The problem of efficiency of use of iron ores reserves, its role in project management of development of iron ore deposits on the basis of computer optimization model of their budget

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Abstract
The core of problem of ensuring efficiency of use of iron ore reserves and the reason of its emergence under operating conditions of iron ore and mining industry of Ukraine are considered in the paper. Definition of this concept is given, features of this problem manifestation at further development of iron ores exploitation in Ukraine are considered, the development parameters optimization approach, which provides achievement of necessary level of efficiency of iron ore reserves use, is described and implemented in the form of computer optimization economic-mathematical model. This approach gives the opportunity to determine the best parameters of development by economic criteria, plays the core role in project management of iron ore deposits development in terms of optimization of their budget.
Key words: COMMERCIAL EFFICIENCY, RESERVE USE, PROJECT MANAGEMENT, COMPUTER MODEL

Problem statement

Iron ore and mining industry represent one the most important components of Ukraine economy. Products of this industry (concentrate, pellets, sinter, blast-furnace ore) are 10-12% of gross domestic product of country. About 60% of these products are consumed by domestic metallurgical enterprises, and 40% are exported to the foreign markets. By production volume this industry lies in the 7th place in the world among 16 leading countries of iron ore and mining production [1].

Large scale of productive activity of this industry is provided with considerable iron ore reserves of industrial categories. Now these reserves constitute

31.9 billion tones those are 14.46% of the world's reserves. Ukraine lies in the second place in the world by amount of these reserves.

Along with that, it should be noted that availability of such natural resources does not provide proper economic benefit for any country which possess them. The corresponding benefit can be obtained only under condition if this resource is effectively used.

For the mining companies of Ukraine, proper use of iron ore reserves is relevant problem. This is due to the fact that in Ukraine development of iron ores is carried out under conditions of increased complexity (by shapes of ore deposits, their morphology, depth, geomechanics). Consequently, owing to a number of the technological, technical and organizational reasons, development of iron ores is characterized by incomplete use of economic potential provided by reserves [2], that is considerable losses of this resource value in case of its development and processing into marketable iron ore products take place. The amount of these losses is up to 15-25% of gross value of ore reserves and sometimes even much more. It causes significant economic damage to mining companies and country in general which provides the corresponding reserves to the company [3].

Analysis of last researches and publications

Many famous scientists in the field of economy, technology and organization of mining production were engaged in the problem resolution of ensuring economic efficiency of use of ore reserves. They are G.M. Malakhov, M.I. Agoshkov, V.A. Shestakov, A.A. Shershov, S.Ye. Nikulin, P.I. Gorodetskyi, D.S. Kutuzov, A.S. Astakhov, L.V. Kryzhov, B.N. Baikov, V.S. Luchko, S.Ya. Rachkovskyi and other. However, papers of these authors are involved almost in development of technical and technological solutions on increase of ore reserves use efficiency. At that, determination of value of effect, which is achieved in case of their application, has been carried out only within that technological process where they are used. They did not consider complex nature of process of mining production where all its constituents (technological processes) are interdependent and interconnected by complex technological, organizational and commercial communications. It often leads to emergence of situation when obtaining of certain positive effect at one of stages of production cycle at the mining company can be followed by absolutely different results at the second stage. Consequently, economic result, which was expected, is not achieved. For example, it can be observed when the aspiration to obtain maximum extraction of ore reserves in case of its removing from extraction space can result in necessity of performance of considerable amounts of drilling and blasting operations with the corresponding increase of financial expenses for breaking and be followed by increased ore pollution with gangue material that in economic dimension is not compensated by increase of reserves extraction degree.

As a result of described situation, the problem of economic efficient use of iron ore reserves and tasks appearing in connection with it are still not solved completely and considerable losses of value continue to take place.

Objective of research

Based on the above, the objective of this paper was to find out substance of matter of ensuring economic efficiency of iron ore reserves use, its features in mining production of Ukraine and to provide reasons for the main direction of its solution which is proposed by authors.

