MACHINE SCIENCE
ISSN: 2227-6912
E-ISSN: 2790-0479
2024, № 1 Pages 24-35

GROWTH DYNAMICS OF STEEL PRODUCTION USING INNOVATIVE TECHNOLOGIES (overview)

Arif MAMMADOV[1,a*], Nizami ISMAYILOV[2,b], Agil BABAYEV[1,c], Mukhtar HUSEYNOV[1,d], Ilham ALİYEV[1,e]

[1]Department of Metallurgy and Materials Technology, Azerbaijan Technical University, Baku, Azerbaijan
[2]Azerbaijan State Marine Academy, Baku, Azerbaijan

E-mail: [a]ariff-1947@mail.ru, [b]nizism@mail.ru, [c]aqil.babayev@aztu.edu.az, [d]muxtar.53@mail.ru [e]ilham.aliyev@aztu.edu.az

https://doi.org/10.61413/QMRR2817

Abstract: In the conditions of new realities, the main trends of the transition to innovative technologies in the world metallurgical industry, including steel production, were analyzed. The importance of using metallized iron in steel production is justified. The state of steel production in the world's leading countries was evaluated based on modern literature sources and statistical indicators. The main features of the transformation that will lead to the correction of the strategic development vector of the ferrous metallurgy industry in the conditions of tough competition and protection policy have been determined. It has been shown that despite the slow progress of the decarbonization process in the world metallurgical production, strategic orientations are aimed at the application of technological innovations and preservation of social and environmental priorities.
Keywords: *new realities, metallized iron, steel production, main trends, statistical indicators*

Introduction.

In the conditions of globalization and new realities, tough competition and sanctions, as well as protectionist policies of national states, a number of trends are observed in the world ferrous metallurgy industry, including steel production. Statistical indicators characterizing the state of steel production in the world's leading countries provide sufficient grounds for assessing the objective picture [1,2].

It is noted that new innovative technologies have a number of advantages compared to the classic scheme of steel production. Thus, the use of a certain amount of metallized iron as a charge material in steel production allows solving the shortcomings of the classical scheme, including shortening the technological chain and reducing the dependence on coke use. The widespread application of electromelting in steel production has already made the abandonment of blast furnace technology, which is very harmful to the environment, in the main leading countries of the metallurgical industry [3-5]. That's why currently there is a strong growth dynamics of metallized iron production in the countries of the world. The advantages of metallized iron in electrosmelting in comparison with other components of the charge highlight its role in quality steel production [6].

After the post-pandemic period, the analysis of the development dynamics of steel production in the countries of the world from this context is of scientific and practical importance. The dynamic development of steel production with the application of electrosmelting, based on innovative technologies, including nanotechnologies, has been strongly observed in the Republic of Azerbaijan in recent years.

Taking this into account, the analysis of the growth dynamics of steel production in the world

with the use of innovative technologies made by us allows to evaluate the directions of future development in this field.

Main part.

It is known that the main components of metal scrap for electric steelmaking processes are cast iron, black metal scraps and metallized raw materials (Direct Reduction Iron - DRI). An overview of the ranges of technological changes in the steelmaking industry is shown in table. It can be seen from the table that the greater variability of the charge is typical for the electro- steeling process.

Table 1.Share of steelmaking processes, %

Indicators	Oxygen converter process	Electro-steeling process	Marten (scrap-ore) process	Marten (scrap process)
Share of the process in world steelmaking	69,8	29,0	1,2	
The share of the steelmaking process in the CIS	64,6	21,1	14,3	
Typical charge, %: - liquid cast iron - black metal scraps - metallized raw materials (DRI)	 75-80 20-25 -	 0-30 30-100 0-70	 25-55 25-75 -	
Max. share scraps in metallic slag	28	100	45	15

Thus, the classic production scheme of steel can be described as follows (Fig.1).

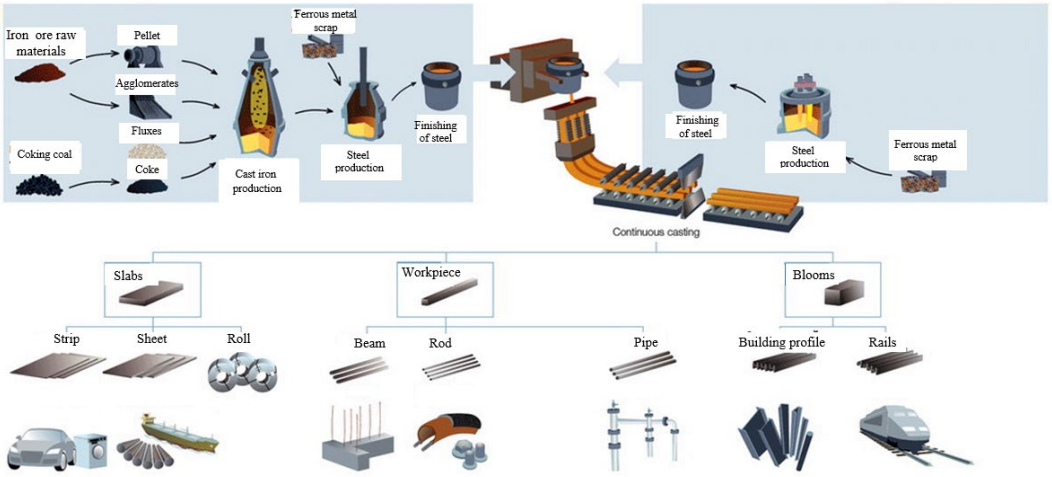

Figure 1. The classic scheme of steel production

The following advantages of the classical scheme can be indicated: high degree of iron separation; high specific productivity; high heat f.i.e.; efficient use of energy resources. Disadvantages of the classic scheme include: high capital costs; the need for preliminary crushing of the shale; coke usage costs; low quality of ferrous scrap.

