"Lean Production" in the Coal Mining Industry

Mikhalchenko Vadim V.[a], Rubanik Yuri. T.[b], Osokina Natalia V.[c], Mikhalchenko Anna V.[d]
T. F. Gorbachev Kuzbass State Technical University, Kemerovo, Russian Federation
[a]v.mikhalchenko@mail.ru, [b]yuri-rubanik@yandex.ru, [c]osokina.kurchin@mail.ru, [d]gannamik@gmail.com

***Abstract* - The issue under consideration is an increase in the efficiency of the coal mining industry due to implementation of "lean production" principles. The proposed solutions will reduce the level of consumption of resources, increase productivity, ensure competitive advantage and, consequently, the viability of enterprises. However, achieving of these results will require cardinal changes in the fundamental principles of the design, construction and management in coal mining.**

Keywords - Coal enterprise, efficiency, resource consumption, resource conservation, management, competitiveness.

I. INTRODUCTION

The emerging global information economics of the XXI century is focused on achieving sustainable development through more efficient use of resources on the basis of the principle: spend less – produce more [1]. This approach is the dominant trend of development of modern production systems in various sectors of the world economy. Powerful modern tool for the implementation of this approach is the so-called "lean production" [2].

This issue is extremely important for the coal mining industry, which is characterized by consistently high levels of resource consumption. Costs of material for majority of coal mining enterprises of the Russian Federation exceed 50% of the total production costs.

Structural transformation of the industry in recent years [3], when there was the closure of unprofitable mines and opening of the new ones in favorable geological conditions, increase of the share of the open coal mining to almost 70 % of total coal production; technical modernization which ensured the increasing concentration and intensification of mining operations, brought the industry to a competitive level of performance and contributed to its integration into the world economic environment.

However, these transformations did not affect the historically established technological paradigm of production systems in coal mining industry. Its persistence limits the ability of coal enterprises to fully realize their economic potential. As a consequence coal-mining industry despite its modernization continues to fail in competition with alternative sources of energy. Its share in the market of hydrocarbons is reduced through increased use of cheaper and technologically more advanced fuels. If in early 90-s of the ratio “coal : oil : gas" consumption in the fuel and energy balance of Russia was 26:33:41 by now the share of coal is reduced to 10-11% [3, 4].

In addition, the modern period is characterized by a vivid trend to create efficient power plants based on alternative energy sources. A number of experts proclaim the end of the "era of mineral hydrocarbons” [5, 6].

However, the globalization of the world economy has strengthened the struggle for cheap sources of energy. The rapid industrial development of the BRICS (Brazil, Russia, India, China, South Africa) countries, Indonesia and others revived global demand for raw materials. The dependence of most economically developed countries on imports of energy and raw materials still remains high [7].

In the circumstances, in order to preserve its position, the Russian Federation as one of the global player on the energy market has to ensure the balanced and efficient use of its energy potential.

The importance of such approach demonstrates the People's Republic of China (PRC), which, essentially, is an "industrial workshop of the world" and in the long term has good chances to become the backbone of the world economy. This makes a development of cooperation between China and Russia an issue of a special importance.

The People's Republic of China is the world's largest manufacturer of solid hydrocarbons, reserves of which are estimated at 114.5 billion tons (13.9 per cent of world reserves). China is the world leader in coal production. It produces annually more than 3 billion tons (almost 50% of world production). Until recently coal mining was carried out on 16 thousand mines and opencast mines, of which 90% are of low production capacity. In accordance with the "Development Plan for the coal industry” the PRC is restructuring the industry. It is planned to close inefficient small capacity companies and to build large coal mining enterprises to supply over 50% of country coal production [8].

China's growing economy requires increasing amounts of primary energy resources. In terms of coal consumption, China ranks the 1st in the world (about 47% of world consumption). Until recently in China, coal was a major primary energy source (its share accounted for about 70% of consumed energy resources). In addition, the current state of world energy markets (drop in hydrocarbon prices) and a deliberate policy of the government (introduction of export and cancellation of the import duty on coal) gives rise to the growth of coal imports in China, which in recent years has increased tenfold (from 2.2 in 2000 to 125.8 million tons in 2009) [8].