Statement of researches results

First of all, it is necessary to provide exact definition of what it is meant by concept "Efficiency of Use of Iron Ore Reserves" as none of authors, who were engaged in development of this direction, has provided such definition. By this notion we mean ratio between actually obtained result according to amount of marketable iron ore products and obtained value from development of iron ore reserves up to technical and economic potential which provides availability of this reserve in subsoil by its amount, quality of ore, geological conditions of its bedding, mining conditions of development, standards of ore raw materials, demand for these raw materials and conditions of market.

The solution of this problem is extremely important for the mining enterprises from the point of view of achievement of necessary economic result from development, as well as implementation of development which requires selection of effective solutions on technology, mechanization, organization and resource ensuring.

The solution of specified problem is rather difficult. It is due to the fact that results of development of ore reserves are affected by many factors of different nature and with various characteristics of action. Nature of action of these factors and large scale cause loss of value and determine its sizes. The phenomena, which action of these factors lead to and cause losses of value, are the following:

- technological losses of part of ore reserves in case of its purifying removing as a result of imperfection of technology and removing technique;
- technological losses of ore quality (iron content) as a result of ore pollution with gangue materials in

the course of its purifying removing for the same reasons;

- losses of part of ore in case of processing of extracted ore into marketable iron ore products as a result of imperfection of technology of this processing;

- increased financial expenses on implementation of development and processing of extracted ore into marketable iron ore products.

It should be noted that because of difficult conditions of iron ore deposits development and modern methods of development, all these losses of ore, quality and value are inevitable. However, their specific value can be various and depends not only on the objective reasons (development conditions), but also on the approach of the mining companies to the solution of specified problem [4].

Recently, necessity of the appropriate solution of this problem is of particular importance in Ukraine. It is caused by the following reason: in the domestic mining industry an underground way of development of iron ore deposits obtains increasing value [5]. With its application in Ukraine 20-25% of marketable iron ore products are produced. Prospects of extension of application scales of this method are caused by feature of its technology which provides extraction of ore reserves under cover of deads. That is this way of development does not require removal of rocks, which are over the deposit and on sides, from subsoil. Removal of these rocks is indispensable condition in case of open development method, which is basic now and with which application 75-80% of marketable iron ore products are produced. The specified feature of underground mining allows economic efficient extraction of iron ores at depths up to 2000-3000 m, in comparison with the boundary (economically reasonable) depth 600-700 m of development by open method. This depth is limited by considerable amounts of removal of gangue materials from subsoil and by amounts of financial expenses for their removal that is typical for big depths of extraction. Considering the fact that in the domestic mining enterprises iron ore pits have already reached depths of 350-460 m, they will reach boundary depth of development in the next 15-20 years. In case of extremely negative dynamics of market prices of iron ore raw materials, which amount decreases in recent years, the boundary depth of pits can also decrease and be reached significantly earlier than the specified term.

Except described benefits, the underground method of development is also characterized by higher level of flexibility in the direction of the front of ore purifying removing and minimization of negative impact of extraction the environment.

Along with it, underground mining has also a number of difficulties, which negatively affect its economic results. To the most powerful of them belong the following:

- higher technological losses and pollution of ore reserves in case of production (losses of ore are 10-18%, pollution is 9-16%, in case of open-cast mining these indicators are 2-3%), it also determines the corresponding losses of value;

- complex technological schemes of ore removal, constructions of extraction units provided by difficult underground conditions of mining operations requiring big finance expenses for their implementation, this negatively influences the value, which is removed from subsoil.

Considering the foresaid, authors have performed the analysis of the existing methods of efficiency increase of ore reserves use developed by the previous researchers and authors. Results of this analysis have shown that one of the most effective methods is optimization of values of technological losses of ore in case of production, values of its pollution (which in total are called "ore extraction indicators"), values of ore losses in case of its processing, and amounts of financial resources, which are invested to development. These reasons cause bigger part of loss of ore reserves value. Certainly, the relevant technological and technical solutions are important in terms of reduction of value losses. However, these solutions also should be optimized because of their application along with reduction of physical losses of ore and its quality can lead to undesirable degree of increase of value.