New processes of obtaining iron.

The main reasons for the emergence of new processes of iron production are the shortcomings of the classic scheme, including the need to shorten the technological chain and reduce the dependence on coke. That is why the new processes are called "direct purchase of iron" or "cokeless metallurgy".

New processes of obtaining iron are divided into solid-phase and liquid-phase processes according to the type of semi-product produced, the share of the latter is very small, ie 5...6% of all non-coke metallurgy. Iron ore and iron ore logs are taken as primary raw materials in the new processes. Gasification products of natural gas or coal are used as a regenerator. Coal is used as a heat

source in liquid phase processes. The scheme of steel production from metallized product is shown in fig. 2 is presented.

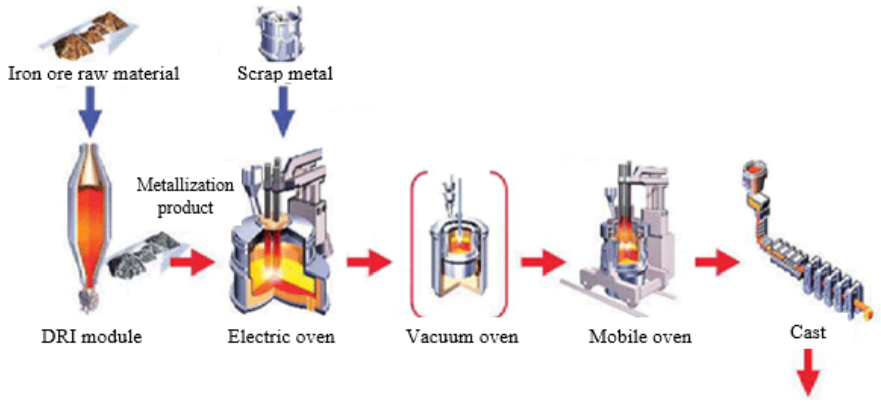

Figure 2. Scheme of steel production from metallized product

It should be noted that numerous ideas and various implementation schemes have created numerous names of processes and products of alternative metallurgy. Let's list the most used of them: DRI (Direct Reduced Iron), SI, SPI (Sponge Iron), HBI (Hot Brignetted Iron), HDRI (Hot Direct Reduced Iron), CDRI (Cold Direct Reduced Iron), etc. In general, the scheme of production of metallized products is shown in Fig. 3 is presented.

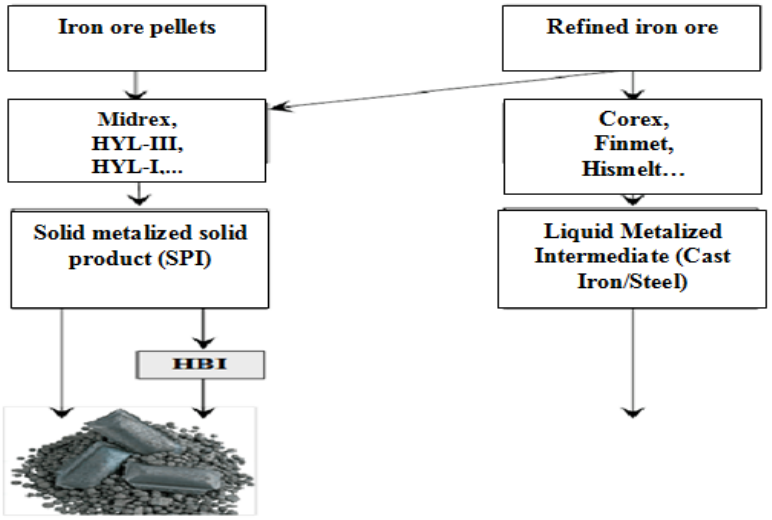

Figure 3. Scheme of metallized product production

Fig. 4 shows the development dynamics of direct iron reduction processes in the total volume of DRI production during 2005-2010: (https://trends.rbc.ru/trends/innovation).

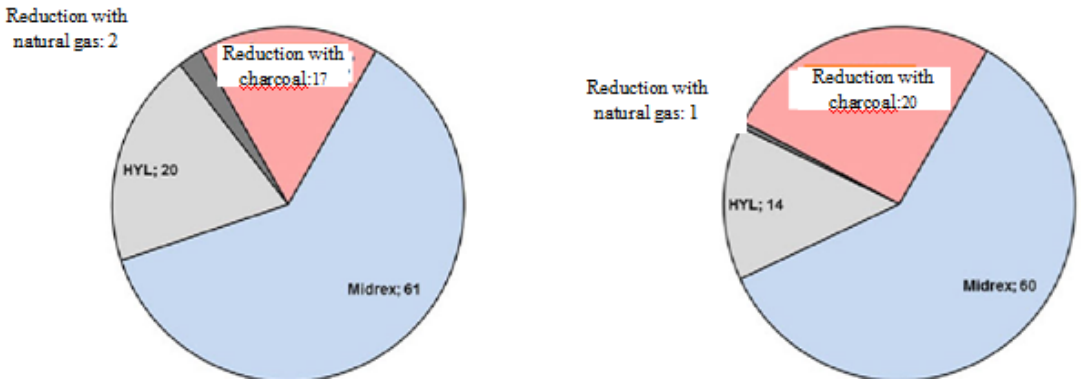

Figure 4. Development dynamics of DRI production

The technological scheme of the production of metallized products imposes certain requirements on the raw materials used and imposes some restrictions:

- the metallization process is carried out in counterflows of solid materials and gases;
- crushing of the two materials is required to improve gas permeability of the shale.

