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DEVELOPMENT OF TECHNOLOGY OF PULVERIZED COAL INJECTION IN UKRAINE'S BLAST FURNACES IN VARIABLE LIQUID AND GAS DYNAMIC CONDITIONS

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The aim of the work is to study the features of the use of pulverized coal (PCI) in the conditions of the blast furnace (BF) No. 5 of Metinvest Holding Ltd (Ukraine). The complex for the preparation and use of pulverized coal includes: a coal unloading and storage area; coal mixing section; coal sampling unit; plot of coal sorting and preparation; installation of drying and grinding coal raw materials, installation for the injection of pulverized coal into the BF. It is shown that the use of rational modes of loading and forming portions of the charge, the choice of rational slag mode allowed to increase the annual consumption of pulverized coal on average up to 130 kg / t of pig iron even in the conditions of variable load of BF and when working on coke of reduced quality. During the research, an operational monitoring of the condition of the lining of the BF shaft was carried out using the indications of the thermocouple of the lining and the body of the refrigerators. The determination of the thermal loads of the cooling system made it possible to develop measures to adjust the distribution of the charge components along the radius and circumference of the furnace. The temperature of the peripheral gas flow along the entire height of the furnace is reduced by an average of 13%, the irregularity of the peripheral temperature is reduced by 11%. The stability of the cooling system and the smooth operation of the blast furnaces.

Keywords: blast furnace pulverized fuel, charge loading modes, lining condition, thermal loads

Problem state. Blast furnace ironmaking of Ukraine is moving to the technology of pulverized coal injection (PCI) in recent years. The development of this technology occurs, mainly, in a difficult economic, organizational and charge conditions. The operation of blast furnaces (BF) in Ukraine on pulverized coal in such conditions requires a special approach to managing the smelting process, that when equipped with modern means of control and reasonable using of information obtained by these means, allows. It is allowed to make effective decisions by technological personnel, both on changing the parameters of the charging mode, and on correcting the blowing mode. It should be especially recorded that the effective use of PCI along with the requirements for the quality of coals, iron ore materials, blast furnace coke and the design features of air tuyeres – their "height", diameter and angle of inclination [1-3], is largely determined by the use of rational charging regimes the realization of which is possible, mainly, by the bell-less charging devices, which are uncontested in these conditions [4].

In one of the blast-furnace shops of Metinvest Holding Ltd (Ukraine), in 2016, the technology of blowing-in of the PCI was started: at BF №5 from 01.03.2016 and at BF №3 from 20.04.2016. The main design characteristics and the list of the main means of control of BF №5 and BF №3 are shown in Table.1.

Table 1. Basic design characteristics and control means of BF №5 and BF №3

Name	BF №5	BF №3
Start after reconstruction, date	June 29, 2007	October 18, 2011
Useful volume, m^3	1513	1719
Shotcrete mine after start-up, date	October 2009, July 2011, November 2013, November 2016	June 2014, September 2016
Radius of the top, m	3.40	3.60
Charging device	Bell-type	Bell-less top
Height of the cylindrical part of the top, m	2,70	2,30
Height of the shaft, m	16,40	16,20
Number of cast iron, pcs.	2	2
Number of air jets, pcs.	20	24
Stationary thermo-probes above the surface of charge charging, pcs.	4	4
Electromechanical probes, pcs.	2	1
Radar level gauges, pcs.	0	2
Gas outlets, pcs	4	4
Thermocouples of peripheral gas flow, pcs.	16	16
Thermocouples of the lining of the shaft, the spray and the shoulders, pcs.	40+16*)	56
Thermocouples of the body of the refrigerators of the mine, pcs.	30	–

*) - restored during the last repair with shotcrete the shaft, 16 thermocouples are additionally duplicated in the heat-stressed zone (above the second cast-iron tap)

Summary of the main results of the study. The complex for the preparation and injection of PCI into the furnaces of the blast furnaces of the enterprise includes: a section for unloading and storing raw coal; a section for mixing coal; installation of coal sampling; plot of screening and finishing of coals; installation of drying and grinding of coal raw materials, equipped with two vertical mills (capacity 52.5 t/h); installation of PC injection. The system for blowing PCI into blast furnaces is equipped with a so-called Oxygen-coal technology "OXYCOAL", the development of which is planned after the relative stabilization of the supply of raw materials.

