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ANALYSIS OF ENERGY DEMANDINGNESS OF METALLURGICAL PRODUCTION

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The article suggests the possibility of using methods of structural analysis to calculate the direct and complex consumption and, on the basis of this calculation, are can determine the energy demandingness of the individual metallurgical technologies.

Key words: metallurgical production, structural analysis, energy demandingness

Analiza energetskih zahtjeva u metalurškoj proizvodnji. Članak predlaže mogućnosti rabljenja metoda strukturalnih analiza za izravnu i cijelovitu potrošnju, te na temelju proračuna moguće je odrediti energetske zahtjeve za pojedinačne metalurške tehnologije.

Ključne riječi: metalurška proizvodnja, strukturna analiza, energetski zahtjevi

INTRODUCTION

The economic development goes hand in hand with increasing consumption of materials and energies. The objectives of the basic concept of sustainable development include, above all, improving the quality of life with gradual minimization of human impacts on the environment and reducing the exploitation of resources [1]. A significant part of the impact on the environment and sustainable development is linked with consumption of energy which has been constantly increasing. The fossil fuels are the predominantly used sources of energy – these are non-renewable sources, their amount is limited and there has not been any available alternative solution of the energy question yet. The aim of modern society is to minimize the consumption of the non-renewable sources, and, at the same time, to minimize the global energy consumption in production processes [2]. The requirement to reduce the consumption of all types of energies therefore implies the need to identify and know the value of all the energy necessary to manufacture a unit of production.

STRUCTURAL ANALYSIS

During the energy crisis in 1973, the method of structural analysis (input-output analysis) was used in the works [3,4] to determine the energy demandingness of products.

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Structural analysis is based on the exact methodical concept introduced the by Leontief in 1936. Its initial objective was to provide a quantified view of relations in the reproductive process on the national economy level – the economic sphere is divided into sectors according to the character of production and products, and the economic transactions among the individual sectors are monitored [5]. The basic model of structural analysis originally showing the reproductive process on the national economy level can also be extended to the level of business subjects, and it can be further completed with information, such as the consumption of resources or the production of waste, etc.

The structural models are the products of the structural analysis and they show both endogenous and exogenous production-consumption relations of any production-consumption system with various prerequisites. They allow a relatively fast and, depending on the quality of the input data, accurate reflections of customer requirements – market requirements into quantities of necessary production volumes of the individual branches, into the material and energy demands on the suppliers, into the demands for labour force and financial means to pay them, into the overall structure of actual production costs, and into the values of gross or net company income [6]. The objective of creation of structural models as products of structural analysis is to quantify the links within the given production-consumption system (among its elements-branches), as well as the links with the surrounding environment and, based on that, in conjunction with IT to create conditions for rational (using other methodological tools) and optimal economic decision-making.

EXPERIMENTAL PART

Metallurgy is generally one of the most demanding industrial branches as far as energies are concerned. High energy demandingness of production of steel and steel products with regard to availability of the individual types of energies and their prices on one hand, and the requirements for reducing environmental burdens on the other hand, require the manufacturing processes to be carried out as efficiently as possible, in order to reduce the energy demands and the energy consumption of metallurgical production.

The article suggests the possibility of using the methods of structural analysis to calculate the direct and complex consumption and, based on that, to determine the energy demandingness of the individual metallurgical technologies. A structural model based on the following production stages is experimentally introduced here: sinter - pig iron - steel. The introduced structural model includes the energy demandingness of the previous stage moving into the following stage through the respective quantity (weight) of the input materials, and it is extended to include the consumption and energy demandingness of oxygen (important medium in oxygen converters and tandem furnaces).

In the procedure described in this article we used data coming from metallurgical annual reports - quantities and production and technical characteristics of steel produced in all at that time used, types of steel furnaces in the CR (oxygen converters, SM furnaces, TM furnaces, EAF), and using the methods of structural analysis, the coefficients of direct and complex consumption were calculated.

The elements in the matrix of direct (technical) coefficients A - the technical coefficients a_{ij} are constant and they result from direct consumption. General technical coefficients a_{ij} express the amount of production of the *i*-th branch needed to produce a units of production of the *j* - th branch, *i, j* = 1,2 ... 6.This is shown in Figure 1.