The main consumers of coal in China are electric power utilities (55%), coke and chemical industry (17%), concrete production (7%), households (4%). In addition, there is a rapid development of advanced technologies in coal consumption. In particular, there is an essential production

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capacity of 30 million tons of synthetic liquid fuel (SLF) which consumes 100 million tons of coal annually [8].

As the world's largest manufacturer of solid hydrocarbons, China, however, is intensively expanding its power base of renewable environmentally clean energy sources (solar, wind, hydro and bioenergy). The installed capacity of renewable energy sources in the current 2016 should reach 560 gigawatts [9], which is almost 50% of the total installed capacity at PRC. The intensive development of the growing solar market through coordinated planning and, increasingly, innovation, is one of the vivid examples of the preparation of the People's Republic of China leadership in a new technological era.

The above shows that the coal mining industry of the Russian Federation, as well as the coal mining industry of China, face serious enough competition and, thus, the struggle for survival on the primary energy market has significantly increased.

In recent years, the expert community has been actively researching the viability of coal enterprises in the current economic conditions and limitations on the level of efficiency to meet the requirements of the world energy market [10,11,12,13]. In the light of the above, this problem continues to maintain its high relevance and needs to be addressed.

In this respect, the study of international experience in the development of resource-saving production systems and their adaptation to the conditions of the coal mining is a timely and urgent task.

II. SUBJECT OF RESEARCH

The object of the study is the production system of open coal mining in an open way, operating in a volatile and uncertain environment in the market economy.

III. RESULTS AND DISCUSSIONS

It is believed that efficient, resource-saving methods of "lean production" have made the achievements of Toyota - Japanese automotive giant possible [14,15,16].

The basic idea of "lean production" - is the pervasive and constant struggle with “wastes”, i.e. the elimination of any activity that consumes resources but does not add up to the customer value [2].
What follows describes the main features of “lean production systems” as applied toward the coal mining.

1. The definition of customer value. Customer focus is a key idea in the "lean production system" approach. Customer orientation means that the main criteria for optimization of all processes in the organization, taken separately and in their interaction, is an increase in customer satisfaction – i.e. maximizing customer value. By doing so, a company concentrates on the main determinant of its survival – the customer. It is the customer who pays for goods and services to satisfy its needs and, thereby, provides an aim and resources for existence of any business.

In relation to the coal mining, the aim of production may be defined as satisfaction of the vital human energy needs: heat, light, food and goods production. Consideration of a number of indicators set out in the table demonstrates that in today's economy the traditional indicators of coal quality and supply volumes retain their value.

TABLE. Basic groups and composition of indicators characterizing the customer value of products of coal mines

Aspect of customer value	Key indicators of customer value
Quality of product	Calorific value Ash content Humidity The content of volatile matters The content of chemical impurities Grade
Resource consumption	The price at the point of extraction (ex-warehouse – coal operation) The price including the cost of transportation (ex- consumer) Payment terms (advance payment, payment upon delivery) The cost of using the product
Product delivery	Readiness for delivery Duration of the delivery cycle Minimum supply lot Discipline of delivery Consistency of product quality between deliveries Information readiness
Environmental impact	Consumption of natural resources (land, air, water, mineral reserves) for production, transportation, storage and use of products

However, this group of features is regarded as being implemented indisputably. Attention of a customer nowadays is on reliability of supply, conformance to delivery schedule, product price at the point of delivery and environmental impact of the mining industry.
In this case the consumer doesn’t take into account mining and geological conditions the company operates or level of technical and technological excellence, geographical location of the company or production costs. In modern economic conditions the manufacturer should clearly define the customer value of a specific product and know exactly what should be done to meet the needs and expectations of the customer. It requires continuous work with customers and implementation of specific technical, technological and managerial solutions to meet the identified needs and expectations of the latter.