For the production of PCI in 2016, low-caking coals of the Bachatsky coal mine were used, the composition and properties of which correspond to the norms accepted in the world practice. Carbon content in the working weight of these coals is 79.82%, ash content ≥ 8.5%, volatile matter content 22.1%, low sulfur content 0.20%. It is worth mentioning two more important indicators characterizing these coals, such as the Hardgrove grinding index (HGI) and the free swelling index (FSI). The low-caking coals have an almost maximum level of grindability, which greatly improves the tonnage of grinding and improves the operating conditions of grinding media. Increasing the fineness of grinding increases the degree of burn-in of the PCI particles, reducing energy costs, which, along with other factors, allows increasing the PCI consumption to 160 kg/ton of cast iron and more. The index of free expansion of a coal particle of this grade of coal improves the gas dynamics of the bottom of the furnace and eliminates the coking of PCI in the blowing channel of air tuyeres.

Given the organizational and complex economic characteristics, the quality of the coke used in the blast furnace shop did not meet the operational requirements of the blast furnace technology using PCI. In Table. 2 shows the characteristics of coke during the development of the technology of injection PCI at BF №5 and BF №3 after the complete removal of natural gas from the blast before the overhaul with shotcrete the shafts blast furnaces in comparison with the required indicators of quality of coke when blowing the PCI.

Table 2. Quality of coke used at BF №5 and BF №3 during the development of PCI technology

Coke quality index → BF↓		*W*	*Ash*	*Sulfur*	*M25*	*M10*	*> 80*	*0-25*	CSR	CRI
In accordance with operational requirements		≤ 0,5	<12%	S<0,6%,	≥ 87,0	≤ 6,0	≤ 5,0	≤ 3,5	>60%,	<30
BF №5	PCI =110 kg/t of cast iron	3,47	10,96	0,90	88,04	7,33	9,36	3,15	49,2	33,5
BF №3	PCI =110 kg/t of cast iron	3,60	10,80	0,92	87,87	7,41	8,75	3,12	49,5	33,3

In addition, the quantitative and qualitative composition of iron ore used in blast furnaces during this period was also unstable. The content of imported pellets produced by Northern Iron Ore Enrichment Works by basicity (CaO/SiO_2) is 0.05 units. In a mixture with agglomerate changed from 10 to 75%, the amount of agglomerate produced by a local sinter plant with a basicity of 1.4 units. With a high content of secondary resources necessitated additional supplies of agglomerate of the production of Southern Mining and Processing Plant with a basicity of 1.6 units, the total iron content in the burden with limestone during the development of the PCI was 54.8%.

The transition to the PCI technology with an increase in the productivity of blast furnaces with a reduced quality of charge materials and a low rate of renewal of the coke nozzle necessitates flushing on an ongoing basis (so-called "soft" flushes). In the blast furnace shop, in order to maintain the satisfactory properties of the primary, intermediate and final slags, manganese-containing materials, in particular manganese ore, are used in the blast furnace blend composition. The manganese oxide of this ore reduces the viscosity of the intermediate slags and reduces the melting point of the mixture of the iron ore portion of the charge. In the second stage, when it enters the lower high-temperature zone, part of manganese is reduced in it with gasification of carbon in the lower part of the blast furnace, contributing to the acceleration of the renewal of the coke nozzle and the stabilization of heating of the smelting products.

Investigations of the influence of manganese in the blend when operating on a combined blast in the conditions of the given metallurgical enterprise before the start of the introduction of the PC injection technology showed that under conditions of blast furnace operation on coke of reduced quality, an increase in the MnO content in the charge by 1 kg/ton of cast iron reduces the coke consumption by ~ 2,7–2,9 kg/t due to the organization of "soft" washing of the furnace from coke of fine fractions and, as a consequence, stabilization of heating of cast iron, the coefficient of transition of manganese to cast iron was ~ 0.47 ± 0.03. The use of manganese-containing materials during the development of the PC injection technology in an amount of ~ 25 kg/ton of cast iron made it possible to increase the processability of blast furnace smelting and to expand its management capabilities with unstable raw materials.

