Panabek Tanzharikov[1], Ulbossyn Sarabekova[2], Gaukhar Tanzharikova[3]

EVALUATION OF ECONOMIC EFFICIENCY OF WASTE OIL RECYCLING TECHNOLOGY

This article considers the usage of waste oil as secondary material resources. The scientific literature review and analysis has been performed; laboratory experiment research has been carried out. The feasibility of recycling of waste oil and rice husk as a binder for a charcoal briquette has been evaluated and reasoned. The optimal technological parameters for the process of briquetting waste coal from rice husk and waste oil are specified. The optimal mixture rate in a new fuel briquette is estimated. The resource-saving technology of briquette fuel production based on waste oil has been developed.

Keywords: *waste oil; asphalt, resin and paraffin deposits; recycling; ecology; briquette fuel; resource saving technology.*

Панабек Танжариков, Улбосин Сарабєкова, Гаухар Танжарикова

ОЦІНЮВАННЯ ЕКОНОМІЧНОЇ ЕФЕКТИВНОСТІ ЗАСТОСУВАННЯ ТЕХНОЛОГІЇ УТИЛІЗАЦІЇ НАФТОВІДХОДІВ

У статті розглянуто питання використання нафтовідходів як вторинних матеріальних ресурсів. Виконано аналіз і узагальнення даних науково-технічної літератури з досліджуваного напрямку; проведено експериментальні дослідження в лабораторних умовах. Обґрунтовано і доведено можливість утилізації нафтовідходів і рисового лушпиння у вигляді сполучного для кам'яновугільного брикету. Встановлено оптимальні технологічні параметри процесу брикетування вугільних відходів, рисового лушпиння з нафтовідходів. Визначено оптимальне співвідношення компонентів у складі нового паливного брикету. Розроблено ресурсозберігаючу технологію отримання брикетованого палива на основі нафтовідходів.

Ключові слова: *нафтовідходи; асфальтосмолисті парафінові відкладення; утилізація; екологія; брикетне паливо; ресурсозберігаюча технологія.*

Форм. 4. Табл. 1. Рис. 2. Літ. 11.

Панабек Танжариков, Улбосын Сарабекова, Гаухар Танжарикова

ОЦЕНКА ЭКОНОМИЧЕСКОЙ ЭФФЕКТИВНОСТИ ПРИМЕНЕНИЯ ТЕХНОЛОГИИ УТИЛИЗАЦИИ НЕФТЕОТХОДОВ

В статье рассмотрены вопросы использования нефтеотходов в качестве вторичных материальных ресурсов. Выполнен анализ и обобщение данных научно-технической литературы по исследуемому направлению; проведены экспериментальные исследования в лабораторных условиях. Обоснована и доказана возможность утилизации нефтеотходов и рисовой шелухи в качестве связующего для каменноугольного брикета. Установлены оптимальные технологические параметры процесса брикетирования угольных отходов, рисовой шелухи из нефтеотходов. Определено оптимальное соотношение компонентов в составе нового топливного брикета. Разработана ресурсосберегающая технология получения брикетированного топлива на основе нефтеотходов.

Ключевые слова: *нефтеотходы; асфальтосмолистые парафиновые отложения; утилизация; экология; брикетное топливо; ресурсосберегающая технология.*

[1] Korkyt ata Kyzylorda State University, Republic of Kazakhstan.
[2] Korkyt ata Kyzylorda State University, Republic of Kazakhstan.
[3] Korkyt ata Kyzylorda State University, Republic of Kazakhstan.

Introduction. The government of the Republic of Kazakhstan pays great attention to the development of the oil and gas industry. Hence, the increase of technogenic impact on the environment is the inevitable consequence. Disturbing of natural ecological balance is observed in the areas of elaboration, production, transportation and refining of crude oil.

In the recent decade the consumption of oil and gas became one of the most important terms of economic development of the Republic of Kazakhstan obviously categorized as the environmentally disadvantaged branches of the domestic industry. Therefore, the oil producing regions require a new approach to their environment preservation projects. At the same time it should cover the practical implementation of the goals set by the President of the Republic of Kazakhstan in his Strategy "Kazakhstan – 2030" that states: "The environmental, sanitary and epidemiological services and standard authorities must work in accordance with the priority aims" (Nazarbayev, 1998).