Thus, the main disadvantages of new metallized iron production processes are: low specific capacity of aggregates; the need to use high amounts of iron and low amounts of loose rock and mixed shale; high demand for energy carriers and oxygen; high requirements for storage and transportation conditions.

Non-furnace iron procurement facilities are mainly typical for developing countries (India, Venezuela, Iran, Mexico, Saudi Arabia) with small steel production and consumption. The dynamics of DRI production in a number of world countries are presented in the corresponding diagrams (Fig. 5 - Fig. 9).

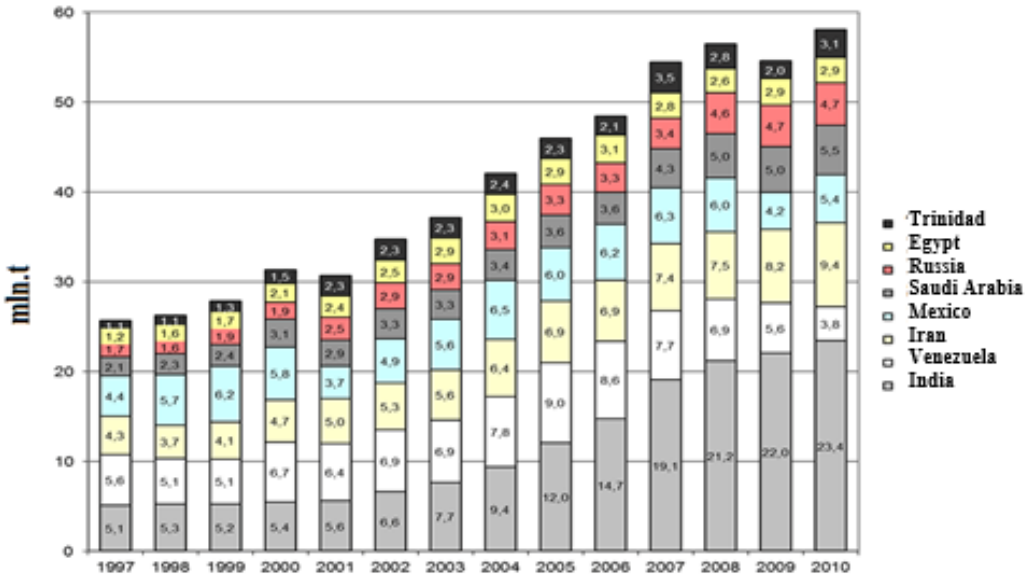

Figure 5. Dynamics of DRI production in a number of countries

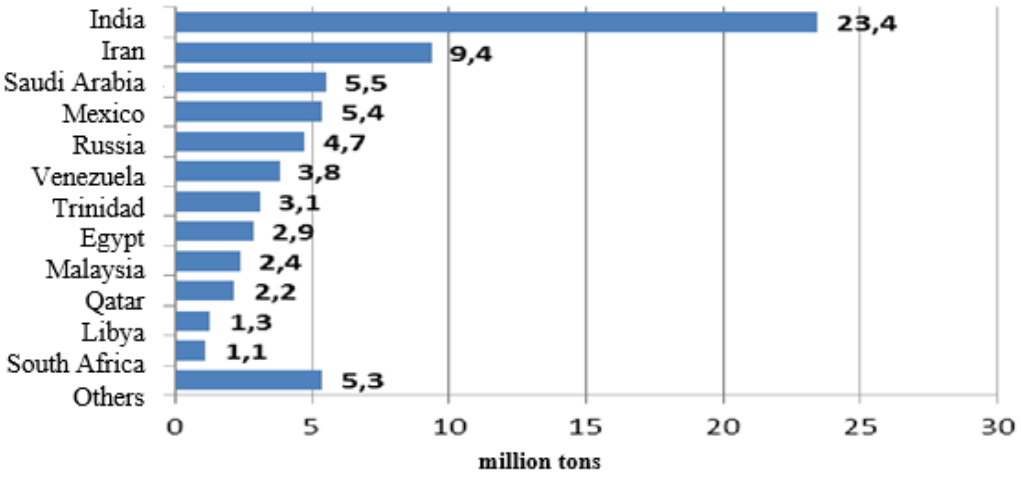

Figure 6. Production of DRI in some countries in 2010

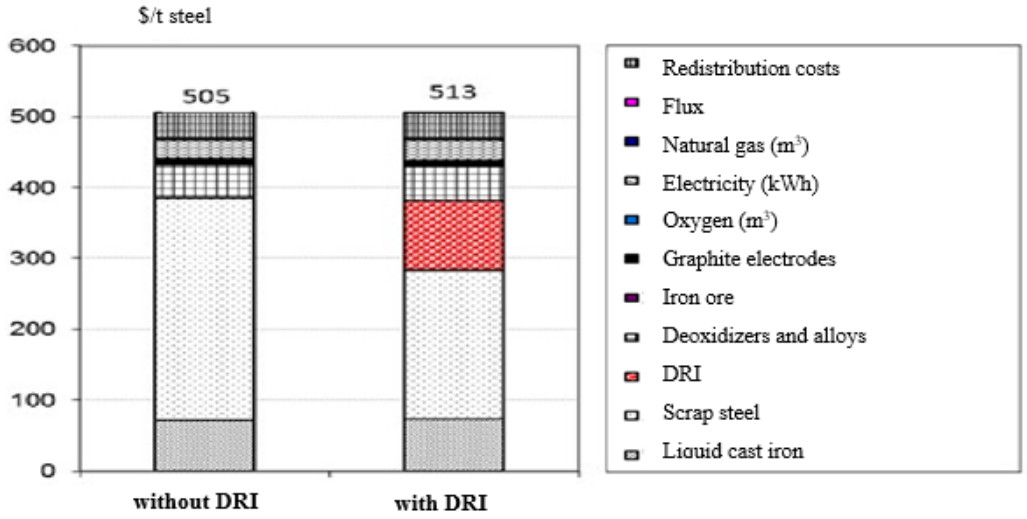

Figure 7. Cost of DRI production in the world

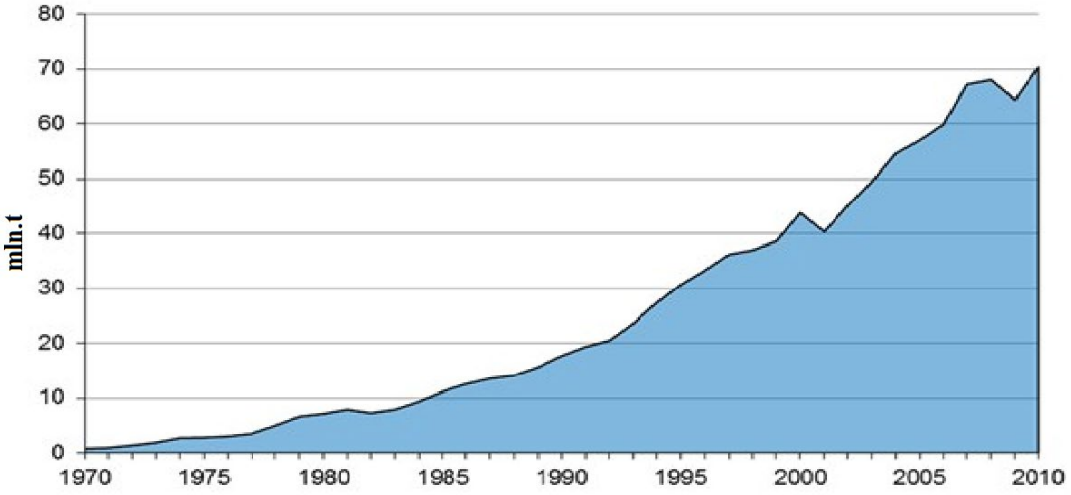

Figure 8. Volume of world trade of DRI by product types

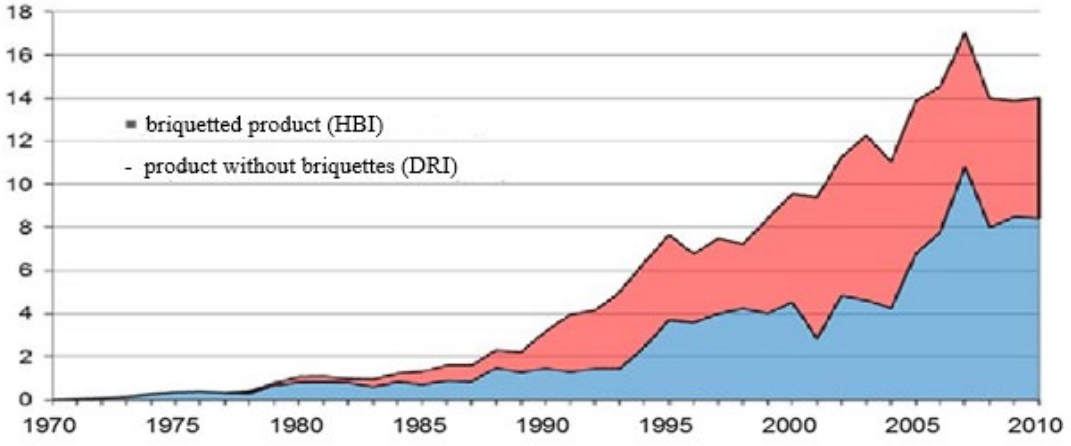

Figure 9. Transportation share of DRI production

It is clear that the main consumer of DRI is the production of electropolishing, because the share of DRI in the metallurgy can reach 70%. DRI has a number of advantages over other components of the system:

- stability of chemical composition; low sulfur and phosphorus;
- absence of elements prone to liquefaction (lead, copper); high spreading weight;
- the possibility of being fed to an electric furnace without stopping the melting process;
- protection of electrodes from mechanical damage.

The disadvantages of using DRI in electric furnaces are:

- increase in energy consumption (every 10% DRI: +15kW.s/t);
- increase in electrode consumption (every 10% DRI: +0.2 kg/t);
- reduction of healthy metal yield (every 10% DRI: - 0.4%);
- increase in thawing time (every 10% DRI: + 2.5 min);
- an increase in the heat load on the masonry of the furnace.

The pros and cons of DRI production and application are reflected in the price of DRI. Replacing 30% of scrap metal with similarly priced DRI increases steelmaking costs by about $8 per ton (Fig. 10). To ensure efficiency, the price of DRI should be ~7% lower than the price of high-quality scrap metal.