The transition to the technology of PC injection in the current conditions of the blast furnace shop caused the need to adjust the charging regime on blast furnaces. Under these conditions, when blowing into the hearth of a PCI, such features of the distribution of the gas stream in the furnace as an insufficiently developed central gas distribution and an excessively developed peripheral flow of gases can take place. At the same time, it should be noted that the technology of PC injection should provide for an increase in the productivity of the furnace, one of the measures of achieving which is to provide a more developed gas transmission capacity, in comparison with working without a PCI, the peripheral zone of the furnace. And in order to achieve a smelting economy, the degree of development of the central gas flow should provide the possibility of regulating the dimensions of the axial coke outlet "without the risk of losing the center". It is also important to note that when using PCI with a large amount of slag at the output of smelting products (398 kg/ton of cast iron – at BF №5 and 393 kg/ton of cast iron – at BF №3), special modes of forming batch batches to prevent particles from entering Not completely burned fuel into primary and intermediate melts, which increases the probability of clogging the furnace with non-melting masses.

Therefore, when regulating the distribution of the gas flow along the radius of the furnace when blowing into the hearth of a PCI to achieve optimal technical and economic parameters of melting, in the conditions of operation characteristic for a given metallurgical enterprise, by distributing the charge materials along the top section, it is necessary:

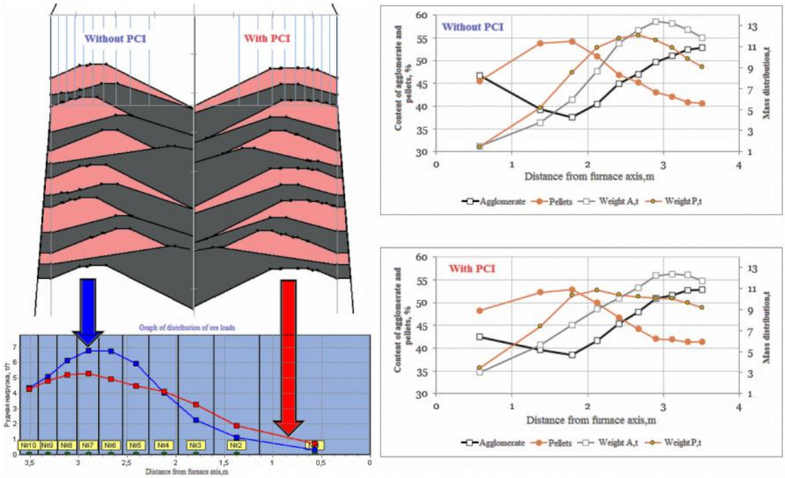
– ensure a stable central gas distribution with a narrow axial coke vent;

- to exclude the localization of individual types of iron ore raw materials along the blast furnace top section;
- provide an increased concentration of low-basic raw materials in the area of localization of PCI particles;
- to form the composition of iron-ore materials in the near-wall zone, providing self-renewal of the skull in the lower part of the blast furnace shaft;
- optimize the gas permeability of the peripheral zone, not allowing excessive "overcharging" of its iron ore materials, which can lead to "upper suspensions" and an uneven collection of charge;
- to ensure the development of a mutual flow of gases between the periphery and the center.

Based on the above provisions for managing the distribution of gas flow using PCI, the authors of this article have developed and proposed for implementation: a new download program developed using the model system [5] and the mode of formation of batches BF №3 (Figure 1). The need to change the charging program was due to the formation of a "gas-tight" intermediate zone in the furnace (zones of increased ore loads) during the development of the PCI, which contributed to the development of an excessive peripheral gas flow, which made it difficult for the gases to transfer from the periphery to the center. These features of the distribution of the gas flow were revealed during the analysis of the information of the temperature probe installed on the furnace [6]. At the beginning of the development of the PCI, the lining temperatures at the mid-well level and the thermal loads of the cooling system in this zone also increased significantly.The implementation of the proposed changes in the charging program and the mode of formation of portions made it possible to reduce the temperatures of the peripheral gas stream throughout the entire height of the furnace by 13%, from 432 °C to 377 °C, on an average, and to reduce the peripheral gas flow temperature unevenness by 11% (Figure 2).

At the BF №3, the thermocouples of the lining of the shaft are established by the height and circumference of the furnace, to a depth of 100 mm [7]. Thermocouples are installed on six horizons of the mine, as well as in the rasp, shoulder and in the zone under tuyeres. The thermocouples are arranged around the circumference of the furnace in the following way: eight thermocouples are installed at the level of the shoulders, the decomposition and the three lower horizons of the shaft, six thermocouples on the next two horizons and four thermocouples on the upper horizon [7, 8].

