Marketing, Manufacturing and Economics: The Foundation for the Competitiveness of a Modern Enterprise

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Abstract: The world market of rolled metal products has been analyzed, the competitiveness of PJSC "ArcelorMittal Kryvyi Rih" has been studied on it. It is concluded that entering new sales markets and stable development of an enterprise in a changing market environment is possible through the introduction of new technologies with minimal costs. A new parameter of the oxygen-converter process is proposed - the radiation temperature of the surface of the reaction zone. The use of this parameter will reduce the number of blows during steel smelting. The economic efficiency of the steelmaking process at a metallurgical enterprise is calculated. A logical relationship has been built between the defining links of modern metallurgical production - from marketing to economic feasibility, using the example of new methods of controlling the steelmaking process. A new mechanism for the efficient operation of a metallurgical enterprise has been developed, which is based not only on production elements, but also on the active involvement of marketing and economic solutions.

1 INTRODUCTION

In today's market conditions, metallurgical enterprises are very important for their successful operation not only to develop and implement new production technologies, but also to be able to present their developments, visualizing them on social networks, booklets and other media to increase potential consumer interest in their products.

Demand for steel is currently deteriorating sharply, particularly in China as a world leader in the metallurgical market, and prices for raw materials and finished products are falling. At the same time, China in 2022 intends to limit steel production to last year's level. It seems that the center of influence on the market has moved from the Asian region. Protectionism is strengthening and taking on new forms with the EU-US agreement. Large restrictions are to be expected, including on higher processed products.

REPAS's forecast for the situation in the last quarter of 2021 turned out to be true in terms of stability. There were many downtime in November and December. In 2022, new production facilities will appear on the market. It will be interesting to see how they find consumers in the face of increasing trade restrictions.

Given this, the purpose of this article is to study and analyze global trends in the ferrous metallurgy market, as well as to develop new integrated methods and marketing activities for the interaction of various departments of one enterprise.

The purpose of the article is revealed in the following tasks:

- to analyze the world market of rolled metal and determine the level of competitiveness of PJSC "ArcelorMittal Kryvyi Rih" on it;
- find new ways to implement the latest metallurgical technologies with minimal production and non-production costs;

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- calculate the economic efficiency of the steel production process at the metallurgical enterprise;
- on the basis of research results to build a logical connection between the defining links of modern metallurgical production – from marketing to economic feasibility;
- to develop a new mechanism for the effective operation of the metallurgical enterprise, which is based not only on production elements, but also on the active involvement of marketing and economic solutions.

The solution of the above tasks will allow to develop new mechanisms for the operation of a metallurgical enterprise, including the synergy of marketing and economics, in today's highly competitive environment can become an important element of effective interaction between the manufacturer and the end consumer.

2 MARKETING RESEARCH

We will conduct a brief marketing analysis of the modern world metallurgical market. Recent trends in global change (in particular, the events of 8-12 November 2021 and as a result – the agreement between the EU and the US on import quotas, the exclusion of European steel products and aluminum from the 25 % duty under section 232 of 1 January 2022) (Holappa, 2021) in the metal market have had a significant impact on the state of the global mining and metallurgical complex.

Interestingly, it was the United States that took the initiative in this agreement, as from December 2021 the EU planned to introduce a second package of measures in response to a total of 3.6 billion euros per year to compensate for losses from US customs tariffs in 2018. The first package worth a total of 3.6 billion euros a year was introduced in 2018, and the second was waiting for its time. And now, instead of a 25% duty, European plants will be able to supply products to the United States duty-free, but within quotas.

Among the points of the high-profile deal, it is important that Europeans offer Americans:

- refusal to introduce compensatory measures;
- refusal to appeal against tariffs in the WTO, including issues between Boeing and Airbus;
- long-term agreements on joint counteraction to surplus capacities in the world steel industry, as well as on promotion of decarbonization.

Such events, in turn, contribute to the desire of full-cycle enterprises to take appropriate measures, such as reducing emissions and expanding the production of electric steel, which is made possible by keeping scrap within their country, creating a scrap procurement business. Increasing the use of scrap and stimulating such a production path is the most affordable way for steel companies seeking to ensure vertical integration and occupy their niche in the scrap market.

