6. O. N. Senkov, D. W. Mahaffey, S. L. Semiatin, Inertia Friction Welding of Dissimilar Superalloys Mar-M247 and LSHR, Metallurgical and Materials Transactions A, 45 (2014) 5545–5561. DOI: https://doi.org/10.1007/s11661-014-2512-x.

7. J. Zhang, R. F. Singer, Effect of Zr and B on castability of Ni-based superalloy IN792, Metallurgical and Materials Transactions A, 35 (2004) 1337–1342. DOI: https://doi.org/10.1007/s11661-004-0308-0.

UDK 669.1+662.6

Y. O. Stupak

Ukrainian State University of Science and Technology (USUST), Dnipro

REGARDING THE ANALYSIS OF THE EFFECTIVENESS OF COKE SUBSTITUTES IN THE BLAST FURNACE PROCESS

Coke was and remains irreplaceable and one of the most expensive components of blast furnace charge, the cost of which only increases over the years. One of the reasons is the reduction of the coal raw material base for the production of coke, which is accelerating. These circumstances constantly prompted scientists and practitioners of metallurgy to search for alternative solutions and technologies, which can be bring to two directions:

- replacement of coke as a reducing agent and heat source in the blast furnace process;
- replacing the blast furnace process with another one, in which the reducing agent can be gas with appropriate properties and/or solid or liquid fuel containing carbon, hydrogen and their compounds.

It is well known that the first direction has certain limitations regarding the maximum possible replacement of coke due to the need to ensure the gas permeability of the charge column. The practice of the blast furnace process with the pulverized coal injection (PCI) into the blast furnace as a substitute for coke showed that achieving high rates of specific coal consumption (200 kg/t of cast iron and more) requires a set of measures that ensure stability (sustainability) of the main process indicators and the use of high-quality coke qualities (strength in a solid and especially hot state). Even under ideal conditions and state-of-the-art PCI blowing equipment and process control, it will still require about 300 kg of coke to melt 1 ton of pig iron. Taking into account the global volume of blast furnace iron production (primarily in China), the amount of coal required for its production will be considerable.

The second direction, embodied in the form of several more or less successful technologies with the so-called "direct" reduction of iron oxides cannot yet completely replace the blast furnace process due to a number of reasons, including - economic. The blast furnace process has been, and in the near future, still remains the most productive and economically feasible, although the relative cost of cast iron is constantly increasing due to the increase in the cost of coke and energy carriers used.

In recent decades, the attention (and volumes of relevant research) to the so-called alternative, including "green" sources of energy resources that can be used in metallurgy, in particular - in the production of cast iron. Among the potentially attractive for use in blast furnace production, it should be noted the waste of agricultural and other industries containing carbon, as well as hydrogen, which can be obtained in "green" energy and used as a reducing agent in blast furnaces [1]. Experiments that were carried out not so long ago in Germany showed the prospects of this direction, although its economic feasibility raises certain doubts. Experiments on blowing plastic, rubber, and other waste into blast furnaces were also conducted, but they remained experiments.

In the opinion of the author, the idea proposed at the time at the Institute of Ferrous Metallurgy (I.G. Tovarovskyi and colleagues) regarding the use of blast furnaces as gas generators, when one or two blast furnaces furnaces from a complex of furnaces, which are at the disposal of separate metallurgical plants, produce generator gas. The raw material for such a technology can be carbon-containing waste, or even household waste, but after certain preparation (sorting, etc.).

In Ukraine, in 2010-2013, the idea of extracting shale gas in the territory of the Dnipro-Donetsk (Yuzivska and other areas) and Lublin (Oleska area) basins was actively promoted. At that time, according to the State Service of Geology and Subsoil, shale gas reserves in Ukraine were estimated at 7.0 trillion cubic meters, or 5.0 trillion cubic meters according to estimates of the then Ministry of Energy and Coal Industry. Proponents of extraction and use of this gas cite the example of the so-called of the "shale revolution" that took place in the United States and Canada and allowed to significantly increase the volumes of gas produced. According to various data (for example [2]), the composition of shale gas is almost no different from the composition of natural gas, which is traditionally used in industry and everyday life. This makes it a fairly competitive fuel alternative to natural gas, despite the relatively high production cost and possible environmental consequences. It is not excluded that in the future energy companies in Ukraine will return to consideration of the issue of shale gas production.

Taking as a basis the algorithm for calculating the parameters of blast furnace melting, proposed in the last century by A.N. Ramm, the author, using electronic spreadsheets, developed and tested a program that allows analyzing the effectiveness of the use of certain fuel substitutes injected into the blast furnace through the tuyeres. Thus, in one of the studies [3], calculations were made to estimate the carbon and ash content in PCI for the specific consumption of coke in pig iron smelting, which gave more or less correct results. The algorithm was slightly improved in such a way that similar calculations could be performed for any other types of fuel (solid, gaseous) injected into the blast furnace. The developed program, combined with the evaluation of economic indicators, can be used in theoretical studies of the effectiveness of using coke substitutes in the blast furnace process, which is very relevant in view of the growing shortage of coke and other types of fuel.

References

1. Андрух Є.О., Ступак Ю.О. Про перспективи використання водню як замінника палива та відновлювачів в чорній металургії / В мат-лах II Всеукр. конф. молодих вчених "Молодь і наука. Практика інноваційного пошуку" (17 грудня 2020, м. Дніпро, Україна). – Дніпро: Дике поле, 2020. – С. 7-11.

2. Ayhan Demirbas, Nurettin Cek & Sukru Acar (2018) Chemical analyses of shale gas and conventional natural gas, Petroleum Science and Technology, 36:20, 1690-1695, DOI: 10.1080/10916466.2018.1504070.

3. Пишкін І.А., Ступак Ю.О. Дослідження зв'язку складу пиловугільного палива з витратою коксу в доменній плавці чавуну / В мат-лах Всеукр. конф. молодих вчених "Молодь і наука. Практика інноваційного пошуку". (18 грудня 2019, Дніпро). – Дніпро: Дике поле, 2019. – С. 119-122.