Analysis of temperature changes in lining (peripheral gas flow) at BF №3 during the development of the PCI injection technology showed the following. When blowing high flow rates (15–18 t/h), the temperature of the middle of the shaft at two levels of the thermocouple installation increased from 215 °C to 550 °C, on average.



Without PCI

Ang position of the tray	C	R	C	R	C	R	C	R	C	R	C	R
R10				28						28		
R9				25	8	10				25	8	10
R8			13	20	17	28		26	13	20	17	28
R7		25	17	15	22	23		22	17	15	22	23
R6		30	17	12	20	23		17	17	12	20	23
R5	10	17	20		14	16	10	17	20		14	16
R4	10	14	14		19		10	18	14		19	
R3	10	14	19				10		19			
R2	20						20					
R1	50						50					

With PCI

Ang position of the tray	C	R	C	R	C	R	C	R	C	R	C	R
R10				34						34		
R9				17		12		15		17		12
R8		13		14	23	25		22		14	23	25
R7		22	25	12	28	23	30	18	25	12	28	23
R6		26	25	12	26	17	15	15	25	12	26	17
R5		15	28	11	23	13	10	15	28	11	23	13
R4	10	12	22			10	10	15	22			10
R3	15	12					10					
R2	15						25					
R1	60											

R – iron-containing materials, C – coke

Figure 1. Calculation structure of layers of charge materials, distribution of ore loads, charge components along the radius of the furnace and charging matrices for two rational modes of BF No. 3 (without PCI and PCI).

The change in the temperature of the thermocouples of the lining of the first row of the bottom of the mine was characterized by a slight change in the beginning of 2016, after which, on passing to the PCI, an unstable temperature change was observed on this horizon. On the second row of the bottom of the mine, an opposite pattern was observed, characterized by the stabilization of temperatures and their root-mean-square deviation along the circumference with the onset of PC injection.

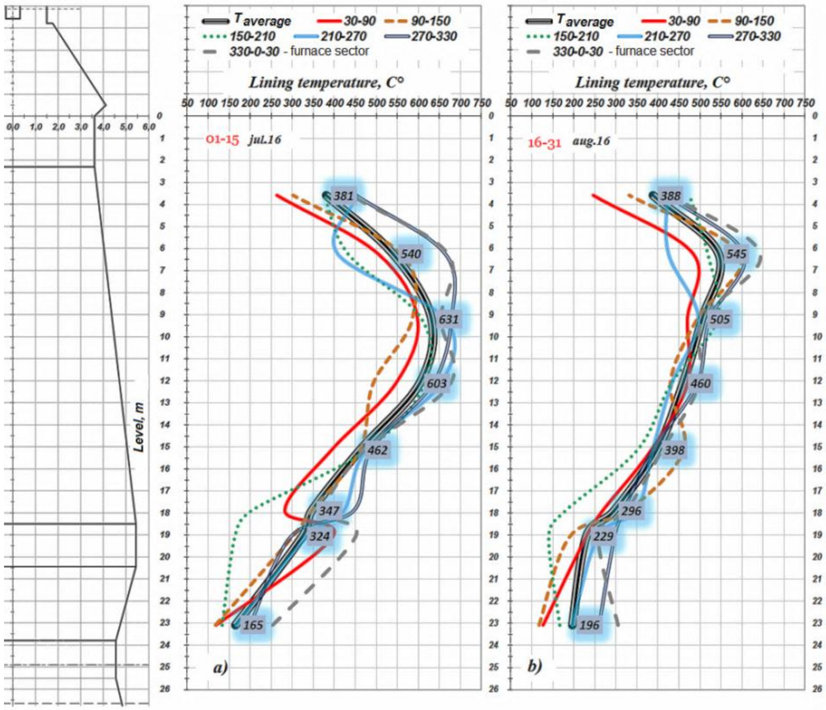


Figure 2. Change in the temperature of the thermocouples of the lining of the mine, the decontamination and the shoulders of BF №3 to (a) and after (b) the implementation of the recommendations for charging

Such a feature of the temperature change in the lower part of the furnace shaft could indicate a change in the position of the root of the zone of the viscous-plastic state upon transition from the BF operation mode to the "gas-free charge" with moistened blasting at the beginning of 2016 for technology using natural gas and then PCI. At the same time, in conditions of blowing up of large PCI expenses, all the temperatures of the bottom of the mine at two levels increased from 215 °C to 390 °C, on average.