A matrix of coefficients of complex consumption B was calculated. In general, the coefficient of complex consumption b_{ij} indicates the total quantity of production of the *i*-th branch needed to manufacture a production unit of the *j*-th branch intended for the final consumption - sales. The indirect consumption is a mediated consumption, given by the fact that the relevant *j*-th branch requires not only the *i*-th branch, but also the production of other branches which also consume the outputs of the given *i*-th branch, *i, j* = 1,2 ... .6. This is shown in Figure 2.

Matrix A

		1	2	3	4	5	6		
	Product t/t	agglo-merate	pig-iron	steel converters	steel TM furnaces	steel SM furnaces	steel EAF	oxygen m/t	energy demandingness GJ/t
1	agglomerate		1,2356						
2	pig-iron			0,8046	0,7744	0,3961	0,1159		
3	steel - converters								
4	steel - TM furnaces								
5	steel - SM furnaces								
6	steel EAF								
	oxygen m/t			55,6	58,5	26			
	energy demandingness GJ/t	2,49	15,591	0,853	1,429	6,727	8,491	0,0094	

Figure 1 Matrix A - matrix of direct (technical) coefficients

Matice B=(E-A)

		1	2	3	4	5	6		
	Product t/t	agglo-merate	pig-iron	steel converters	steel TM furnaces	steel SM furnaces	steel EAF	oxygen m/t	energy demandingness GJ/t
1	agglomerate	1,000	1,237	0,995	0,958	0,490	0,134	0	0
2	pig-iron	0,000	1,000	0,805	0,774	0,396	0,116	0	0
3	steel - converters	0,000	0,000	1,000	0,000	0,000	0,000	0	0
4	steel - TM furnaces	0,000	0,000	0,000	1,000	0,000	0,000	0	0
5	steel - SM furnaces	0,000	0,000	0,000	0,000	1,000	0,000	0	0
6	steel EAF	0,000	0,000	0,000	0,000	0,000	1,000	0	0
	oxygen m/t	0,000	0,000	55,600	58,500	26.000	0,000	1	0
	energy demandigness GJ/t	2,490	18,670	16,397	16,437	14,367	10,655	0,0094	1

Figure 2 Matrix B - matrix of coefficients of complex consumption

RESULTS

We used retrospective data of technical nature, which are published and commonly available, for example in statistics of metallurgical yearbooks and in some reports, for comparison of the fuel-energy demandingness of the individual technologies of steel production by means of the structural analysis methods. These sets of aggregated data can form the basis for defining the basic matrix of production and consumption relations and subsequently, by means of a simple software transformation, it can be used for calculation of the matrix of the so called coefficients of complex (both direct and indirect) consumption, as the dominant quantity of structural analysis the explanatory power of which is absolutely fundamental within the scope of solutions of various tasks on the structural models.

Based on the calculated results, it can be said that the most demanding stage is the production of pig iron itself (18,670 GJ/t pig-iron). As far as the production of steel is concerned, the least energy demanding process is steel production in EAF (10.655 GJ/t of steel). The model works with certain degree of simplification, since the energy demands include only the direct inputs of energy carriers (electricity, coke, heat, gas) into metallurgical production stages and, apart from oxygen, it abstracts from energy demandingness of other external inputs (ferroalloys, lime, transport, refractories, etc.). However, the authors are convinced that the comparison of order of energy demandingness of the individual steelmaking technologies in production of comparable steel grade has not been affected by this simplification.