Such optimization should be performed on the basis of certain optimality criteria, which reflect productivity of development and its economic efficiency. For such criteria a complex of parameters can be used:

- amount of obtained value from development of certain amount of ore reserves which depend on all above-mentioned characteristics of development;

- amount of extracted ore which depends on amount of ore reserves in subsoil which has been developed from the value of technological losses of ore in case of development of this reserve;

- quality of the extracted ore mass which depends on quality of ore reserve and value of ore pollution with gangue material; importance of this indicator is determined by the fact that amount of marketable products made of extracted ore mass depends significantly on its amount;

- amount of the marketable iron ore products made of extracted ore which depends on quality of the extracted ore mass and level of losses of ore in case of its processing into products;

- value of finance expenses on development and production depends significantly on losses of ore and its pollution, as one of the main criteria, by which technological, technical and organizational solutions on development are selected, is level of losses and pollution of ore; and as a rule, the less they are, the more valuable are technologies, technical means of development and organization of operations on production of ore and its processing into products.

- ratio between the gross value, which is presented by ore reserve, and the obtained value according to characteristics of marketable iron ore products; this ratio is the principal exponent of efficiency of use of ore reserves.

It should be noted that all above-mentioned parameters, which efficiency of reserve use depends on, are under control. That is levels of ore losses, its pollution and amount of finance expenses, which are necessary for development, can be controlled. Such control can be exercised by technological, technical, organizational, management and economic means. Moreover, between all these parameters there is close cause-and-effect link, that is their values are interconnected and nature of dependences between them is rather rigid.

In such situation, achievement of acceptable levels of ore losses, its pollution and finance expenses on development and processing of ore may be provided by balancing of their values (method of multidimensional optimization), proceeding from certain geological, mining and economic conditions of mining company operation.

As a rule, these conditions at various mining enterprises, and also conditions of development of reserves of various extraction units in the same enterprise are unique. Therefore, such balancing must be performed for each case that is for specific amount of ore reserves subjected to removal in a certain quantity and in fixed terms. These amounts and terms are determined by plans of depletion of deposit reserves and development plan for mining operations at the mining companies, by which graphs of reserves operation of each extraction unit are developed.

The specified circumstance significantly complicates the problem solution of ensuring necessary level of efficiency of ore reserves use according to amount of works.

Indicators of ore extraction have special value for ensuring efficiency of ore reserves use. It is caused by the fact that their values are normalized, that is their planned values are calculated at the mining companies before development of each planned to removing ore reserve, are protected by state control authority of efficiency of use of minerals reserves and affirmed by this authority as standard rates of losses of ore pollution in case of this reserve development. On the basis of these standard rates, at the enterprises all decisions on technology of development, designs of extraction units and their parameters, means of mechanization of mining operations are selected, schemes of their performance are developed, parameters of these works are calculated, decisions on resource ensuring of development are made. These decisions are directed to achievement of the required productivity of development and quality of the extracted ore under condition of obligatory holding of restrictions of losses and pollution of ore when purifying removing (drilling and blasting ore breaking, its removing from purification space and loading into means of mine transport). Moreover, on the basis of these standard rates at the mining enterprises indicators of development productivity and economic efficiency are planned. The same standards are basis for detection of irrational and wrong solutions on development, which is carried out by comparison of design and actual results of development.

Development of iron ore reserves is performed by preparation and implementation of separate projects for each amount of ore reserve. Proper control of these projects implementation with obtaining of necessary results of development is possible only under condition of corresponding parameterization of projects. That is all the decisions, which are made for their implementation, namely: creation of project team, resource ensuring, project budget and results of its implementation by obtained value and efficiency of reserve use should have accurate and exact parameters and be optimum. All these aspects form the project budget, which should be optimum [6].

The corresponding technique is developed by authors for determination of the project budget and optimization of its parameters; and on its basis the special computer program of economic-mathematical modeling of project is developed.

According to this technique for optimization of the corresponding parameters, the level of inconsequential loss of value is selected as the main criterion. This loss is established proceeding from economic conditions of development and operation of enterprise in general which determine necessary profit and profitability of the project and its budget. For determination of the corresponding level such approach is suggested.