At the level of decomposition with increasing flow rate, the temperatures of the lining thermocouples increased, on average, by 1.8 times (up to 310 °C), compared to the beginning of 2016. The temperature of the lining thermocouples at the level of the shoulders changed stably, this indicated the presence of a stable skull in shoulders, which was then confirmed by visual inspection of the mine after blowing. In absolute terms, the temperature at the shoulder level increased slightly – from 125 °C to 175 °C.

Thus, it was found that at the mid, lower and lower levels in the transition blowing and fuel modes of operation of the BF №3, including with the beginning of injection of the PCI, significant changes were observed both in the absolute values of the temperatures of the lining thermocouples and in their standard deviations along the circumference furnace. This was a consequence of both the change in the position of the root of the zone of the viscous-plastic state and the deterioration of the lining of the mine, considering that at the time of injection of large PCI costs, the mine shaft campaign was already two years, which necessitated another shunting. The use in the technology of melting of rational charging regimes during the injection of PCI made it possible to ensure the operational stability of the cooling system and the trouble-free operation of the blast furnace at the BF №3 without the lining of the shaft. After shotcrete the shaft of BF №3 in September 2016, the distribution of liner temperatures from the level of the shoulders to the upper horizon of the mine leveled, the temperatures varied from 100 °C to 200 °C, until January 2017 inclusive.

In addition to the established features of the influence of the PCI on the temperature changes of the liner over the height of the BF, in 2016, studies were also made of the possibility of using the thermocouple indications for the height of the BF shaft in the absence of a lining of the furnace shaft for evaluating the processes in the peripheral zone of the furnace.

The investigations were carried out for the operating conditions of the furnace in four periods, common for which was the absence of the lining of the furnace shaft:

1. Mode of operation on "gas-free charge" with moistened blowing – the steam consumption averaged 2.4 t/h (01.01–14.03.2016) – period 1.
2. Mode of operation with natural gas (NG) – NG consumption was, on average, 58.9 m^3/ton of cast iron (15.03–20.04.2016) – period 2
3. The operating mode with NG (10.8 m^3/t) and with PCI (91.8 kg/ton of cast iron) at the initial stage of its development (21.04-03.06.2016) – period 3.
4. The mode of operation with the PCI (129.6 kg/ton of cast iron) (29.06–13.09.2016) to stop the BF for shotcrete mine – period 4

In Fig.3a shows the distribution of the temperature of the gas flow in the peripheral zone along the height of the BF for the four periods under study, in Fig.3b – temperature distribution for the fourth period, conditionally divided into three regimes with different consumption of the injected PCI. As can be seen from Fig.3, the nature of the distribution of the temperature of the gas flow in the peripheral zone along the height of the BF is largely determined by the gas-blown mode and the amount of the PCI used.