Thus, according to (Kim, 2022) in the fall of 2021 in the US, manufacturers bought their own scrap companies in order to provide themselves with scrap, for example, BlueScope bought MelalX for $ 240 million, Cleveland Cliffs bought for $ 775 million Ferrous Processing and Trading Company (FPT) to continuously provide scrap resources for the operation of its planned expansion facility.

By collecting and processing 3 million tons of scrap per year, FPT earns $ 100 million. EBITDA per year. That is, the multipliers to EBITDA at the level of more than 7.0 in scrap harvesters are much higher than the average multiplier in steelmakers - 5.0. In addition, the case with MelalX is also interesting in that the sellers are the family of American businessmen Rifkin. They founded MelalX from scratch in 2012 with $ 1 billion in proceeds from the sale of the same OmniSource Corp scrap business to OmniSource Corp. Also, in the United States, the scrap procurement business is in high demand. Steelmakers are actively entering the upstream to provide themselves with raw materials, and entrepreneurs are operating on a business model suitable for replication and scaling.

According to the American media, in the United States, along with plans to reduce emissions and expand production of electric steel, there is an increased demand for scrap assets. In mid-2020, Steel Dynamics signed another agreement to buy a waste scrap company in Mexico - Zimmer, which processes 500 thousand tons of scrap per year. Active M&A processes take place within the procurement industry between operators. In general, it is natural that the most affordable way to reduce emissions now is to increase the use of scrap, as stimulating such a production path leads to vertical integration and participation in the scrap market, as discussed above.

Concerns about steel producers in the United States about providing their assets with scrap are due to the fact that they see for themselves the risks associated with possible increases in scrap prices, its deficit. For example, in China in the first half of 2021, scrap consumption increased by 47%. That is, in the United States, a region that is one of the largest exporters of scrap, steel producers fear possible difficulties with raw materials. The activity is not aimed at purchasing by iron ore raw materials assets or coal assets. Scrap becomes the central object of mergers and acquisitions.

A fateful decision to ban scrap exports may also be made in the EU in the near future. Demand for steel is weakening in these countries, so, for example, traders are trying to export g/k roll to Egypt to unload their warehouses.

Turkish producers fear that because of the agreement they will lose in competitiveness to European exporters, who have received a significant advantage in the form of the absence of a 25 % duty. Turkey buys scrap in the EU, ie loses in the cost of raw materials. Therefore, the Turks may lose their small exports to the United States.

By the way, Ukraine can lose in the segment of pipes on the American market, for which seamless pipes were the main export item to the United States. The issue of negotiations on Ukraine's exclusion from Section 232 was periodically raised, but this remained at the level of initiatives. It is advisable to intensify this direction, because the more countries conclude such agreements (Canada, Mexico, Brazil, Argentina, and now the EU), the greater the volume of exports will be lost by domestic producers.

At the same time, financial analysts trace the probable consequences of this trend of increasing demand for scrap assets, the most important of which is the inverse relationship between the role of steel companies in the scrap market and the supply of scrap to foreign markets. After all, producers have become interested primarily in providing themselves with their own raw materials, and only then - in sales to the free market and for export. At the same time, increasing the concentration and entry of steel companies into the scrap market in the long run will lead to a reduction in world trade in scrap. Now this trend is typical for the United States, but its occurrence is predicted in other regions (Kim, 2022).

According to (Holappa, 2021), in 2020 Europeans exported 2.4 million tons of steel products to the United States. The main export items were flat rolled products with coated and special alloys (about 1 million tons), as well as pipes (about 0.4 million tons). EU producers have previously received exemptions from Section 232. According to EUROFER, last year about 1 million tonnes of these 2.4 million tonnes fell under these exemptions. Therefore, quotas and exemptions together give the potential for exports of 4.3 million tons, which is 2 million tons higher than exports in 2020.

However, such trends are more theoretical than practical, because it is fundamental and strategically important to identify products that have the greatest potential for export. Thus, in 2017, European exports to the United States amounted to 4.5 million tons.

As a result of the introduction of section 232, exports from the EU to the US of long-term rolled products decreased the most - by 700 thousand tons. But these are less marginal products, European producers do not have special advantages over American ones. Therefore, opportunities to increase long-term rental exports to the United States are limited. While the export of flat rolled products with coating and special steel fell by 500 thousand tons, and the export of pipes - by 600 thousand tons. These segments have the greatest potential. However, there was a shortage of capacity in the flat-rolled segment in the EU this year. Therefore, the expected supply potential may remain open.

