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THE MODEL FOR THE CALCULATION OF THE DISPERSED IRON ORE RESOURCE PURCHASE COST IN THE WORLD CLASS MANUFACTURING (WCM) LOGISTICS PILLAR CONTEXT

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In the blast-furnace production, raw materials may account for approx. 50 % of the pig-iron manufacture costs. Therefore, any, even small, saving in the sphere of raw material purchasing will translate into the reduction in the cost of the pig-iron manufacture. The selection of appropriate supply sources and the associated raw material quality influencing the economic viability of the charge blend constitutes a multi-faceted optimization task. The paper presents a modified model for production cost estimation at the moment of making raw material purchasing, which is possible to be used in the logistics pillar of the WCM concept.

Key words: Iron ore, costs, pig-iron, value in use

INTRODUCTION

An increasing number of metallurgy industry enterprises are implementing the WCM concept. The basic assumption underpinning the WCM is the optimization of manufacturing processes through continuous improvement and elimination of any waste. The elimination of losses is preceded by their identification and cost valuation. This valuation is associated with the area of loss occurrence. In the supply process, losses also occur, and their detailed estimation allows a better calculation of the actual production cost.

In the blast-furnace steel production process, many types of ores are used. Each of them is characterized by different physical and chemical properties. They have an impact on the Key Performance Indicators (KPI) and, as a consequence, on the costs. Each of these characteristics influences the furnace operation conditions, which also has an effect on the finished product manufacture cost.

Traditional supply source selection methods do not prove themselves in the WCM, as they are not able to simultaneously optimize so many factors (chemical, physical, mechanical, etc.) in such a variable environment (short-term purchase contracts). In addition, the WCM requires the ongoing valuation of production losses which, with high raw-material diversification, require the correction of the methods of their valuation (A-F matrices). Production cost calculation methods that are currently used in many metallurgical enterprises do not meet the WCM assumptions and should therefore by replaced with other ones which will be more effective in ongoing decision making.

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Choosing the proper group of raw materials from the several dozen types of ores, selecting their proportions and the fact of diversification and dispersion of suppliers, all constitute a complex optimization problem. Without computer support, there is no possibility of making correct purchasing decisions on an ongoing basis.

FACTORS DETERMINING CHANGES IN IRON ORE PURCHASE COST CALCULATION

Over recent years, changes in the trends in steel market functioning have been observed. Long-term contracts have become a scarcity, having been replaced by several-months' purchase agreements. The specificity of the iron ore market in Poland significantly changed when first quarterly and shorter purchase contracts were concluded (previously, long-term contracts, most often signed for a duration of one year, had been standard). That meant the need for interfering in the market of dispersed and network-organized resources, which in turn resulted in an increase in the frequency of deliveries and diversification of supply sources. The steelmaking industry, being shaped mainly by factors such as energy and raw-material prices, has registered a significant increase in the prices of these resources. While the energy prices (the coking coal price) increase in a relatively predictable manner, the iron ore market has experienced recently considerable fluctuations (rises) [1]. The lack of the possibility of precisely predicting raw-material prices reduces the ability to calculate the planned production cost. The constant (even slow) increase in raw-material prices results either in an increase in finished product prices or (rarely) in a reduction of the margin. It is important therefore to have tools for fast cost calculation.

The main factors that force changes in the method of selecting supply sources and calculating the raw-material acquisition cost include the following:

– the need for considering the quality of ordered raw materials in the actual cost calculation process (the more accurately estimated the effect of raw-material quality on the production parameters, the more accurate the planned cost),
– the need for dispersing the supply sources (smaller-volume orders mean lower discounts and therefore higher their handling costs) [2],
– the non-linear variability of the prices of factors affecting the production costs,
– the worldwide WCM implementation trend of transferring the supply area to the sphere of integrated logistics (instead of the supply sphere - the integrated production chain),
– the possibility of using the services of supply centres,
– other factors, such as those resulting from Poland's membership of the EU [3] or the globalization [4].

All of the above-mentioned factors create the need for considering a very large number of variables in the purchasing process. In view of the above, a simplified computer model was created to estimate the values of individual raw materials, representing the cost determinants resulting from their use. This model was integrated into the Kaizen Costing tool being used in the WCM concept.

THE CONSTRUCTION ASSUMPTIONS AND OPERATION PRINCIPLE OF THE MODEL

In the face of the current economic conditions, the decision-making process in the raw-material purchase sphere is gaining importance. In addition to the increased ordering frequency, fast decision making is primarily required. In practice, models exist, which calculate the optimal iron-bearing mix charge in respect of specific needs and conditions. Unfortunately, the complexity of detailed models reduces the speed of their use, requires the specialized knowledge and extends the time needed for extracting the definite data that is essential at the raw-material purchase stage. It should be noted that during the purchase process it is only required to estimate the ultimate effect of a specific ore on the pig-iron production cost. Therefore, the so called Value in Use (ViU), as modified for being used in the Kaizen Costing, was used for building the model.