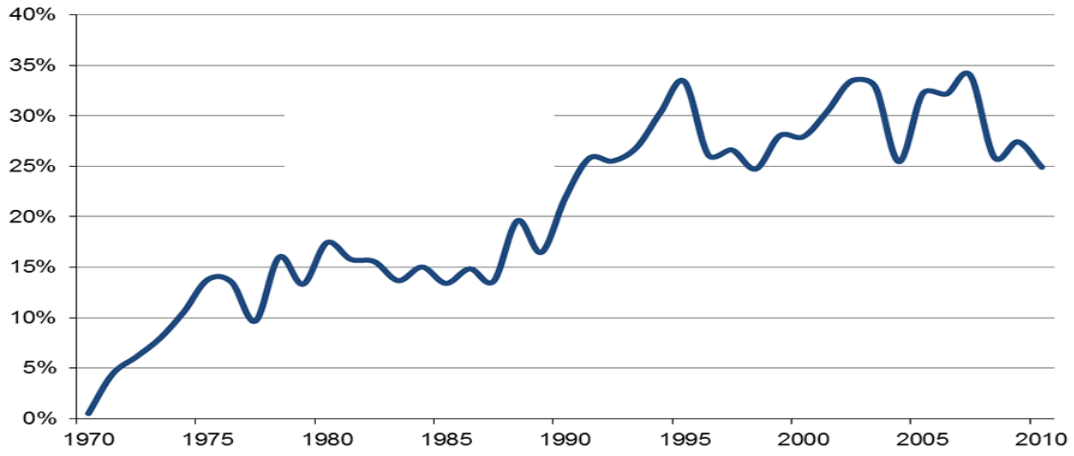

Figure 10. Cost of steel with and without DRI

The price dynamics of DRI and scrap metal in 2009-2012 is presented in fig. at 11:

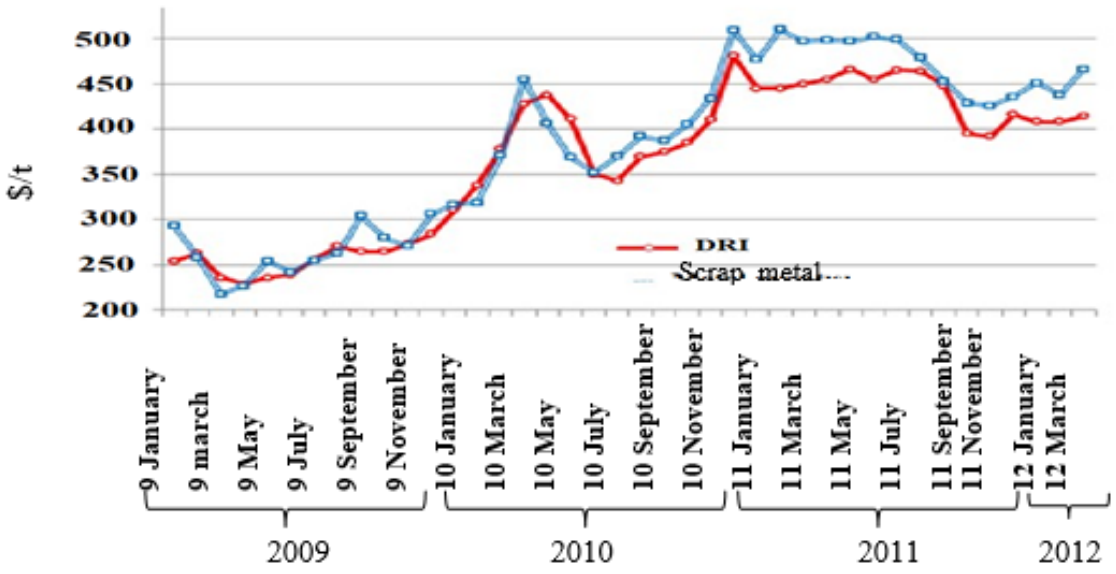

Figure 11. Price dynamics of DRI and metal scrap

[7] - in the "Metallurgical" scientific and technical bulletin, an analysis of the general trends of the development of the Russian and world metallurgical industry in the first quarter of 2023 was carried out. Factors affecting the results of the industrial sector were evaluated and forecasts for the upcoming period were given. It is noted in the bulletin that in 2023, the world prices of steel products continued to increase, but a certain decrease was observed against the background of the recovery of the Chinese economy.

The prices of non-ferrous metals and alloys are formed under the influence of fluctuations in the dollar exchange rate and the threat of a possible decrease in the growth of the world economy. World steel production decreased by 0.1% during the investigated period. However, China and India increased their production of steel products, but other countries saw a slight decrease. A bigger decline was seen in metallurgy in sister Turkey, and the main reason for this can be explained by the devastating earthquake in the south-east of the country.

Russian metallurgical production increased in the first quarter mainly due to non-ferrous metallurgical output, although ferrous metallurgical output decreased due to a sharp drop in exports. In non-ferrous metallurgy, there was an increase in the production volume of gold, silver and primary aluminum, copper and zinc, but a decrease in nickel production was observed due to repairs at "Norilsk Nickel" enterprises.

Despite the significant decrease in the production of large-diameter pipes in Russia, the production of steel pipes in general increased again at a record level. Experts believe that metallurgical production in 2023 may remain at the level of 2022, provided that the stability of the world economy is ensured.

In works [8-10], considerations were put forward about the future of Russian metallurgy. It is noted that in recent years the metallurgical industry in Russia has been developing and updating more actively than other sectors. New technologies and innovative solutions make it possible to improve product quality, increase production efficiency, and reduce production costs. The article focuses on the following recent innovations in Russian metallurgy.