There are significant opportunities in the pipe segment, where investment in the oil and gas segment is expected to increase in the United States next year. That is, Europeans can increase their exports to the United States next year from 0.5 million tons to 1 million tons, which, in principle, a lot, but not critical for the American market. Americans do not agree to trade concessions for the sake of hype or PR - they clearly understand that such agreements will not harm their industry.

Returning to China, it should be noted a sharp decline:

- the cost of futures for iron ore on the Dalian Exchange, just for one week in mid-November - by $ 85.6 per ton, or 2.6 %;
- value of coking coal futures - up to $ 345, or 8.7 %;
- prices for finished steel products, namely, fittings - by 17 %, hot-rolled coil - by 14 %.

According to the forecasts of (Kim, 2022), the current negative trend will continue until the end of 2021, and steel production in China may show a further decline in the first quarter of 2022.

The Chinese Federation of Logistics and Procurement predicted that in November 2021 the steel market will continue to shrink. Production was constrained by environmental restrictions, which are traditionally introduced in the autumn-winter period to reduce air pollution. In conditions of lower temperatures, there was a seasonal decrease in demand for steel for construction work. At the same time, enterprises are very cautious about the prospects for economic development: the index of productive business activity fell by 10.3 percentage points. relative to the previous month (up to 46.1%). That is, we see a tendency to slow down.

The federation expects raw material prices to fall: with the resumption of supply, coal prices have returned to a reasonable level, and iron ore prices may re-enter the downward trend amid declining domestic demand. Under the influence of demand in the southern regions of China, steel prices may rise in the first half of January 2022, but with worsening weather conditions, demand will weaken, and in the second half of the month prices will fall.

In addition, China is an important source of demand for semi-finished products, due to increased control over the dynamics of steel production, even using the method of re-exporting previously imported semi-finished products to Southeast Asia.

At the same time, we observe a reduction in demand for iron ore, which caused it to fall in price from mid-October to mid-November 2021 by 21 % (Kim, 2022).

Instead, the price of coal was constant due to the shortage of its supply on the market. However, experts predict a rapid fall in prices in the future due to the collapse of steel production in China and abroad. At the same time, along with coal, there will be a new wave of falling steel prices around the world.

With regard to fittings, it should be noted that the International Association of Manufacturers and Exporters of Fittings (IREPAS) (Kim, 2022) notes the balance of supply and demand in the global long-term rental market, as well as the willingness of manufacturers to ensure timely delivery. Demand in Europe and North America is strong, stocks are actively replenished after depletion. It is expected that active demand will continue in 2022 due to steady growth in investment.

However, one should also take into account such a deterrent to the development of international trade as high freight rates. Every contract signed in the second quarter now has high transportation costs, which nullify profits. Given this fact and rising scrap prices, long-term rental prices in the US market can be expected to remain high in the first quarter of next year.

The intensification of the process of introduction of decarbonization of metallurgical production testifies to the awareness of the fact that a "revolution" of technologies is imminent in the world metallurgy.

According to the British center "Agora", by 2030 71 % of blast furnaces in the world will be decommissioned or will need to replace the lining. This creates opportunities for large-scale transformation of the industry during this period and the replacement of blast furnace production with other technologies, in particular the production of direct reduction iron (DRI) (Holappa, 2021). Agora estimates that 40 million tons of green DRI (hydrogen-assisted) capacity will be built by 2030, while companies are barely investing in industrial-scale CO2 capture and disposal technologies (there are only pilot plants, such as within the project "Hisarna on Tata Steel").

The prioritization of hydrogen technologies is due to the fact that they completely prevent CO2 emissions at the stage of production, while capture projects are already struggling with the consequences and, in addition, there are several complex problems with the capture of captured CO2:

- incomplete availability of natural reservoirs suitable for CO2 storage;
- the need to take into account which products are made from captured carbon dioxide. If in the process of using these products CO2 is released into the atmosphere again, the feasibility of such utilization of carbon dioxide is questionable.