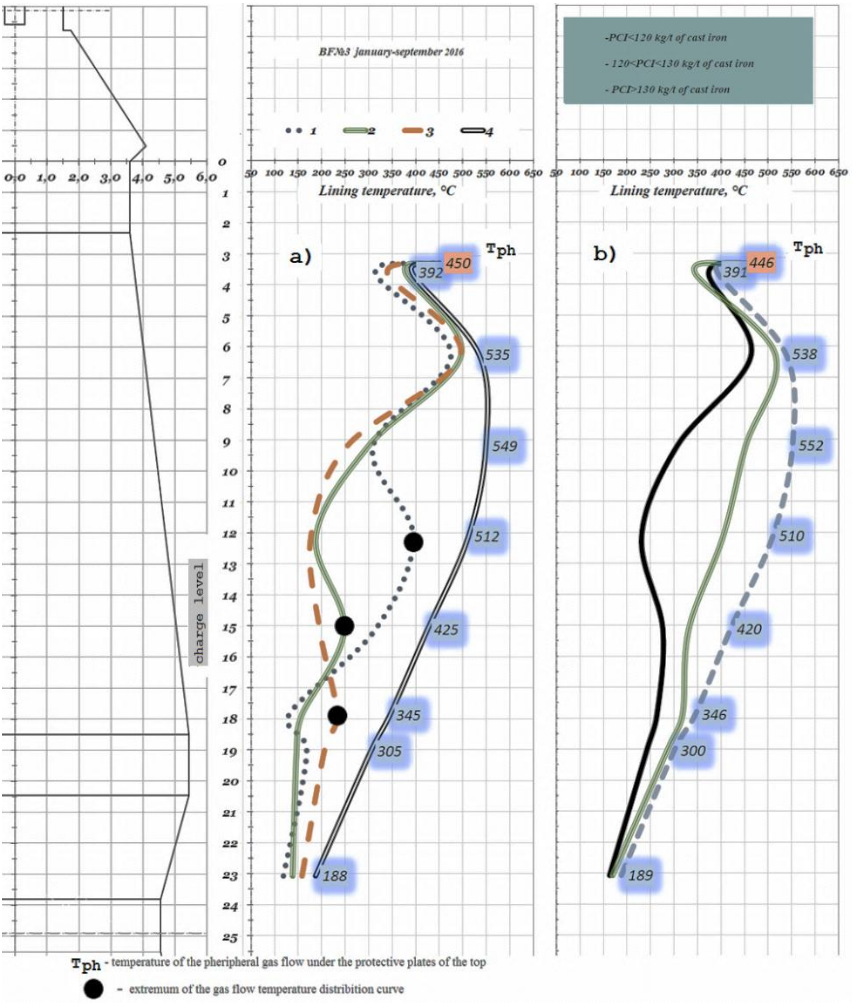


Figure 3. Distribution of the temperature of the gas stream in the peripheral zone along the height of the BF for various gas-blowing and fuel conditions

Thus, when analyzing the temperature of the gas flow of the bottom of the shaft, the spray and the shoulders, the maximum value of the temperature (the extremum of the curve) in the first period of work is marked at a level of 12 m from the technological zero (TZ) – from the top of the protective plates of the top, or 13 m from the axis of the air lances WF), in the second period - at a level of 15 m from the TZ (10 m from the WF), in the third – at a level of 18 m from the TZ (7 m from the WF), in the fourth period there was no clearly pronounced extremum in the lower part of the furnace, the temperature The gas flow monotonically increased from the shoulders to a level of 6 m from the TZ. Extremes of the temperature curves of the lower zone of the furnace for the first three periods of operation of the BF can characterize both the position of the root of the zone of the viscous-plastic state (plastic zone) and the boundary of the stable component of the garnish formed in the furnace. In favor of the assumption about the position of the root of the zone of the viscous-plastic state at the extremum point of the temperature curve, the results of investigations on a BF with a working volume of 3594 m^3 of the Thyssen plant in Schwelgern [9–11] testify. Determination of the position and profile of the plastic zone by the authors of the publication [9, 10] was based on the distribution of pressures, lining temperatures and gas composition at the wall along the height of the furnace. On this BF, the lining temperatures of the mine were determined at 16 levels above the axis of the air tuyeres and at 13 levels the static pressure drops were determined. According to the studies [9, 10], with a poor furnace stroke, the height of the plastic zone, its upper limit, was 14 m above the level of the tuyeres, at an average speed - at a distance of 9 m, with a good course – at a distance of 8 m.

In addition, it should also be noted that in the first study period of the BF operation, the maximum pellet content in the mixture with agglomerate (54.8%) was used, which, as is known, has low melting properties and high content in the charge Promotes the formation of a stretched over the height of the plastic zone. And taking into account that the first period is characterized by the maximum distance from the level of the tuyeres to the extremum point of the temperature curve along the height of the lower part of the shaft, this may also indicate the position of the upper boundary of the zone of the viscous-plastic state at the extremum point.

An increase in the flow rate of the pulverized coal injected into the hearth of the investigated BF (Fig.3b) contributed to an increase in the gas flow temperatures along the furnace height with a maximum amplitude of the change at the midpoint of the shaft. The increase in temperature was caused by the intensification of the peripheral gas flow with increasing flow rate, and the explanation for the maximum amplitude of temperature changes at the midpoint of the shaft was the increased distance from the axis of the tuyeres to the bending of the furnace profile and the rational design of the air tuyere used in the blast furnace shop.