Each of the raw materials used in the blast-furnace process is characterized by a number of properties. Each of these characteristics affects the furnace operation conditions, which ultimately influences the finished product manufacture cost. The commonly used Value-in-Use of raw materials represents a considerably wider notion of value than that indicated by the market price. It constitutes the value that a specific good provides to a given customer in respect of his specific needs. Thus, the Value-in-Use of a specific ore relies on the actual conditions of use, increasing the importance of some properties which contribute to the determination of the economic viability of that raw material to the greatest extent. The ViU takes account of the main chemical and physical properties of raw materials, allowing thereby the utility value of concentrates or agglomerates to be estimated. This allows a number of raw materials necessary for steel production to be compared with one another (with a specific accuracy).

The basic assumption on which the model is based comes down to the use of the reference consumption of ores in the process. The input data concerning historical actual consumption enabled particular raw materials to be compared to reference characteristics (including cost and technological limitations). Based on the main ore properties, such as the content of iron, sulphur, aluminium oxide, water, etc., and with reference to the model assumptions, the most important indices influencing the process effectiveness were calculated. This came down to the calculation of: the consumption of fluxes, the amount of generated slag, fuel consumption, and the losses of iron during the process. The cost of the charge was additionally estimated based on the consumption of the ore under consideration on the assumed level. The deviations from the characteristics influencing the process effectiveness have an effect on the ultimate pig-iron production cost; so, any difference relative to the optimal value translates into the process effectiveness, which in turn influences the cost [5]. To relate the effect of individual characteristics and their deviations to the costs, appropriate conversion factors were used, which were calculated based on empirical studies. Finally, the cost of the ore under consideration was calculated on this basis, which included the ViU. A significant difficulty in the model was the proper examination of particular characteristics and correct prioritizing of the effects caused by respective changes in properties. For example, the change in the iron content of the ore has an inversely proportional effect on the amount of fuel consumed for the reduction process, as well as on the amount of slag generated to the pig iron; while the amount of slag present in the blast furnace hearth has a directly proportional effect on the amount of consumed fuel. Thus, the key objective during building the relationships was to avoid the multiple consideration of the influence of an individual characteristics. This objective was achieved by considering only those relationships in the model, that were important from the point of view of the final cost (this constitutes a significant simplification, since it had been assumed that the process efficiency is largely determined by the chemical properties, such as the content of iron, iron oxide, phosphorus, sulphur, aluminium oxide (dialuminium trioxide), water and basicity (the ratio of CaO to SiO_2); thus, the model includes in total 12 elements and chemical compounds). Figure 1 shows a simplified schematic illustrating the influence of chemical properties on the

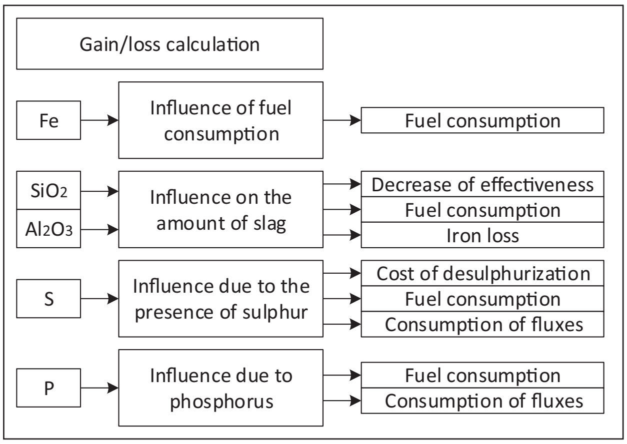

Figure 1 A simplified schematic of the influence of chemical properties on the calculation of financial gains and losses

calculation of financial gains and losses in the blast-furnace process. Based on empirical studies and data from detailed models, a database of conversion factors has been created.

The conversion factors perform the function of translating individual properties into process effectiveness indices. The following has been assumed in the model (with the percentage change relative to the input factor increase by 1 %):

– the effect of iron: the more iron, the less fuel (a change of minus 1 %) and slag (a change of minus 1,6 %),
– the effect of iron oxide: with the increase in FeO, the fuel consumption increases (a change of plus 0,35),
– the effect of fluxes: the reduction of, e.g., silicon to slag (a change of 1 %),
– the effect of slag: with the increase in the amount of slag, the amount of fuel increases (a change of plus 0,05 %),
– the effect of sulphur: with the increase in sulphur content, the fuel consumption increases (a change of plus 7 %), so does the flux consumption (a change by plus 12 %),
– the effect of phosphorus: the reduction in phosphorus means an increase the amount of fluxes (a change of plus 0,9) and an increase in fuel consumption (a change of plus 0,4),
– the effect of aluminium oxide: the increase in aluminium oxide results in an increase in its slag content (a change of plus 0,3 %).