We are even aware of the fact that in the future there will be a gap in the pace of decarbonization of metallurgy in developed and developing countries. The majority of projects are being implemented or will be implemented in the former as not only having cheap sources of funding and technology development centers, but also creating infrastructure and implementing appropriate government policies to promote decarbonisation.

ArcelorMittal, the world's largest steelmaker, recorded a net profit of $ 4.6 billion in its financial report published on the company's website (https://ukraine.arcelormittal.com/?lang=en) in the third quarter of 2021. This is a record figure since 2008. In the third quarter of 2020, the company received a net loss of UAH 261 million. Compared to the second quarter of 2021, ArcelorMittal increased its net profit by 15 % in the third quarter of 2021. Management explains these results for the third quarter by the successful maintenance of strong price conditions, which led to the highest net profit and the lowest net debt since 2008.

ArcelorMittal's revenue in July-September 2021 increased by almost half compared to the third quarter of 2020 - to 20.2 billion dollars.

The company's EBITDA (net income before taxes and depreciation) in the third quarter of 2021 amounted to 6.058 billion dollars. In July-September 2020, the figure was UAH 901 million.

Operating profit in the third quarter of 2021 amounted to 5.3 billion dollars, in the third quarter of 2020 - 718 million dollars.

As of the end of September 2021, ArcelorMittal's net debt fell to $ 3.9 billion of $ 5 billion as of the end of the second quarter of 2021.

Despite the corporation's financial success, we are also seeing a reduction in steel volumes. Thus, ArcelorMittal in the third quarter of 2021 reduced steel shipments by 19.8 % compared to the third quarter of 2020 - to 14.6 million tons. The corporation-maintained steel production at last year's level - 17.2 million tons. Iron ore production in three months decreased by 13.8 % to 13 million tons.

As you know, ArcelorMittal is the world's leading steel and mining company with a presence in 60 countries and production assets in 18 countries. According to the results of 2020, the steel giant reduced steel production by 20.3 % compared to 2019 - to 71.5 million tons (Lehenchuk, 2021).

As we can see, the autumn of 2021 turned out to be difficult for metallurgists: the world industry is reducing production and Ukraine is no exception.

In September 2021, the volume of steel smelting by domestic enterprises decreased by 8.4 % compared to August 2021. The same trend was observed in October. According to (Holappa, 2021), steel production in October fell by another 5.8 % m/m. That is, the negative dynamics relative to August is minus 13.6 %.

Among the main reasons is the 45-day suspension for the repair of the largest blast furnace №9 at PJSC ArcelorMittal Kryvyi Rih. There is also a shortage of coke due to problems with coal supplies, especially local. According to the Ukrkoks association, production restrictions related to coal and coke shortages persisted in November-December 2021.

In November 2021, the situation did not improve significantly. The №9 blast furnace was still under repair. The problem with coke did not go away. Some improvements did not appear until December 2021. At the end of September 2021, there was a certain rebound in prices and, consequently, an increase in demand in December. But in the new 2022, the market will face a new challenge - a shock to demand under the influence of high energy prices and a gradual strengthening of monetary policy of central banks.

PJSC "ArcelorMittal Kryvyi Rih" is a full-cycle metallurgical enterprise, part of the ArcelorMittal group. The plant covers the entire production cycle - from iron ore mining and coke production to the manufacture of finished metal products. The company produces semi-finished products, as well as high-quality and shaped products.

Examining the features and results of PJSC "ArcelorMittal Kryvyi Rih" for 2019-2021, it should be noted that PJSC "ArcelorMittal Kryvyi Rih" in January-October 2021 increased iron production by 13.9 % compared to the same period last year - up to 4.57 million tons (Chaika, 2021).

During this period, rolled production increased by 5.4 % compared to January-October 2020 - up to 3.9 million tons, steel smelting - by 8.9 %, to 4.17 million tons. In October, the plant produced 400 thousand tons of rolled products, 410 thousand tons of steel and 405 thousand tons of pig iron.

However, in 2020 PJSC "ArcelorMittal Kryvyi Rih" reduced the production of rolled products by 7.6 % compared to 2019 - to 4.3 million tons. Steel production for the year fell by 12.1% to 4.7 million. tons, and cast iron - by 6.9% to 4.9 million tons.