DISCUSSION

The situation of the world economy is characterized by considerable instability which forces companies to apply greater flexibility than ever before. The outlook on the global steel market in 2011 anticipates stable volumes, but rising prices of steel. The price of input raw materials has significantly increased (five times) in the last five years, which is why the cost burden of the steel industry is increasing as well. The level of prices of used raw materials is affected not only by the situation on the market where it is influenced by many often contradictory forces (either objective or speculative), but there are different prices for long-term contracts and spot trades as well, and there can be biased prices even in barter trades. The prices of raw materials reflect the tax and customs policy of the individual countries, and the cycle of boom and recession in the metallurgical industry and, more recently, the impact of global financial crisis are also very significant. Absolutely fundamental differences in prices of raw material prices arise in international transactions where the exchange rates, parity of supplies according to INCOTERMS, political, and dumping influences, etc. can represent the decisive factors. That is why no comparison of the cost of production of steel and the final metallurgical products can ever be objective, whether it is a comparison in time (statistical data of time series) or according to location (comparison of different producers, different technologies, etc.). From this perspective, when the market price of steel and the final steel products does not fully reflect the actual costs of production, the value of their energy demandingness expressed in technical units (with defined structure of resources, for example gas, coal, electricity, steam, etc.) might seem as a significant objective factor for comparison of various types of production of steel and finished metallurgical products. With regards to the specific peculiarities of metallurgical production, this aspect becomes increasingly important, because metallurgical production has a high share of energy and materials consumption (more than 80 %), while the metal in metallurgical companies is not lost, it is only converted and returned back to the metallurgical cycle, which is why the indicators of specific consumption of material loss in the individual stages actually represent the energy consumed during new melting and processing of the same metal.

The problem of determining the energy demandingness in metallurgical production can be successfully solved using the methods of structural analysis, where the matrix of direct consumption will consist of calculation of the energy demandingness of the relevant production stages (or technologies), including the energy demandingness of the external inputs, and the recalculated coefficients of complex consumption will then reflect the continuous, complex calculation of energy consumption reflecting the energy demandingness of the consumed products in all previous stages. The aim could be to create an integrated structural model of steel production and final metallurgical products including all the production stages which should allow the calculation of energy demandingness of the combination of structural models, and calculations of "energy requirements" of other elements of calculation. Subsequently they should allow the optimization of the production process while respecting the requirement to minimize the energy consumption, because due to considerable pressure to reduce consumption of all types of energies in production of steel and final metallurgical products, all the proposed rationalization measures should also be judged in terms of their energy demandingness.

CONCLUSION

Metallurgy is generally one of the most demanding industrial branches as far as the material and energy demands are concerned. Reduction of material and energy demandingness in production of metallurgical products can be understood as a permanent competitive advantage, but also as a necessary step to preserve the metallurgical production in the developed countries. That is why it will be absolutely essential in the future for metallurgical companies that want to maintain their competitiveness to have detailed knowledge of energy and economic demands of the individual company processes, to have the ability to predict the development of costs in connection with the decision-making process in the company in the area of substitution of input materials, and not only in this sphere. The economic and mathematical methods (in particular the approaches of structural analysis) have irreplaceable position in these considerations.

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REFERENCES

[1] P. Horváthová, M. Davidová, Operations Management As an Instrument of Organizations´ Competitiveness Increase in Relation to the Environment, Proceedings of 12th Conference on Environment and Mineral Processing, Ostrava, 2008, pp. 341-346

[2] M.Mikušová, N.Klabusayová, Sustainable development – the matter of all of us. Proceedings ECON 07´, Ostrava, 2007, pp. 128-136.

[3] C.W. Bullard, R.A. Herendeen, The Energy Cost of Goods and Services, ENERGY POLICY 3, (1975) 4,268 – 278

[4] B.Hannon,T.Blazeck,D.Kennedy,R. Illyes, A comparison of energy intensities. RESOURCES AND ENERGY 5, (1983) 1, 83 – 102.

[5] W. Leontief, E. Dietzenbacher, M. L. Lahr, Wassily Leontief and input-output economics Cambridge University Press, Cambridge, 2004, pp. 396

[6] K.Janovská, I.Vozňáková, L.Švajdová. The Verification of Applicability of Economical-mathematics Methods of Structural Analyses as a Tool for Optimising Economic Proceedings of Metallurgical Enterprise, Proceedings of the 19th International Metallurgical & Materials Conference METAL 2010. Ostrava, 2010, pp. 121-125.

Note: The responsible translator for English language is Petr Jaroš (English Language Tutor at the College of Tourism and Foreign Trade, Goodwill - VOŠ, Frýdek-Místek, the Czech Republic).