Application of linear programming techniques to optimize the choice of coal and water coal fuel

K V Osintsev\(^1\), Iu S Prikhodko\(^1\)

\(^1\) South Ural State University, 76, Lenina Ave., Chelyabinsk, 454080, Russia

E-mail: pte2017pte@mail.ru

**Abstract.** It is proposed to put the linear programming method into the basis of the optimization problem of a mathematical economic model of fuel type selection in the boiler house. The linear programming method is used in modern computer programs for calculating various economic models. It is proposed to use graphical or vector methods for solving optimization problems when constructing a mathematical model after analyzing the boiler room operation data. Scientific novelty consists in the fact that for the first time it is proposed to use linear programming methods for an energy technology complex when choosing coal-water fuel based on various coals. Such calculation algorithms allow us to make recommendations to reduce fuel losses during transportation and storage. The solution of the optimization problem of a mathematical economic model can lead to a significant reduction in fuel consumption and an increase in economic efficiency when using energy technology complexes based on coal-water fuel.

1. Introduction

Water-coal fuel is one of the promising fuels for remote areas located either in mountainous areas or away from gas pipelines and railways. A variant of using the fuel selection scheme for the optimization problem of mathematical modeling of the energy supply of consumers is proposed in the article. Moreover, the choice takes into account both the thermophysical properties of the fuel and the economic component of the preparation and delivery of coal-water slurries. The work is carried out with the aim of reducing fuel consumption, as well as reducing economic costs when choosing fuel. The authors performed the following experimental studies in the process [1,2]: coal crushing using laboratory-type hammer and jaw crushers, formation of a coal-water mixture, dependence of sedimentation of a coal-water mixture upon the storage time at its different concentration, grindability of different classes of coal and changes in the content of particles less than 0.05 mm during simulation of hydrotransport at 60 km on semi-industrial and laboratory stands, dewatering coal after transport for 60 km on a precipitation filtering centrifuge, dependence of sediment moisture on particle less than 0.05 mm content, effects of steam supply on sediment moisture reduction. The physical properties of the transported slurries are investigated, their features are noted [3,4]. The influence of various technological factors that characterize the flow carrying the suspension on the main parameters of transportation and flow regimes of slurries of Karakechinsky brown coal has been revealed. The paper deals with the formation of sludge during pipeline shutdown as a special case [5,6]. Dependencies to determine the specific pressure losses and the choice of the mode of movement in the hydrotransport of Karakechinsky brown coal in the form of a coal-water mixture with a weight concentration up to 57% in pipelines with a diameter from 100 to...
400 mm proposed on the basis of basic experimental data, their analysis and generalization [7,8]. The results of the study can be used at the pre-design and design stages of developing a variant of the hydrotransport system of fuel supply for a promising hydroelectric power station based on brown coal from the Kara-Kech deposit.

2. Description of the principle of the complex operation for coal-water fuel preparation
Water-coal fuel requires a technological complex for the preparation, storage and supply to the boiler. The scheme of this complex is shown in Figure 1. The principle of operation is as follows. Pre-prepared fuel is sent to the receiving tank, then to the storage tank, and finally to the boiler. Circulation pump used for mixing the mixture.

Several types of coal-water fuels are distinguished. They differ in the number of coarse particles and the presence of impurities of combustion catalysts. Let us consider the simplest option. It is a mixture with particles up to 40 microns in size.

3. Setting a research problem. Scientific novelty. Practical significance.
It is advisable to use modern economic methods in solving the optimization problem of a mathematical economic model of a boiler house in accordance with the principle of operation of boilers using coal and coal-water and their disadvantages. The article proposes to put calculation methods based on linear programming into the basis of this mathematical model.

The scientific novelty is that for the energy technology complex for the first time it is proposed to use linear programming methods when choosing coal-water fuel based on various coals.

The practical significance of the work is to reduce fuel consumption for the boiler unit. Fuel consumption for heat generation depends on the type of fuel being burned. It can be coal-water fuel based on a specific type of coal. Also fuel consumption depends on the possibility of utilization of the heat of combustion products. Construction of a mathematical model can lead to a significant reduction in fuel consumption and an increase in economic efficiency when using energy-technological complexes in areas remote from gas pipelines and railways.