Thus, as a result of the performed studies, the effect of gas-blast furnace parameters, including when using natural gas and pulverized fuel in the blast, was shown to change the shape of the temperature distribution curve of the peripheral gas stream. The established features of the influence of the features of the gasdynamic mode of blast furnace smelting on the temperature of the gas flow will allow to adequately detect and correctly monitor charging parameters that influence the gas temperature distribution when the furnace load regime changes.

In control system of BF №3, the indicator of total thermal loads of the cooling system is registered, both in the furnace as a whole and in individual zones. The performed analysis of the change in this indicator in 2016 showed that at the initial stage of the development of PCI, the average daily values of this indicator reached 10,000 kW per day. When the PCI costs reached 130–140 kg/ton of cast iron on separate days, thermal loads increased, reaching its maximum value for the whole period – 19180 kW. In October 2016, at the output of BF №3 for the planned indicators for the daily capacity of the furnace after repair, the total heat losses in terms of its value of 6000–9000 kW reached the level of the beginning of 2016, when the technology of PCI melting was not used. It should also be noted that the thermal loads of the middle zone play a decisive role in the value of the indicator of the total thermal loads of the cooling system, which is in agreement with the analysis of the lining temperatures of the mine, from which it follows that the middle of the mine was the most heat-directed zone along the height of BF №3 during the development of the PCI. An explanation for this is the increased distance from the axis of the air tuyeres to the profile bend (bottom of the shoulder) of the BF №3 and the rational design solutions of the air tuyeres with a protrusion of 0.7 m, which are characteristic for the blast furnace shop [8].

If the total thermal load of the cooling system is increased severalfold and the lining temperatures are controlled at the same time, it is possible to judge the wear of the lining of the shaft, the decontamination or the shoulders, and plan technological and capital measures to prevent the failure of the cooling plates of the thermally stressed zone. A significant increase in the value of this indicator can explain the high consumption of conventional fuel, which will be compensated for covering thermal losses.

Analysis of the state of the metal receivers of blast furnaces during the development of the PCI showed the following. Since the start of the injection of PCI at BF №5, the temperature of the central part of the floor has increased slightly, but has not exceeded the maximum values observed on the furnace earlier, which indicates the absence of wear of the liner. The temperature range of the lining testified to a stable rational layer of the skull in the area. Thermal loads in the most heat-stressed sector of the area, under the cast iron tapholes remained at the level before injection of the PCI (~ 2000 W/m^2). After the start of PCI injection at BF №5, the temperature of the lining of the peripheral part of the hearth and the floor at the levels from the third to the eighth level of the thermocouple installation remained at the same level. Consequently, the residual thickness of the lining did not change, the wear of the lining averaged no more than 20%. After the start of the injection of PCI, a number of control measurements of thermal loads on the cooling system of the furnace and floor were carried out. The conducted measurements of the thermal loads on the metal receiver refrigerators did not exceed the maximum values recorded earlier in the furnace campaign since 2007. Due to the lack of automated control and the noted tendency of growth of thermal loads on the refrigerators of the furnace cooling system, it is recommended to conduct regular control measurements of the thermal loads on the refrigerators of the cast iron chutes, the lower and upper horns at the BF №5

Lining of the metal detector BF №3 is made of various refractory materials from GrafTech International (USA) and NDK (Japan). The working surface of the metal receiver is protected by a ceramic glass made by Saint Gobain International (France). Since the beginning of the injection of the PCI into the BF №3, the thermal load on the central part of the area has remained at the same level, on the average, of the order of ~ 1500 W/m2. The wear of the lining of the central part of the floor was absent, the surface of the floor was covered by a layer of a skull. The main part of the thermal load on the peripheral cooling refrigerators during the five years of operation of the BF №3 was stable and did not exceed 20,000 W (in the bundle on the upper and lower floor cooler) and 30,000 W (in combination with the upper and lower furnace coolers). After the start of PCI, the temperature of the lining and the thermal load on the refrigerators, including the refrigerators of the cast iron zone, remained at the same level. The thickness of the lining of the peripheral part of the horn and wood outside the iron casting sector remained projected and covered with a layer of skull. In the sector of cast iron chambers, the permissible wear of the ceramic layer is fixed – no more than 25%, caused by the erosive effect of metal and slag flows.