Negative dynamics in the sphere of production is also connected with the growth of energy prices and the state's attempts to control energy consumption (these factors affected both producers and consumers). The decline in exports was influenced by the decline in domestic steel production, as well as the resumption of production abroad.

3 ANALYSES OF PREVIOUS STUDIES

Currently, specialists of the State University of Economics and Technology with scientists from other educational institutions of Ukraine are working on a comprehensive improvement of metallurgical processes, ranging from technologies for coke (Kormer, 2021) and metallurgical raw materials (Zhuravlev, 2021) to environmental issues (Radovenchyk, 2021). However, a special role in improving the work of metallurgical production are the processes of steel smelting.

Currently, the technological process of converter melting is corrected by the total oxygen consumption, as well as the data obtained during the "rolling" of the converter in order to take a sample of metal for carbon content and measure its temperature (Tanzer, 2021). The number of such "rolls" of the converter can reach two, three or more times, which negatively affects the performance of the converter, temperature losses of metal and slag, slag thickening and other disorders of converter melting (Rout, 2018; Li, 2021). The experience of industrialized countries, in particular Japan, shows that the melting in the required chemical analysis and temperature is 99.8% without the implementation of "rolling" the converter and corrective "additional" (Brämming, 2016).

It is possible to predict the time of completion of the oxygen purge of the converter smelting and to monitor the course of its main processes on the basis of real-time calculation (during melting) of the melt temperature (reaction zone) (Mason, 2020; Kumar, 2016). The temperature of the melt (reaction zone) is easy to determine from the equations of the balance of heat (Liu, 2019; Arnu, 2017; Zhou, 2017; Sohn, 2019; Rieger, 2020; Zhu, 2020; Florén, 2019; Manabe, 2019; Madhavan, 2021) radiated by the hemisphere of the reaction zone to the water-cooled oxygen lance and the heat removed from the oxygen lance by water.

4 RESULTS OF THE STUDY

To calculate the temperature of the melt, input information is required: about the water temperature, its flow rate and pressure at the inlet and outlet of the oxygen lance; temperature, flow rate and pressure of injected oxygen. The mathematical model for calculating the melt temperature introduces information about the position of the oxygen lance, raw materials, molten steel grade, as well as chemical analysis of metal samples and direct temperature measurement during the "rolling" of the converter.

Using a mathematical model, the current temperature (during melting) of the reaction zone (Trz) of the metal is calculated and the dependence Tr.z. of time. Changes in the temperature of the reaction zone during melting characterize the processes occurring in the bath of the converter. Analysis of the obtained dependence in real time allows us to quickly predict the end of oxidation [Si] and [Mn], the content of [C] in the melt. In addition, the thermal energy of radiation in different periods of melting is predicted to adjust the flow of injected oxygen during melting, the need to adjust the position of the oxygen lance relative to the metal, and most importantly, you can predict with high reliability the end of purge.

The technological means of the automation system implementing the developed model include sensors of temperature, flow, water and oxygen pressure, lance position, means of communication with ACS TP converter smelting, control and workstation control, as well as a set of algorithms and programs.

The algorithm for calculating the current temperature of the reaction zone (Tr.z.) during melting is based on the consideration of the melt as an energy emitter. Thus, when purging the melt in the converter with technical oxygen through a multi-nozzle lance, the surface of the steel melt is a sphere of radiation with a high temperature, the temperature of the reaction zone (Tr. z.). This temperature is analytically related to the metal temperature (Tm).

The flow of electromagnetic radiation from the sphere of the reaction zone through the space of hot gases (blackness coefficient 0.8-0.9) falls on the surface of the water-cooled lance (technical oxygen is injected through the lance), and consumption, pressure, temperature and O2 content may vary. as well as changes the position of the lance in different periods of melting).

The energy of radiation from the surface of the reaction zone obeys the Stefan-Boltzmann law:

$$E = \boldsymbol{\varepsilon} \cdot C \cdot (T/100)^4,\ W/cm^2, \qquad (1)$$

where ε - is the blackness coefficient (0.8-0.9), C is the radiation coefficient of the absolute body 5.68 W/cm2·K4, T is the temperature of the radiating surface, K.