The problem of environment preservation in handling waste oil and salid waste is crucial all over the world but it is especially acute in Kazakhstan, practically in each oil producing region.

As a result of the research on recycling the technogenic wastes and its further analysis, the most important problems were identified: the minimization of waste formation, environment preservation handling, the waste split into as many groups as possible at the time of formation in order to use the most efficient methods of recycling or disposal of each waste group, the development of affordable and technically feasible technology for involving wastes in recycling. It is necessary to elaborate the alternative methodological approaches that would solve the disposal problems of industrial waste. But also the techniques to improve the consumer properties of purification from unwanted substances in the adjacent to production areas should be worked out. Such approaches of involving wastes into the recycling process should be used as the basis for strategies of handling industrial wastes and technical solutions.

The research objective is to show the ways to reduce negative impact of industrial waste on the environment by recycling secondary raw materials. Ensuring environment preservation while handling waste oil by developing and implementing science-based resource saving technologies for the waste oil and solid waste.

Within the given research we explored the usage of waste oil as the secondary material resource. The research included the review and of scientific literature in the studied field; the experimental laboratory investigation; the development of resource saving technologies; the comparison of theoretical calculations and experiment results.

The prospective solution for emerging environmental and economic concerns is the compression of substandard coal by size and consequently utilize wastes as a commodity product.

Applying the briquetting technology of substandard coal enables to avoid environmental payments and also gain profit from further manufacture of commodity products – briquettes.

Briquetted fuel is mechanically and thermally robust graded product having a specific geometrical shape, size and weight. It is obtained as an outcome of physical and chemical processes applying additives (binder) either without them. Briquettes

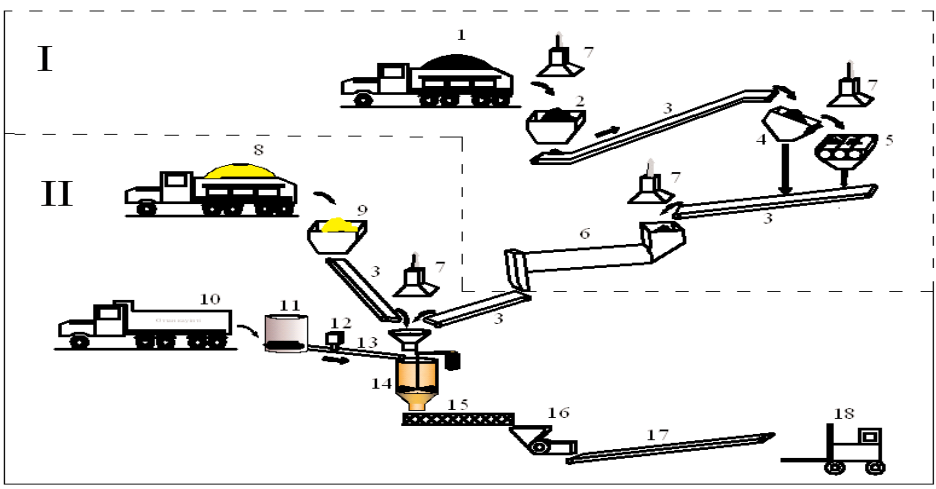
should meet the following requirements: have atmosphere resistance, mechanical strength, sufficient porosity, temperature resistance, contain a minimum quantity of moisture (Elishevich, 1968).

There are no briquette factories in Kazakhstan yet. Nowadays numerous private entrepreneurs are trying to establish the production of briquettes. The technology of briquette manufacturing seems simple at a glance. But all the attempts have failed due to the lack of scientific, technical and systematic preparation (background).