2. Systems optimization of the customer value chain as the basic organizing principle of lean production. Systems optimization of the entire production and logistics chain of creating customer value is the key moment of "lean manufacturing" focused on the final customer.

The chain "production of coal - consumer" represents such production and logistics system. Its goal - maximum satisfaction of needs and expectations of the consumer can be achieved only if actions of all components in the system are well coordinated. It does not make sense to improve quality and cost indicators of the system components individually, if the entire gain is lost because of inconsistency of the interaction at the junction. An attempt of this kind would be a case of "suboptimization", i.e. local (pseudo) optimization, which does not create advantages from the point of view of the system as a whole.
The practice of management of production and logistics systems in coal mining provides a significant number of examples of suboptimization. Let us mention some of common, widely-known examples.

The railway takes railcars for loading at the time and schedule that is convenient to it, complicating coal miners operations, resulting in overall lengthening time of delivery and unnecessary waste!

Coal production does not conform to the standards with regard to coal quality and it brings losses again.

The railway supplies unwashed wagons, coal mines load coal into them; a power plant is forced to carry out control and do additional cleaning of products -another loss!

At first glance, these are independent losses, but in fact they are ultimately reflected on increased supply costs. On the other hand, they directly influence the price of the products and, consequently harm competitiveness of the production – supply chain as a whole.

A classic example of the effects of suboptimization is a chain reaction of total growth of coal price as a result of inconsistent increase in tariffs and prices at the components of the chain. Such an attempt eventually leads to a drop in efficiency of the entire system. The natural result of such a local suboptimization is losses for everyone.

As many Western scholars specify, the negative effect of suboptimization is significantly multiplied by some fashionable management practices such as Management by Objectives (MBO). This technique motivates production units for achieving their local goals. Trying to improve financial performance, the managers introduce a system of internal self-financing centers (local profit centers), each with its own budget and financial results [17]. As practice shows, the first victims of this kind of management practices is the quality of products supplied to the customers down in the production-supply chain. Lower quality leads to higher costs at subsequent stages of the chain with a total negative effect for competitiveness of the whole enterprise.

For example, the desire to lower local costs in the first technological process of open mining – drilling and blasting operations by reducing the volume of drilling works provokes a cost rise down the production chain. Cost reduction may be achieved by making a more sparsely located grid wells net or by reducing consumption of explosives, or by using cheaper explosives with low parameters of brisance and so on, so forth. Ultimately this will lead to the lower quality in preparation of the rock mass and, consequently, increase in the costs of the next process – excavation-and-loading work and further down the chain of production. In this situation it is hard to blame representatives of the individual units; they behave completely rationally within the system that was created for them by the top management.

From what has been mentioned follows the important role of managers in creating such conditions (the system!) within the enterprise that would focus production units on achieving their common objective – maximize customer value and lower total cost of production .

Of fundamental importance to ensure coordinated activities of all participants in the coal production system, is the selection of control criteria. The concept of "costs", i.e. the cost for the unit of product is widely used as such a criterion. The allocation of operating expenses per unit of production is to some extent a mathematical abstraction that allows giving a quick estimate of the consequences of management decisions on the resulting performance of the enterprise, its profit and profitability.

However, in recent years the concept of "costs" is being criticized. By now, a sufficient number of examples of negative consequences of its application have been accumulated. It is linked with the local suboptimization of separate parts of business systems to the disadvantage of their efficiency as a whole. A significant progress towards developing a set of indicators to provide systems optimization has been achieved in the works of E. Goldratt [18]. As shown by Goldratt, the fundamental problem in the control system based on costs control is inability to take into account interaction of various components of the value chain system. But in many cases the level of costs depends on the interaction of elements of the system and is determined by the actions and circumstances prevailing at the previous stages. According to Goldratt, in modern times, implementation of the systems optimization requires rejection of using the concept of "costs" and transition to the use of "global operational criteria". According to him [18], the composition of this system includes:

- the rate of income generation by the system;
- operating costs;
- average level of the associated capital (inventory) over the period.