1. Use of nanotechnologies in steel production. The use of nanoparticles in steel production processes is considered one of the most promising technologies. Nanoparticles make it possible to improve the important properties of metal, such as strength, corrosion resistance, and resistance to thermal effects.

2. Development of electrometallurgy. Electrometallurgy is characterized as a progressive technological process that opens wide opportunities for obtaining metals and alloys from their oxides and other by-products. In recent years, this technology has gained more popularity due to its undoubted advantages over the traditional blast furnace technology. The fact is that electro-metallurgy has the possibility to be applied in the production of rare metals and alloys that are difficult to obtain by traditional methods.

3. Application of new materials for construction and construction sector. Modern construction materials should be strong and light at the same time. One of the materials that meet such requirements is sandwich type composite steel. Sandwich-type composite steel consists of several layers of different materials, which make the steel strong as well as light. Composite steel also makes the product resistant to various types of corrosion and has sufficient longevity.

4. Development of new types of equipment for the metallurgical industry. Modern metallurgical equipment should be more efficient and easy to use. In this context, one of the last successful operations can be considered a device for automatic welding under high pressure. This

technology allows welding metal structures with high speed and precision.

Thus, the article concludes that despite all the difficulties, the development of Russian metallurgy continues. New technologies and innovative technical solutions make it possible to increase production efficiency, improve product quality and reduce production costs. Based on these trends, the metallurgical industry will continue to develop and will be able to maintain its position as one of the leading sectors in the country's economy.

In cases no. [11-14] (Black metals, 2022, №2, DOI 10.17580/chm.¬2022.02.13) trends and prospects in the market of ferrous metals are analyzed in the context of the impact of the world crisis. The article examines the current state of the world and Russian ferrous metal markets. Special attention is paid to the formation of the metallurgical product price. Research is based on statistical and comparative analysis, as well as rating and prognostic assessment methods.

It was determined that at the beginning of 2020, the main blow to the world metallurgical industry was the decrease in demand for metals and alloys against the background of the collapse of the economic activity of many states and entities within the framework of anti-coronavirus restrictions.

The reasons for the sudden increase in demand and prices in the market of ferrous metals in 2021 have been determined. The serious recovery of developed countries after lifting the lockdown in their economies, the implementation of long-term infrastructure projects, the shortage of metal resources in the world, the transition of the metallurgical industry to the "green" economy, etc. reasons are given. On the basis of established trends and expert opinions, perspectives of production, consumption and price formation in the market of metals, alloys and metal products were predicted.

In the article "Analysis of trends in the world metal complex in the post-pandemic era: ferrous and non-ferrous metallurgy" (Innovation and investment, No. 3, 2021), the following results were obtained [15-21]:

- the world steel market faced difficulties during the pandemic and showed a trend of decreasing production and consumption; however, the pandemic itself did not have a serious long-term negative impact on the field;
- the revival of the metallurgical market has already been observed in the second quarter of 2020, which can be mainly attributed to the gradual recovery of business activity in China;
- the restoration of economic activity in the fields of steel consumption has led to an increase in the price of metal products and demand for steel in the world market;
- cross-border restrictions have led to greater localization of a number of production and operations during the pandemic and post-pandemic period;
- the need for maximum protection of human resources has created an opportunity to optimize supply chains due to robotization, automation, remote control and electronic commerce.

Thus, unlike many other industries, the ferrous and non-ferrous metallurgy industry has been in a pre-crisis state since the second half of 2019. This situation was reflected in the decrease in demand and prices for basic metal products. Although the negative impact of the pandemic was significant, it did not have a dramatic negative impact on the field.

In the post-pandemic period, the field quickly recovered its potential, and the main indicators of the metal market showed stable growth. The management systems of metallurgical companies have undergone significant changes, which has created the basis for increasing the efficiency of adaptation to modern world realities for the long term.

In the article **“Analysis of trends of the world metallic complex in the period of post-**

pandemic recovery: black and non-ferrous metallurgy" by A.C. Kharlanov, published in issue No. 3 of 2021, interesting facts attract attention [17].

The article shows that as a result of the spread of the coronavirus infection, product production in the world metallurgical industry decreased in 2020 to 1,850 million in 2019. 1,799 million from t. t, partially restored in 2021 to 1,900 mln. t, and 1,988 million in 2022. t organized.

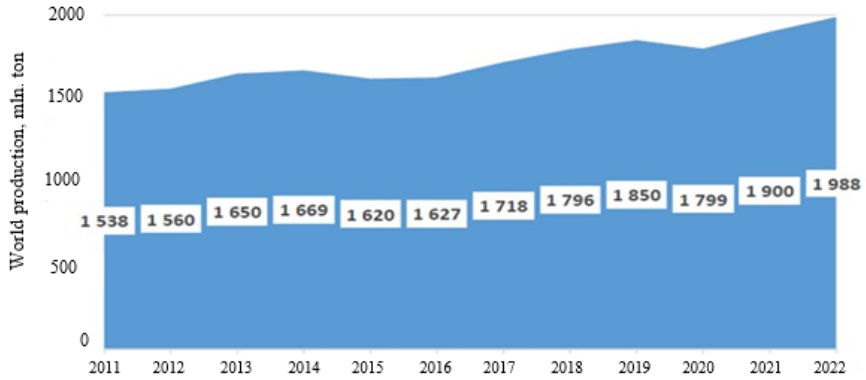

Figure 12. Dynamics of steel production in the world in 2011-2022

Fig. 12, the dynamics of steel production in the world in 2011-2022 is described based on the data of Worldsteel website. Fig. In the 13th, the dynamics of the annual growth of steel production in the world during the same period is presented. Fig. 14 shows the annual dynamics of world steel consumption in 2011-2022. Again, the dynamics of steel production and consumption in the world for that period is shown in fig. It was presented on the 15th. Fig. Figure 16 shows the dynamics of iron ore price changes in the world market in 2016-2023.