The necessary level of enterprises profit P from development of ore reserves and production profitability R on certain project are determined by the fol-

lowing formulas

$$P = QC_m - V_{ex}; \quad R = P/V_{ex}; \qquad (1)$$

where Q_m – amount of marketable iron ore products made of processed ore reserves, t; C_m – selling price of products, UAH/t; V_{ex} – amount of finance expenses on production of marketable products in amount of Q_t.

If values P and R are specified according to (1), it is possible to predict values of other parameters by their variation selection.

The potential level of profit can be determined from the following expression:

$$P = C_{gr} - \Delta C; \quad from\_here \quad \Delta C = C_{gr} - P; \qquad (2)$$

where C_{gr} – gross value of balance reserves of ore, UAH; ΔC – loss of value as a result of all the expenses types, quality of ore and finance expenses, UAH.

The forecast value of loss of value ΔC can be determined by a formula

$$\Delta C = C_{gr} - C_{ob} = B\frac{S_r}{S_m}C_m - DK_{ex}C_m = B\frac{S_r}{S_m}C_m - B\frac{100-k_{ex}}{100-k_p}K_{ex}C_m \qquad (3)$$

where C_{ob} – obtained value, UAH; B – reserve, t; S_r – content of metal in reserve, %; S_m – content of metal in marketable products, %; D – extracted ore mass, t; k_{ex} – coefficient of technological expenses of reserve (standard), %; k_p – coefficient of technological pollution of ore mass (standard), %; K_{ex} – coefficient of extraction of marketable ore from ore mass, unit fraction.

The level of value losses can be also determined proceeding from amounts of finance expenses by development processes (process-oriented approach [7])

$$\Delta C = B\frac{100-k_{ex}}{100-k_p}(1-K_{ex})C_m + C_{gin} + C_{con} + C_{op} + C_p + C_{dbo} + C_{pr} + C_{tr} + C_h + C_{proc} \qquad (4)$$

where C_{gin} – finance expenses for geological investigation and delimitation of reserves, UAH; C_{con} - expenses for construction of superficial complex, UAH; C_{op} - for opening of reserve, UAH; C_p - for preparation of reserve to extraction, UAH; C_{dbo} - for drilling and blasting operations, UAH; C_{pr} - for purifying removing, UAH; C_{tr} - for transportation, UAH; C_h - for ore mass hoisting to the surface, UAH; C_{proc} - for processing of ore mass into marketable iron ore products, UAH.

The value (C_{gin}+…+C_{proc}) is the volume of the project budget E_b determined according to project processes. Expression (4) allows considering functional connection between various parameters, for example $C_{pr}=f(C_{dbo})$; $C_{proc}=f(C_{dbo}+C_{pr})$ etc. The specific form of such connections should be established by technical and economic modelling of the corresponding processes for specific conditions.

If expressions (3) and (4) are reduced into one equation with parameter ΔC, function, which allows optimizing of any parameter or several parameters from their structure, is obtained. For this purpose, having imposed restrictions to some parameters, it is possible to calculate values of other parameters.

Consequently, described model allows optimizing project budget E_b under financial expenses items in case of specified values of parameters which determine efficiency of reserve use k_{ex}, k_p, K_{ex} and productivity of development P and R.

Conclusion

Thus, on the basis of foresaid it is possible to draw the following conclusions:

1. The problem of ensuring economic efficient use of iron ore reserves is one of the most relevant for the mining industry of Ukraine due to considerable losses of value of ore reserves.

2. Relevance of this problem increases owing to the fact that in Ukraine significant increase of application of underground method of iron ores development characterized by the increased level of technological losses and pollution of ore, which is one of the most notable factors in forming of level of value losses, is planned.

3. One of the most efficient and effective methods of value losses reduction is optimization of projects parameters of development of ore reserves on the basis of process-oriented approach, which considers connection between parameters of all processes of development and its resulting economic effects of implementation.

4. The economic-mathematical model, on which basis it is possible to perform such optimization by various criteria, which can be provided by mining enterprises proceeding from economic results of development of specific amounts of iron ore reserves necessary for them, is developed by authors.

5. The direction of further researches in this sphere is development of full-function computer system of economic-mathematical modelling of packages of projects of extraction units development in the mining companies with multicriteria optimization of economic parameters of annual plans of mining operations.

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