Application of the system focuses on organizing optimal interaction of elements and processes of the system under management to identify and eliminate the limits in speed of income generation by the whole system, reducing the capital linked with it.

Thus, the secret of a successful, future-oriented strategy of the company development including coal companies is to create such a set of system factors within the company that gives opportunity and directs employees to achieve overall

optimization both within the enterprise and in the chain of partners - in the interests of the end customer.

3. The principle of the pull production. Production systems, according to the method and nature of synchronization of a user's needs, can be divided into the system of "push"and "pull" types [19].

Until now, most production and logistics systems implemented in the coal mining industry belong to the"push" type systems. The logic of production systems of this type is determined by the requirement of maximum full utilization of expensive fixed assets. "The equipment should not stand idle! Every lost minute of the equipment operation is money lost for the company, for the country economy!" In support of this approach an "obvious" fact has been used - the transfer of the capital invested in fixed assets is only possible when these funds are working. In accordance with that the system of organization and production management, the system of organizational policies of the company including the labour cost system guide managers and employees for the maximum possible utilization of assets.

Initiation of the next production process stage, in fact, is carried out by the first operation of the technological cycle, equipped by costly machines. As soon as it completed with a previous portion of work, the next portion of "the material in process" is launched into production. All other technological operations are forced to push the material in process in the system to the log-off hence the term "push" production. In the end, if the system operates under conditions of significant level of variability of the demand, which is very typical for the coal mining industry due to its objectively existing seasonal and market variability, the specified organization of work will lead to the fact that output of products in the production system will fail to be coordinated with the volumes of sale. As a result, the production system periodically increases the level of work in progress and stock of finished products in the warehouse resulting in significant capital tie-up and, consequently, in significant economic risks [20].

Capital tie-up has a direct and significant impact on the cash flow and the level of external borrowings required to ensure its continuity and, consequently, determines an increase in operating costs. Ultimately, capital tie-up and withdrawal of significant working capital sharply exacerbate the problem of investment deficit and reduce profitability of production.

There are also indirect negative effects generated by the "push" type of production organization. However, their impact on the efficiency and stability of the company operation is very large.

Manufacturing "in stock" leads to the fact that products of the desired type, grade or class may not be available at the moment when there is a demand for them. At the same time, resources and money were spent on making those types and grades of products which are stocked in the warehouse unused. This means loss of additional generation of income, loss of competitiveness.
In the framework of "push" type production systems an attempt to respond to the changing market conditions and to start up production of the desired type is blocked by the fact that machinery and equipment, the downtime of which is tried to be avoided at any cost, are already involved in the production of unclaimed products and to interrupt this process is often impossible.

In terms of mining production, this effect may be even more significant due to the high inertia of mining operations. This is reflected in such an indicator of competitiveness, as duration of the delivery cycle. From the point of view of a consumer the enterprise in this case looks like inflexible, slow to react for market demand entity.

As a rule the negative results of the company of the "push" production type are greatly aggravated by organizational mechanisms of control and motivation. In particular, indicators of equipment efficiency are used not only as planned targets, but as control ones as well. And efficiency of the units is evaluated according to the degree of their utilization. In an effort to provide a high level of utilization, production units tend to load the equipment with work at any cost doesn’t matter if the next operation is expecting for the result of it. So in this way the loss of capital tie-up and losses from excess production are stimulated. The same behavior is also stimulated if a company uses job wage schemes for labour.

Setting arbitrary numerical targets and goals also contributes to internal overproduction. High variability of production processes gives rise to high risk of value creation flow break up. The need to report in time, to meet their planned targets and standards, makes each production unit (section, workshop) to create their own reserves, increase work in a progress.

A high level of work in a progress affects the ability to identify bottlenecks, sources of key factors of variability, and thereby contributes to conservation of low level of technical and economic efficiency. If the work which is urgent from the standpoint of the immediate needs of the market is replaced by another one that will be needed (maybe!) in more distant terms, workshops and administrative personnel may have an illusion of continuity of the production process. As a result the reasons of failures and delays are not exposed. They do not become a source of signals that require urgent consideration and actions upon the causes of failures. Figuratively speaking, a high level of production supplies "floods" and makes invisible the pitfalls that block material and financial flow.