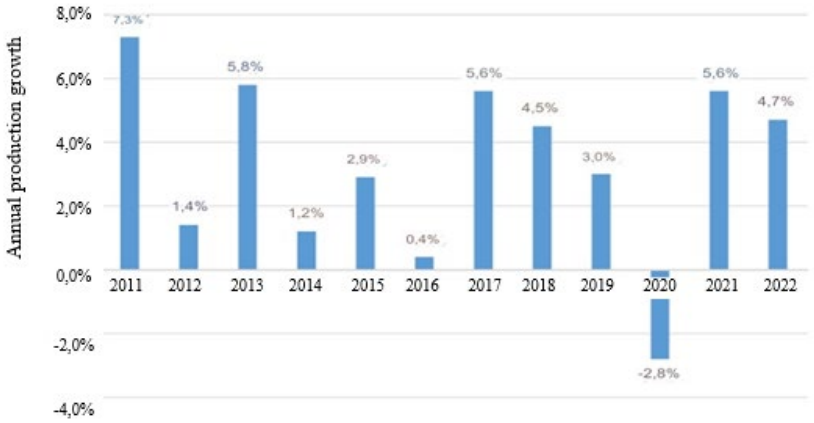

Figure 13. Dynamics of annual growth of steel production in the world in 2011-2022

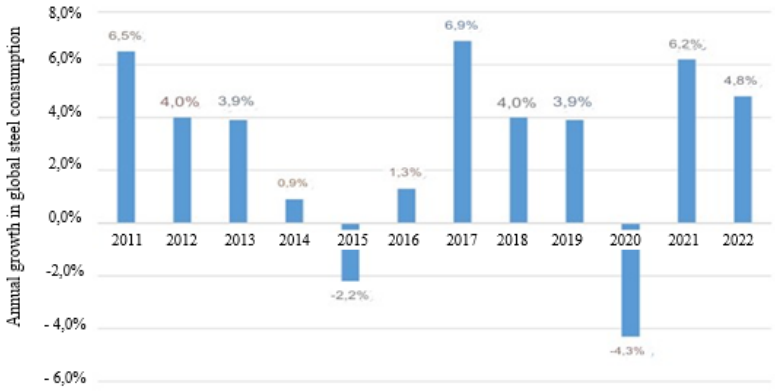

Figure 14. Annual dynamics of world steel consumption in 2011-2022

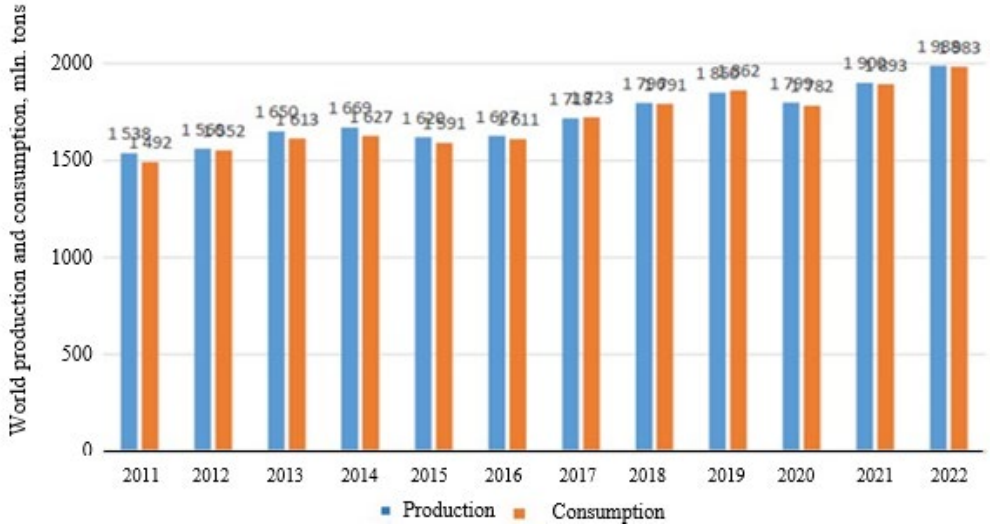

Figure 15. Steel production in the world in 2011-2022 and dynamics of consumption