The power (P) of radiation incident on an oxygen lance with a surface area (Sf) will be:

$$P = E \cdot S_f = S_f \cdot \varepsilon \cdot C \cdot (T/100)^4,\ W \qquad (2)$$

The power of the energy obtained by water (Pw) cooling the lance from the flow of energy radiated by the surface of the reaction zone can be estimated by the formula:

$$Pw = V \cdot (\rho 2 \cdot h2 - \square 1 \cdot h1),\ kW, \qquad (3)$$

where V is the volume of water cooling the lance per unit time, m3; ρ2 - density of water, kg/m3 at a temperature of T2 at the outlet of the lance; ρ1 - density of water, kg/m3 at a temperature of T1 at the entrance to the lance; h1 - specific heat of water, J/(kg·°K), at a temperature of T1 at the entrance to the lance; h2 - specific heat of water, J/(kg·°K), at a temperature of T2 at the outlet of the lance.

The given values of water parameters are calculated from measurements of temperatures T1 and T2, pressure and water flow.

The cooling effect of oxygen blown through the lance is taken into account by a factor of k1, and the effect of the distance from the lance to the surface of the reaction zone by a factor of k2, (lance position).

As a result, the energy power obtained by cooling water, taking into account the effect of oxygen purge through the lance and its position relative to the surface of the reaction zone (measured oxygen flow, pressure and temperature, and the lance distance to the melt surface) will be:

$$Pw = k1 \cdot k2 \cdot V \cdot (\rho 2 \cdot h2 - \rho 1 \cdot h1) \cdot 103\ ,\ W, \qquad (4)$$

The power of the flow falling on the surface of the lance is compared with the power obtained by cooling the lance with water:

$$P = P_w = S_f \cdot \varepsilon \cdot C \cdot (T/100)^4 = k_1 \cdot k_2 \cdot V \cdot (\rho_2 \cdot h_2 - \rho_1 \cdot h_1) \cdot 10^3,\ W, \quad (5)$$

where from

$$(T_{rz}/100)^4 = (k_1 \cdot k_2 \cdot V \cdot (\rho_2 \cdot h_2 - \rho_1 \cdot h_1) \cdot 10^3)/S_f \cdot \varepsilon \cdot C, \quad (6)$$

$$T_{rz}^4 = (10^3 \cdot 10^8 \cdot k_1 \cdot k_2 \cdot V \cdot (\rho_2 \cdot h_2 - \rho_1 \cdot h_1))/S_f \cdot \varepsilon \cdot C, \quad (7)$$

then the temperature of the reaction zone will be:

$$T_{rz} = \sqrt[4]{10^{11} \cdot k_1 \cdot k_2 \cdot V} \cdot \sqrt[4]{(\rho_2 \cdot h_2 - \rho_1 \cdot h_1)/S_f \cdot \varepsilon \cdot C},\ K. \quad (8)$$

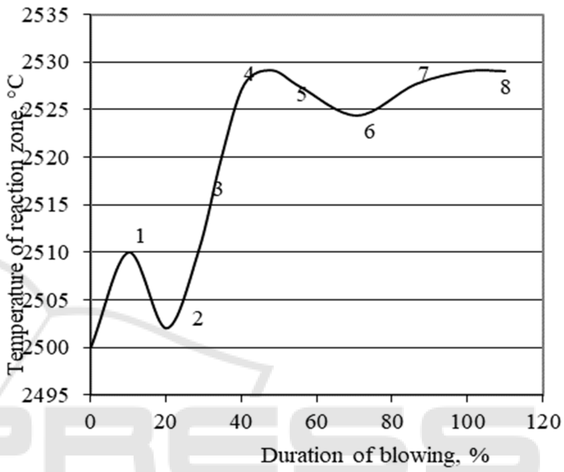
Thus, by measuring the heat flux obtained by cooling water and introducing correction factors for oxygen consumption and lance position, it is possible to calculate the current temperature of the radiating surface of the reaction zone using a computational algorithm, which allows to have a new process parameter throughout the melting time.

Connections Tr.z. with technological parameters of converter smelting installed in the oxygen-converter shop "ArcelorMittal Krivoy Rog".

