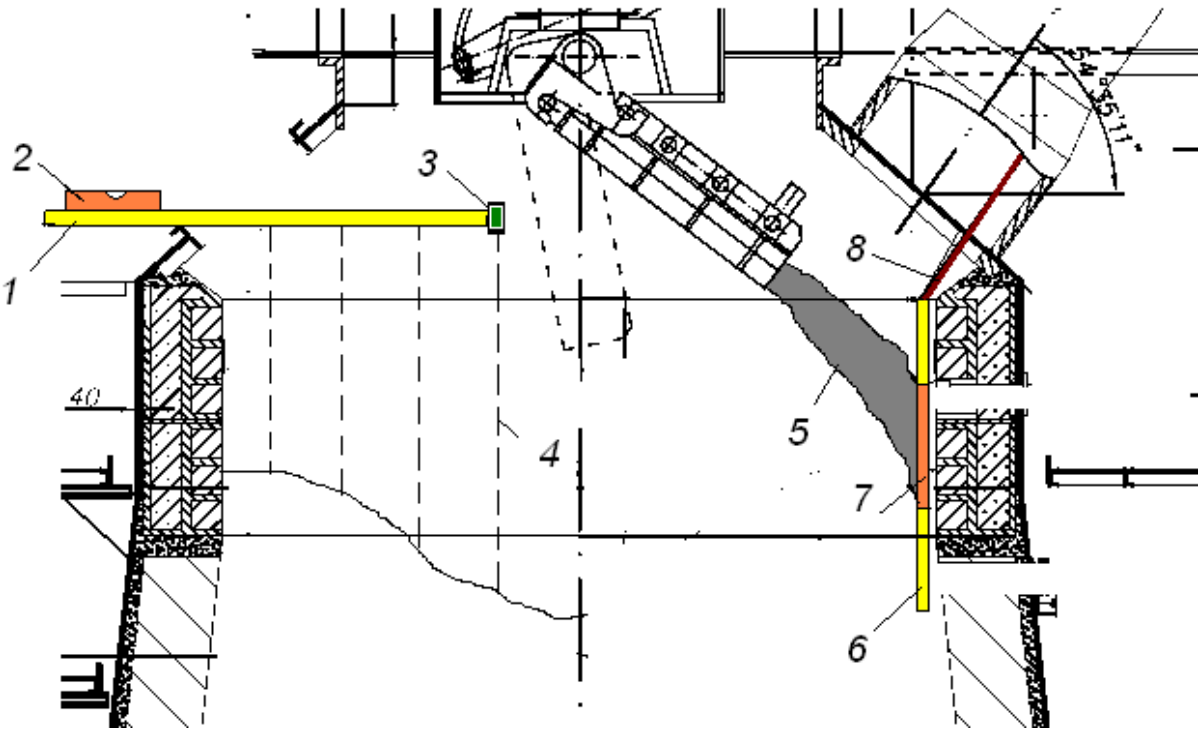

Figure 4. The definition of stock surface profile of the charge with laser profilometer through the fitting hole and trajectory borders of charge materials according to the marking left on the wooden rods: 1 – dimensional beam; 2 – level; 3 – laser distance gauge; 4 – laser ray; 5 – charge material flow; 6 – gauging rod; 7 – charge flow marking on the rod; 8 – rope