CONCLUSION

The development of the PCI technology in the blast furnace shop Metinvest Holding Ltd (Ukraine) in variable charge conditions and with work on reduced quality coke with the use of rational charging regimes, forming portions and selecting a rational slag regime, allowed to increase the consumption of PCI in 2016, on average, up to 130 kg/ton of cast iron. The operational control of the state of the lining of the mine shaft of blast furnaces, carried out according to the indications of the lining thermocouples, thermocouples of the body of refrigerators and thermal loads of the cooling system, made it possible to carry out both garbage-forming measures in time and to adjust the distribution of the components of charge materials along the radius and circumference of the furnace. The implementation of the proposed changes in the charging program and the mode of formation of portions made it possible to reduce the temperatures of the peripheral gas flow throughout the furnace altitude by an average of 13% and reduce the circumferential temperature unevenness by 11%. The use in the technology of rational charging regimes during injection of PCI allowed to ensure the operational stability of the cooling system and the trouble-free operation of blast furnaces. The initial stage of PC injection in the blast-furnace shop of Metinvest Holding Ltd (Ukraine) did not affect the heat loads of the blast-furnace metal receivers. The performed analysis of the state of the rock and borehole BF №3 showed the effectiveness of the design solution for the use of a ceramic glass, the wear of which for five years of operation of the furnace was 25% in the zones of the cast iron sectors.

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Разработка технологии распыления пылеугольного угля в доменных печах Украины в переменных жидких и газодинамических условиях

Целью работы является изучение особенностей использования пылеугольного топлива (ПУТ) в условиях доменной печи (ДП) № 5 компании "Метинвест Холдинг Лтд" (Украина). Комплекс для приготовления и использования пылеугольного топлива включает в себя: участок разгрузки и хранения угля; секцию для смешивания угля; установку отбора проб угля; участок сортировки и подготовки углей; установку сушки и измельчения угольного сырья, установку для инъекции ПУТ в ДП. Показано, что использование рациональных режимов загрузки и формования порций шихты, выбор рационального шлакового режима позволило увеличить годовое потребление ПУТ в среднем до 130 кг/т чугуна даже в условиях переменной загрузки ДП и при работе на коксе пониженного качества. Во время исследований проводился оперативный контроль состояния футеровки шахты доменной печи с использованием показаний термопар футеровки и корпуса холодильников. Определение тепловых нагрузок системы охлаждения, позволило разработать мероприятия по корректировке распределения компонентов шихты по радиусу и окружности печи. Температура периферийного газового потока по всей высоте печи снижена в среднем на 13%, неравномерность окружной температуры уменьшена на 11%. Обеспечена стабильность работы системы охлаждения и бесперебойная работа доменных печей.

Ключевые слова: доменная печь пылеугольное топливо, режимы загрузки шихты, состояние футеровки, тепловые нагрузки

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Розробка технології розпилення пиловугільного вугілля в доменних печах України в змінних рідких і газодинамічних умовах

Метою роботи є вивчення особливостей використання пиловугільного палива (ПВП) в умовах доменної печі (ДП) № 5 компанії "Метінвест Холдинг Лтд" (Україна). Комплекс для приготування і використання пиловугільного палива включає в себе: ділянку розвантаження і зберігання вугілля; секцію для змішування вугілля; установку відбору проб вугілля; ділянку сортування і підготовки вугілля; установку сушки та подрібнення вугільної сировини, установку для ін'єкції ПВП в ДП. Показано, що використання раціональних режимів завантаження і формування порцій шихти, вибір раціонального шлакового режиму дозволило збільшити річне споживання ПВП в середньому до 130 кг / т чавуну навіть в умовах змінного завантаження ДП і при роботі на коксі зниженої якості. Під час досліджень проводився оперативний контроль стану футеровки шахти ДП з використанням показань термопар футерування і корпусу холодильників. Визначення теплових навантажень системи охолодження дозволило розробити заходи щодо коригування розподілу компонентів шихти по радіусу і окружності печі. Температуру периферійного газового потоку по всій висоті печі знижено в середньому на 13%, нерівномірність окружної температури зменшено на 11%. Забезпечено стабільність роботи системи охолодження і безперебійну роботу доменних печей.

Ключові слова: доменна піч пиловугільне паливо, режими завантаження шихти, стан футеровки, теплові навантаження

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