It was found that the temperature of the reaction zone Tr.z. reflects its changes in different periods of melting technological processes in the converter (Fig. 1):

- the temperature of the steel melt Tsm and the temperature difference ΔT = Tr.z. – Tsm;
- the first maximum ΔT reflects the intense course of the oxidation reaction Fe in the reaction zone with weak heat dissipation due to poor mixing of the bath and low rate of carbon oxidation - VC;
- the next rise in ΔT is associated with the active oxidation of [Si] and [Mn], which oxidize more actively than [C], and as their content decreases, the bath overheats weakens;
- the completion of the oxidation of [Si] and [Mn] creates the preconditions for less active [C] to combine with O2 under favorable external conditions (high temperature), to stir the bath more intensively and remove heat, reducing ΔT;
- after the intensification of endothermic processes due to Fe oxides in the slag there is a new rise ΔT;
- after decreasing the concentration [C], its oxidation rate VC decreases, the mixing of the bath with the formed CO decreases and the growth of Tr.z. with a rate (2-3 °C) per minute with its final stabilization; then Tsm increases, and ΔT decreases with constancy Tr.z.;
- temperature difference ΔT = Tr.z.-Tsm allows you to predict the change in the content of [C] in the melt from its second maximum (there are experimental dependencies that need to be adapted to the conditions of the shop and empirical dependencies, for example:

$$(\Delta T/100)^2 = 10(5 + 4[C] - [C]^2). \quad (9)$$



1 - intense oxidation of Fe with weak stirring, 2 - the beginning of active oxidation of [Mn] and [Si], 3 - endothermic processes of Fe oxides in the slag, 4 - growth retardation due to active stirring of the bath, 5 - fall due to reduction [C], 6 - deterioration of mixing, 7 - temperature increase by 2-3 ° C, 8 - temperature stabilization

Figure 1: Change in the temperature of the reaction zone during different melting periods in the converter.

It should be noted that after the second maximum ΔT there is an accumulation of O2 in the melt and oxidation [C] there are periods when the amount of carbon monoxide formed exceeds stoichiometrically possible, based on oxygen consumption in the melt bath (these ratios can be calculated), due to excess oxidation melt.

This situation can be calculated and influenced by the gas-blowing mode to reduce the supply of oxygen to the melt to reduce the oxidation of steel and reduce deoxidizer consumption when casting steel or provide for the replacement of oxygen with air without compromising bath mixing.

The efficiency of control over the steel smelting process will be higher with the use of additional compensatory measures to reduce the likelihood of overfilling (Chuprinov, 2021) - the use of limestone in the amount of 130-140 kg/t of pig iron in the case of the latter, the addition of coolant in the form of ground coke in the amount of 120 kg/t scrap when using it, as well as overheating of the metal by 20-30 °C in the case of an oxygen converter on the "goat" scrap.

5 ECONOMIC JUSTIFICATIONS

An important stage of any research process, including the process of improving metallurgical technologies, is to understand, formulate and justify the factors that determine the economic efficiency of decisions.

In particular, one of the determining factors that led to the expediency of eliminating the addition of steel is a significant saving of time spent on one smelting of steel. Thus, if the duration of one melting is considered to be 53-54 minutes, then due to the elimination of the last stage of melting - supplementation, the duration of which is 3-4 minutes, it becomes possible to achieve one melting lasting 50 minutes.

In metallurgical practice it is known that in the conditions of standard smelting of steel (with the stage of supplementation) with an approximate duration of 54 minutes for one smelting one converter is capable to smelt 140 tons of steel. Accordingly, for the day under this scheme is 26.6 smelts and can be obtained 3724 tons of steel.

If you consider the option of smelting without supercharging (lasting 50 minutes), then in a day it is possible to carry out 28.8 smelting of steel under this scheme, ie to smelt 4032 tons of steel.

Determining the volume of steel smelting with/without taking into account the finishing process makes it possible to estimate the change in the daily volume of steel smelting by one converter by reducing the time spent on additional welding. This can be calculated by the following formula:

$$K_{sp} = \frac{V_2}{V_1}, \qquad (10)$$

where K_{sp} - growth rate of steel smelting one converter per day;

V_1 - daily volume of steel smelting by one converter (3724 t),

V_2 - daily volume of steel smelting as one converter as a result of technological change, in particular, avoidance of the additional process (4032 tons).