4. The main provisions of the scientific part of the study
There are special problems, which are called linear programming problems, among the set of optimization problems [9,10]. The following specific features are inherent in linear programming tasks. Elements of the solution are a series of non-negative variables $x_1, x_2, \ldots, x_n$ in each of the tasks. It is required to choose the values of these variables in such a way that certain restrictions are fulfilled, having the form of linear inequalities or inequalities with respect to variables $x_1, x_2, \ldots, x_n$. It is also required that some linear function $f$ of the same variables should turn into a maximum (minimum). In our case, we consider a problem with two variables. It is convenient to use the economic interpretation of the...
coefficients and states of this problem to explain a number of points in the process of solving this problem.

Let us suppose that it is necessary to find the maximum value of the function: \( F = 2x_1 + 3x_2 \). The system of restrictions and non-negativity conditions are set:

\[
0.6x_1 + 0.4x_2 \leq 5, \quad 0.7x_1 + 0.3x_2 \leq 3, \quad x_1 \geq 0, \quad x_2 \geq 0.
\]

We assume that this task describes the boiler house, where: \( x_1 \) – the amount of coal-water fuel with the heat of combustion of Karakechinsky coal, \( x_2 \) – the amount of coal-water fuel with the heat of combustion of Tashkumur coal. We choose one ton as the unit of measure for the unknowns. Let the first resource be water coal fuel based on Karakechinsky coal, its stock is 4 tons. Let the second resource be water coal fuel based on Tashkumur coal, its stock is 6 tons. We consider the economic meaning of the remaining coefficients of the problem: 0.6 tons of coal and 0.4 tons of water are used for the production of one ton of coal-water fuel based on Karakechinsky coal; 0.7 tons of coal, 0.3 tons of water are used to produce one ton of coal-water fuel based on Tashkumur coal. We construct the domain of feasible solutions to the problem [11,12]. Let us consider the equations of straight lines and use for their construction the formula for the equation of a straight line in segments.

We get the following:

\[
L_1: 0.6x_1 + 0.4x_2 = 5. \quad \text{Then we divide the equation by 5. We get: } 6x_1/5 + 4x_2/5 = 1,
\]

\[
L_2: 0.7x_1 + 0.3x_2 = 3. \quad \text{Let us divide the equation by 3. We get: } 7x_1/30 + x_2/10 = 1.
\]

The solution of this system of inequalities is the shaded area on the graph in \( x_1 \) and \( x_2 \) coordinates (Figure 2). This is a domain of feasible solutions, a quadrilateral that is bounded \( L_1, L_2, x_1, x_2 \). Now you need to choose from all possible acceptable options. To do this, we construct a line corresponding to the objective function and call it the level line: \( 2x_1 + 3x_2 = 0 \). One should find out at what point of the found region the function reaches its maximum value. To find the best option, it is enough to “move” from one level line to another in the direction of increasing the objective function. In this case, point B will be a critical point, a line from the family of parallel lines in question passes through it. Any point of any line from the same family passing “above” point B delivers a greater value to the objective function, but any such line will not have common points with the region of admissible solutions. And the straight line passing “below” intersects the domain of feasible solutions at point B, but the value of the function \( F \) at all these points will be less than the value of \( F \) at point B. As a result, point B is the best option, which brings us the greatest profit or the best option for the purchase of water-coal fuel of the first and second types. Let us determine the coordinates of point B, that is, the plan that delivers the maximum profit.

For this you need to solve the initial system of equations, that is:

\[
0.6x_1 + 0.4x_2 = 5 \quad \text{and} \quad 0.7x_1 + 0.3x_2 = 3.
\]

We get: \( x_1 = 17, \ x_2 = -3 \). Thus, point B has coordinates \((17, -3)\). The coefficients of the objective function show the profit from the sale of a unit of the produced product or from the combustion of coal-water
fuel. In the task, we have a profit of two thousand monetary units from the sale of 1 ton of coal-water fuel of the first type, and our profit is equal to 3 thousand monetary units from the sale of 1 ton of coal-water fuel of the second type. We define the value of the objective function, which corresponds to the optimal variant B: \( F=2\cdot17+3\cdot(-3)=25 \). That is, this is the optimal value when using any of the first and second types of coal-water fuel in the boiler house. Thus, we can conclude that the reserves of the fuel itself must be significant, and it is necessary to use a reservoir for storing a mixture of two types of fuels.

5. Conclusion
The linear programming method is used in modern computer programs, including those based on neural networks. The method can be supplemented with a developed way for selecting the type of coal-water fuel. These methods should be used when solving the optimization problem of a mathematical economic model of a boiler house in accordance with the principle of operation of coal-fired boilers and coal-water boilers and their disadvantages.

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