Analyzing the abovestated arguments the authors suggest the introduction of fiber structurants blend that is not a binder. It was supposed that these structurants should be a kind of "fittings" that reinforce briquettes. Feasibility of recycling asphalt, resin and paraffin deposits (hereinafter – ARPD) and rice husk as a binder for coal briquette has been evaluated and reasoned. The next step is estimating the optimal mixture rate in new fuel briquettes. As a result, resource saving technology for obtaining briquetted fuel on the basis of ARPD is developed.

According to the results of the experimental studies on the production of briquettes by ARPD, the technological parameters of briquetting were achieved. The primary important factor while briquetting is to establish the quantitative and qualitative ratio of components of ARPD, coal and rice husk (Babii, 1986; Elishevich, 1968, 1990).

The technological scheme of briquetting solid coal briquettes using ARPD and rice husk is shown in Figure 1.



1 – coal waste; 2 – receiving hopper; 3 – conveyors; 4 – sieve; 5 – shredder; 6 – dryer; 7 – dust collector; 8 – rice husk; 9 – receiving hopper; 10 – ARPD; 11 – preheater till 80–90єC; 12 – automatic measuring instrument; 13 – tube; 14 – mixer; 15 – auger; 16 – press; 17 – cooling conveyor; 18 – end product.

Figure 1. **Technological system of briquette samples preparation,** *authors' development*

The petty enriched concentrate (1) of the size 0–3 mm enters into a receiving hopper (2). Next, moving on conveyor (3) passing through 2.5 mm sieve (4) large pieces fall into the shredder (5) and decomposed till 0–2.5 mm. Then moving on the conveyor fed to dryer (6). In the process of drying the coal is heated to 55–60°C and

enters into the mixer through the batched conveyer (14). Dust collectors (7) are mounted to capture excessive dust while processing. Simultaneously, rice husk (8) poured out into receiving hopper (9), then dried and then fall into the mixer through the batched part (14). Meanwhile, ARPD is heated to 80–90°C in special utensils (11) and liquid state ARPD passes through automatic measuring instrument (12), through tube (13) falls into mixer (14). The mixture of solid components enters the vortex mixer for combining with preheated ARPD at 55–60°C. The components of briquette blend are mixed and discharged in cooling augers (15). All the processes (dosage of coal and binder, loading, mixing and discharge of blend) in the mixer (14) are automated. Right after cooling to 30–40°C in augers the briquetting mixture arrives to the roller press STB-1 (16). Briquettes coming out of press undergo riddling and proceed cooling ribbon conveyor (17). Cooling of briquettes is performed on both branches of conveyor. To intensify the process of cooling at summer period an additional air blowing would be provided. Cooled to 20°C briquettes are transported by the conveyor to the point of loading.

Basically, during the preparation of briquettes the proportion of oil binder is 6–8% from the total weight of a briquette. When using oil the waste relative expense is about 9–67%. Thus, relying on the research the optimal mixture rate has been calculated. ARPD: 20–25%, coal: 60–75%, rice husk: 5–10% (Table 1).

Table 1. **Features of fuel briquettes prepared by ARPD,** *authors' development*

Mixture	Briquette fuel composition, weight %		
	Briquette on bituminous binder	Briquettes on oil waste	Briquettes on ARPD
Coal	92–94	33–91	60–75
Binder	6–8	9–67	20–25
Rice husk	–	–	5–15

Solid particles bind under the thermal influence in the process of mechanical impact of coal-ARPD-husk. As a result, a firmly linked mixture is formed. Then, this mixture is being poured into the template shapes and pressed at a certain temperature.

The calorific capacity of briquettes is going to be higher than the initial coal by increasing the density when its ash content does not increase due to inorganic binder.

During the fuel combustion the release of heat takes place which is used in technological processes or could be converted to another energy type. Carbon substances are one of heat releasing stuff.

For example, in this case the investigated composition and the structure of asphaltic resinous paraffin deposition as a matter of fact is a complex hydrocarbon compound. Composition of oil wastes is: 80.0–86.0% carbon, 7.0–9.0% hydrogen, 9.0% sulfur, 1.0–9.0% oxygen and 1.5% nitrogen. Also, a little amount of resin, oil, water and mechanical impurities are present there.