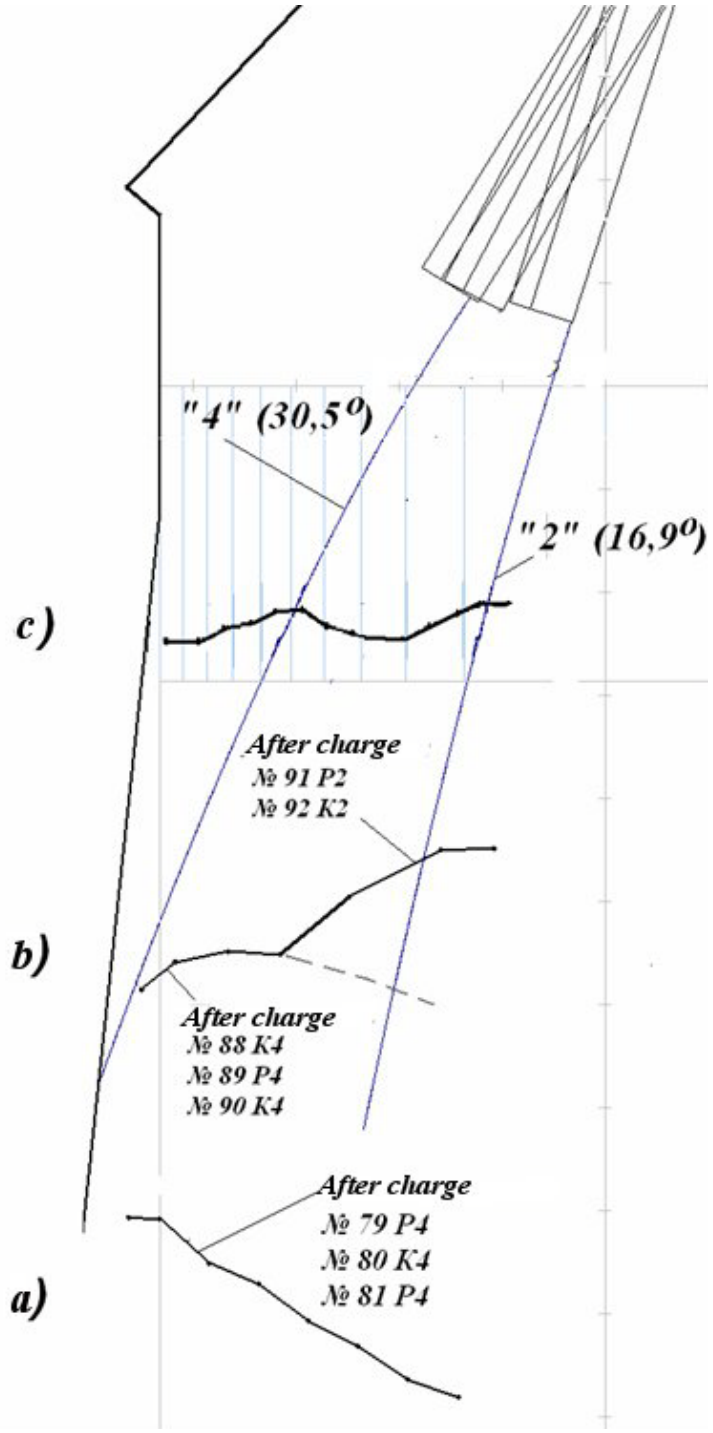

Figure 5. Precalculated trajectories of material flow trajectories in the furnace working space with capacity 3 000 m^3 and profiles of charge stock: *a* – after the charge of 3 portions from the 4th angle position of bell-less top charging system; *b* - after the charge of 3 portions from the 4th angle position and 2 portions from 2nd angle position; *c* – charge of iron-ore materials from 4th angle position and portion of coke from 2nd angle position

Conclusions

The expansion of bell-less top charging system application on the blast furnaces of different capacity, the change of constructive solutions and creating of alternative bell-less top charging system constructions with different kinds of charge distributors increases relevancy of development and application of new means and methods of pre-launch investigations running for comparative

estimation of constructive solutions and production of data for definition of reasonable charging programs.

The results of investigation of charge materials flow trajectory in shaft top space and their position on the stock surface which were mentioned in this article are completed according to the new technique by measuring with laser distance gauge after its discharge in the set point of chute distributor slope. These investigations are accomplished by the author in 2010 on the BF with the capacity 3 000 m^3 and equipped with chute bell-less top charging system. The measuring of crest position and estimation of stock profile formation with the laser distance gauge through the fitting hole of bell-less top charging system enables to accomplish such researches without putting the investigators on the stock surface and to hold them during short stops of the furnace with opening of fitting hole because of the high temperatures in shaft space and gas contamination. The application of new technique essentially expands the opportunities of immediate realization of such investigations and production of great amount of information about the trajectories of charge flow and stock surface formation during the charge of different materials and their compositions, reduces labor intensity required for investigations and provides their safety.

References

1. V.I. Bolshakov *Teoriya i Praktika Zagruzki Domennykh Pechey*, Moscow, Metallurgiya, 1990, 256 p.*

2. V.I. Bolshakov *Tekhnologiya Vysokoeffektivnoy Energosberegajushchey Domennoy Plavki*, Kyiv, Naukova Dumka, 2007, 412 p. *

3. V.P. Tarasov *Gazodinamika Domennogo Protsessa*, Moscow, Metallurgiya, 1982, 224 p. *

4. V.I. Bolshakov, A.Ju. Zarembo, A.S. Salo *Voprosy Proizvodstva Chuguna V Domennykh Pechakh*, Moscow, Metallurgy, 1984, No.11, pp. 60 – 64. *

5. V.L. Pokryshkin, V.I. Bolshakov, I.T. Khomich *Stal*, 1982, No. 11, pp. 13 – 16. *

6. V.I. Bolshakov, A. Yu. Zarembo, N.G. Ivancha *Obzornaya Informatsiya*, Moscow, Institute “Chermetinformatsiya”, 1989, 53 p. *

7. V.I. Bolshakov, A.Ju. Zarembo, N.G. Ivancha *Metallurgicheskaya i Gornorudnaya Promyshlennost*, 2007, No. 4, pp. 75 – 79. *

8. V.I. Bolshakov, N.G. Ivancha, V.V. Lyebed’, S.T. Shuliko *Metallurgicheskaya i Gornorudnaya Promyshlennost*, 2008, No. 4, pp. 99-104. *

* Published in Russian

Received February 18, 2011

Новая методика предпусковых исследований на доменной печи

Большаков В.И., Лебедь В.В., Жеребецкий А.А.

Рассмотрены методы проведения предпусковых исследований траекторий движения шихты в колошниковом пространстве и её расположения на поверхности засыпи при загрузке бесконусным загрузочным устройством. Представлены методические основы проведения предпусковых исследований с применением лазерного дальномера.