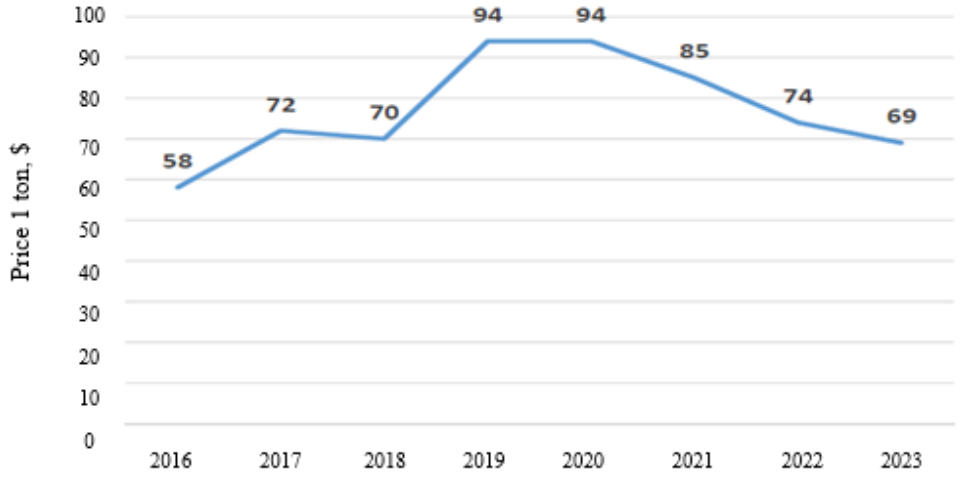

Figure 16. Iron ore on the world market in 2016-2023 price changes

Result.

1. The advanced methods of metallized iron production, which determine the growth dynamics of steel production in the world with the application of innovative technologies, have been analyzed, and their positive and negative aspects have been examined. It was determined that the purchase of non-blast iron can be considered effective mainly for the production of electrosteel. Therefore, the volume of metallized iron production increases at an increasing rate every year and contributes to steel production.

2. The modern state of the world's ferrous metallurgy was analyzed, new trends in steel production were determined under the conditions of globalization and new reality, tough competition and sanctions, as well as protectionist policy. The objective picture was evaluated based on the statistical indicators characterizing the state of metallurgical production in the world's leading countries. It has been shown that the development of ferrous metallurgy is characterized by the new reality of the modern world, constant change, geopolitical instability, constantly increasing tension and complexity.

Funding Acknowledgements.

This article was created under the support of the Azerbaijan Science Foundation - Grant No. AEF - MCG - 2023 - 1 (43) - 13(01)1-M-01.

REFERENCES

[1] Chebotarev Sergey, Korotchenko Anna. Metallurgy of the future: what awaits the industry in the era of the 4th industrial revolution // using the example of NLMK Company //up-pro.ru/strateg

[2] Review of the metallurgy industry for the 1st quarter of 2023 // Bulletin Metallurgy: trends and forecasts, RIA Rating, 2023, issue No. 50, rating@rian.ru

[3] Harlanov A.S. *Analysis of trends in the global metallurgical complex during the post-pandemic recovery period*. Economics and business, 76-83.

[4] *Development of electrometallurgy - ferrous and non-ferrous metallurgy*. metallome.ru

[5] Vladimir Safonov, Alexey Smirnov (DNTU). *Where are the leaders of electrometallurgy heading?* read-metal.com

[6] Budanov I.A. *Management of the Development of Metallurgy and the Global Metal Market*Studies on Russian Economic Development. 2020. Vol. 31, No.6. pp. 663–673.

[7] Zinovieva N.G. *Ferrous metallurgy of the world and Russia in a pandemic. Ferrous metallurgy.* Bulletin of scientific, technical and economic information. 2020. T. 76, № 7. pp. 657–664.

[8] *London Metal Exchange /LME - prices. Central metal portal of the Russian Federation.* URL: https://www/metallicheckiy-portal.ru/index-cen-lme (date of the application: 24.11.2021)

[9] *World Steel Association. World Steel in Figures.* URL: https://www.worldsteel.org/steel-by-topic/statistics/World-Steel-in Figures.html

[10] Tarnavsky V.V. *Chinese acceleration*. Metal supply and sales.2020. № 11. pp. 86

[11] Kaukin A. S., Kosarev V. S., Miller E. M. *Metallurgical industry in 2020 and early 2021. Monitoring the economic situation in Russia* // Trends and challenges of socio-economic development. 2021. T. 144, № 12. pp. 16–20.

[12] *Federal State Statistics Service (Rosstat).* URL: https://rosstat.gov.ru

[13] *The pace of economic recovery in Russia is accelerating.* Russian Economic Report (World Bank Group). 2021. No. 45. P. 88.
URL: https://www.vsemirnyjbank.org/ru/country/russia/publication/rer

[14] Adno Yu.L. *World metallurgy 2020: consequences and lessons of the pandemic*. Ferrous metals. 2021. No. 8. pp. 61–67.

[15] *"Russian Steel" - results of 2020: the situation in the industry*. Metals of Eurasia. 2021. No. 1. P. 4–5

[16]Tarnavsky V.V. *There would have been no happiness, but misfortune helped*. Metallosnabzhenie and sales. 2020. No. 12. P. 18

[17] Kharlanov A.S. *Analysis of trends in the global metal complex during the post-pandemic recovery period: ferrous and non-ferrous metallurgy*. Innovations and investments. 2021. No. 3. P. 76–83

[18] Bolotin M. *On the prospects of hydrogen metallurgy*. Metal supply and sales. 2021. No. 2. P. 86

[19] Fedoseev S.V., Tsvetkov P.S. *Key factors of public perception of carbon dioxide capture and disposal projects*. Notes of the Mining Institute. 2019. No. 237. P. 361–368

[20] Pei M. *SSAB is determined to take leadership in the global transition to "green" steel* . Metals of Eurasia. 2021. No. 4. P. 16,17.

[21] Rakhlis T.P., Skvortsova N.V., Koptyakova S.V., Balynskaya N.R. *Development of Microelectronics on the Circumstances of the Innovative and Technological Growth of the Russian Economy*. International Business Management. 2016. Vol. 10, Iss. 4. P. 401–407

Received: 13.01.2024
Accepted: 17.06.2024