An integral negative consequence of "push" type production is predetermined by the fact that optimization of the system is not built on system-wide criterion of economic efficiency, but on combination of local performance criteria. Figuratively speaking, instead of optimization of the ability of production system as a whole to ensure maximum efficiency of speed of cash flow generation at a minimum level of resources used as well as tie-up of capital, the system is configured to "minimize costs", "uniformity" or "continuity of production", "permanent employment" etc., i.e., to local optimization.

Negative effects of the "push" production system for the company stimulated the development of "pull" type systems. The main distinguishing feature of such systems is their ability to produce popular consumer products in sync mode with the dynamics of demand. However, the transition to the operation mode of "pull-in" production is possible only in case of significant capital investments in fixed assets of the company to create the required protection capacity. The increase of excess capacity gives rise to another type of risk – the risk of unproductive use of capital invested in additional production capacity in case of a significant fall in demand, for example, as a result of economic recession. However, as shown by economic analysis [21], in many cases, the negative effects of the push system made capacity reserve and transition to "pull" mode of production feasible.

In this case an important task of reducing the reaction time of the production system to the consumer demand is solved. Under variable demand "pull" systems allow to abandon the practice of production for expected demand based on unreliable long-term forecast. Transition to the "pull" system of production in which production operations are performed in just-in-time mode, in accordance with the schedule, ensures order fulfillment in time. The immediate consequence of this approach is a drastic reduction of the work in progress, storage space reduction with a corresponding decrease in total costs pf production and reduction of production and economic risks.

4. The principle of continuous improvement of processes and systems and team work. Lean manufacturing is a manufacturing system in which the concept of continuous improvement of processes and systems is "structurally" embedded. As a result of constant struggle with wastes of various kinds high quality product with minimum production costs is provided.

However, a high rate of continuous improvement and quality enhancement processes is impossible without creative participation of workers who, together with the company management, identify and solve production problems. The true involvement is possible only under the condition of cooperation of all units and workers in the company.

The same kind of trust and cooperation needs to be developed not only within the company but also among all stakeholders, i.e. all organizations, groups or individuals that affect the performance of the company. In this case, first of all, we imply customers and suppliers of the company.

Thus, if the leaders do intend to bring their company to the world level of efficiency, they will have to begin to shape a balance of interests of all stakeholders, to develop an environment of cooperation in which every employee feels satisfaction and joy from their work. It should be noted that this conclusion is of a universal nature. It is applied irrespective of the geographical zone or country in which the enterprise is located. However, specific forms of these relationships and the conditions under which the environment can be set up [17] significantly depend on the level of expectations of employees, cultural and national characteristics of the country or region, as well as many other specific factors, and can be very diverse.

IV. Conclusion

The accumulated global practice of transition to the principles of "lean production" allows to evaluate the impact of such changes as highly effective. The transition to "pull" systems and work flow mode of production can roughly double productivity level. The cycle time from order receipt to products delivery to consumers may be reduced by 90%. The level of the associated working capital can be reduced radically. The outstanding attractiveness of the "lean production" is determined just by these economical estimations.

The industrial leaders should abandon a superstitious belief that lean production approach can not be used in “old industries” such as mining, steel making, gas and oil excavation etc. However, indicators of the scale of changes taking place in consuming and supplying industries of products, means of transport, in technologies and management practices demonstrate that there is no future for those companies which slow down the pace of development and improvement. Yes, one has no doubts in the future of coal industry. But the future for an individual company cannot be guaranteed by anyone.

Thus, the review leads to the conclusion that re-engineering of the production systems of coal mining on the principles of "lean production" will contribute to the significant increase in the efficiency of resources use and, consequently, increase the competitiveness and viability of coal enterprises in the current economic conditions.

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