VALIDATION OF THE MODEL

The model was created using the Witness Optimizer software. The performance of the model in terms of the ViU was validated based on historical data. Data from previous periods were input into the model, and then computations of the total cost of ores necessary for producing 1 ton of pig iron was carried out. Similar computations were performed for the cost of the entire iron-bearing charge. The computations were done for 50 different periods. The calculation made based on the ViU model yielded a comparable deviation from the actual data in each period of the considered time horizon. This allowed the calculation of the average error of the model, which enabled the estimation of the future costs. The deviation of the actual value results relative to the model was contained in the range from minus 1,5 % to minus 2 %. In addition, for validation purposes, the cost of producing 1 ton of pig iron, as calculated from the model, was compared with the real data. In this case, the discrepancy between the computation and real data amounted to 3 %, where the cost as per the ViU model represented, on average, a greater value. Thus, the validation of the model has shown the usefulness of the model for estimating the Value-in-Use of utilized raw materials.

CASE STUDY

The subject of the study (a steel mill in Poland) makes use of a dozen or so raw-material suppliers, chiefly located in Ukraine due to rich ore deposits and a relatively small distance. The raw-material quality is strictly defined in the contract. It is characterized by a number of chemical and physical properties, such as mechanical properties or metallurgical properties. The object of the study operates in the market as an independent entity in the area of raw-material contracting, which means that it is able to shape its purchasing policy by itself. By implementing the WCM in the area of logistics, the Steel Mill plans to reduce the costs by outsourcing the supply processes. For the Steel Mill's needs, two computer models for cost calculation have been built: a ViU model and a mixed model (ViU with an additional supply centre – the supply centre hypothetically combines orders from different steel mills, and thanks to the increased volume of ordered raw materials it obtains a quantity purchase premium). Using historical data (from the period of November 2011 to November 2013), a series of simulations of the costs of producing 1 ton of pig iron were carried out, and the obtained results are presented in Figure 2. The analysed costs are shown as an index related to the real base cost

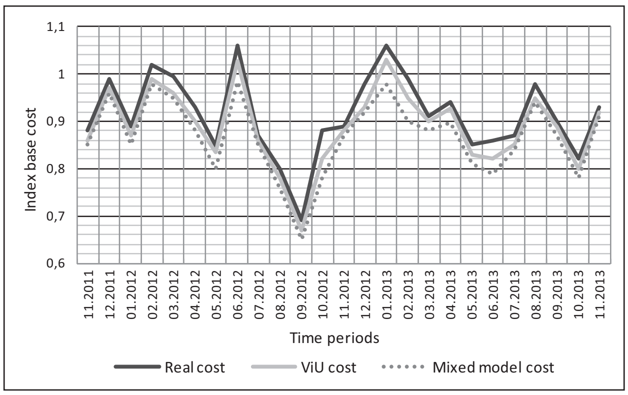

Figure 2 Index comparison of the pig-iron production cost for the ViU model and the mixed model

for the production of 1 ton of pig iron, calculated in October 2011.

As can be seen from Figure 2, the cost of producing 1 ton of pig iron in the considered periods by using the ViU model could be lower by 3 % then the real cost. In addition, there is a possibility of reducing the cost still by approx. 5 % due to the centralization of the purchasing by using the services of the Supply Centre (thanks to combining the Steel Mill's own orders and competitors' orders).

SUMMARY

The analysis of the obtained data indicates that it is possible to fast compare individual raw materials in respect of their Value in Use by correcting the supply price by characteristics representing the most important utility criteria. This has become possible due to the construction of the database of conversion factors performing the function of translating the effect of individual properties into pig-iron production process effectiveness indices. The use of the ViU model has determined the level of uncalculated production losses at 3 %, which are due to failure to consider the effect of raw-material chemical and physical properties on the real cost at the stage of placing orders. In addition, it is possible to reduce the pig-iron production cost, on average, by 8 % when using the Supply Centre operating in line with the assumptions of the ViU model. The basic functionality of the presented models is their capability to be used for assisting the decision-making process during purchasing and ease of being integrated with Kaizen Costing in the WCM.

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Note: The professional English language translator is Czesław Grochowina, Studio Tekst, Poland