Also, the growth rate of steel smelting per converter per day will be:

$$K_{sp} = \frac{4032}{3724} = 1{,}0827$$

If we talk about the absolute changes in achieving economic efficiency of our proposed measures, it is advisable to calculate the amount of additional steelmaking. Thus, in one day, provided that the additional process is avoided, one converter will make it possible to obtain the following increase in the volume of steel:

$$\Delta V = V_2 - V_1, \qquad (11)$$

where ΔV is the daily increase in steel volume.

That is:

$$\Delta V = 4032 - 3724 = 308 \text{ (t)}.$$

Given that the use of specially adapted to the described process of steel smelting mathematical models, we managed at the stage of chemical analysis of the sample to obtain a 50 percent quality result of the chemical composition of steel, for greater accuracy of further calculation of additional profits. twice less than expected, ie 154 tons.

Since, as mentioned above, according to the standard scheme of smelting, the size of the daily volume of steel smelting is 140 tons, it turns out that in the conditions of smelting without refueling for each subsequent smelting is an additional 14 tons of steel.

As a rule, 5 converters work in the converter shop of PJSC "ArcelorMittal Kryvyi Rih" at the same time, so the daily increase in steel smelting in the whole shop (ΔV_c) due to our proposals will be:

$$\Delta V_c = 154 \cdot 5 = 770 \text{ (t)}.$$

Knowing the value of the average market value of steel (Bm = 7000 UAH.), It is easy to determine the amount of additional profit of the shop per day (GP) as a result of the implementation of measures:

$$\Delta \Pi = B_m \cdot \Delta V_c, \qquad (12)$$

or

$$\Delta P = \text{UAH } 7{,}000 \cdot 770 = 5{,}390{,}000 \text{ (UAH)}.$$

Thus, due to the elimination of the additional stage of the steel smelting process, which, in turn, reduces the time of one smelting, it becomes possible to achieve economic efficiency of our proposed measures, as the daily profit increase of converter shop PJSC "ArcelorMittal Kryvyi Rih" will be 5.39 million. UAH.

6 CONCLUSIONS

1. The results of marketing research show that against the background of the extremely difficult situation on the world metallurgical market and its unstable situation, PJSC "ArcelorMittal Kryvyi Rih" needs to apply the latest approaches to increase its competitiveness, one of which should be a comprehensive approach. combining efforts and results from marketing and production activities of the enterprise.

2. Application of mathematical model and system of automatic control of melting on the basis of operative control of change of temperature of reaction zone will allow to reduce time on "rolls" of the oxygen converter at reception of steel with the set characteristics, and also to reduce melting duration by 2-3 minutes (to 4%). In addition, the use of additional compensating mechanisms developed earlier (Mason, 2020) will significantly increase the economic efficiency of the steelmaking process in the converter shop

3. Coefficient analysis and economic assessment of changes in the daily volume of steel smelting by one converter by reducing the cost of additional time, as well as the use of specially adapted to the described process of steel smelting mathematical models allowed to obtain 154 tons of steel as a daily increase in steel t more than in the standard scheme of melting. This, in turn, in the scale of the converter shop of PJSC "ArcelorMittal Kryvyi Rih" with five converters allowed us to achieve economic efficiency from the measures proposed to us, namely, to receive UAH 5.39 million. additional profit of the shop.

4. It should be noted that in the article the authors managed to fulfill all the tasks set at the beginning from the standpoint of innovation. So, for the first time, an innovative approach to organizing the work of a metallurgical enterprise is proposed, which is based on close cooperation of important processes - marketing, production and sales. This approach is based on the invention of new ways of implementing the latest metallurgical technologies with minimal production and non-production costs, which allowed to increase the level of economic efficiency of the steel production process at the metallurgical enterprise. Also, the newly developed production, economic and marketing mechanism of efficient operation of the metallurgical enterprise allowed to build a logical connection between the defining links of modern metallurgical production - from marketing to economic efficiency.

5. The solutions developed in the technological part were included in the automation equipment for the oxygen-converter shop of AMKR. Models based on 500 heats of various steel grades have allowed technologists to introduce new methods of process control, thereby increasing the efficiency of the steel shop. To date, the elements of the presented study have already been introduced into the production process control scheme of the steelmaking department.

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