The general equation of the combustion of any hydrocarbon is:

$$C_m H_m + (m + n/4)O_2 = mCO_2 + (n/2)H_2O + Q, \quad (1)$$

where m, n – the number of carbon and hydrogen atoms in the molecule; Q – is the heat of reaction or the amount of heat energy of combustion. The heat of combustion is the energy released during the combustion of 1 kg of fuel.

In this regard the mathematical model of combustion process of solid fuel was drafted. Presented differential equations take into consideration all physical and chemical processes that occur while combustion of fuel briquettes. For the given dynamics of combustion the methods of phenomenological thermodynamics were applied (Makarov and Shagarova, 1997).

The low heat of combustion is the most important characteristic of fuel and for each substance is determined experimentally. When the elemental composition is known the heat of combustion is defined by D.I. Mendeleev's formula:

$$Q_H^P = 339C^P + 1256H^P - 109(O^P + S_L^P) - 25.14(9H^P + W^P), \quad (2)$$

where C^P, H^P, O^P, S_L^P, W^P – are the component of fuel: carbon, hydrogen, oxygen, sulfur and the total value of moisture, respectively.

The quantity of heat of combustion of the investigated fuel briquette is obtained by measuring. The calculations were made by varying concentration of briquettes' components in possible range. The system of equations that defines the combustion of solid fuel are obtained taking into account all conditions and adopted amendments. On the basis of simulation of mathematical model the average value of heat of combustion of substances calculated whose chemical composition is the same as oil waste. That has been accomplished by integrating equations and using the approximate methods considering only hydrogen and carbon. The research results on the heat of waste oil combustion are shown in Figure 2. The quantity of heat during the combustion of investigated fuel briquettes is identified. The calculations have been made by varying concentration of briquette components in possible ranges. For calculation purposes software was compiled and obtained results are shown in Figure 2.

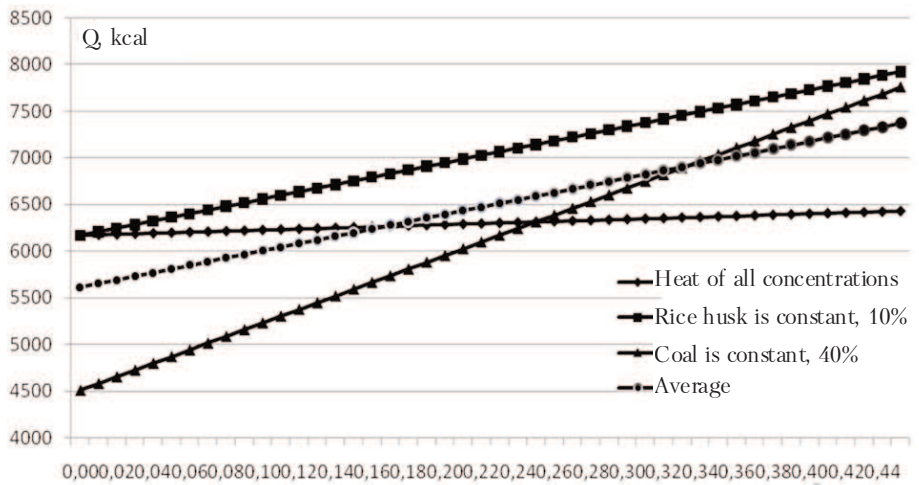


Figure 2. **Values of heat while combustion of briquettes obtained for different concentrations,** *authors' development*

The minimum and maximum values of heat of combustion were experimentally defined and are equal to Q_{min} = 4500 kcal and Q_{max} = 7923 kcal respectively.

In accordance with the method of (Bystrov, 1986), the economic effect of recycling ARPD within the components of hydrocarbon lubricants is determined by the formula:

$$E = P - Z, \quad (3)$$

where P – the cost of the results of activities in the accounting period; Z – the production expenditures.

On the result of measures the cost is determined by the following formula:

$$P = D + U_{cp}, \quad (4)$$

where D – additional revenue from implementation of environmental measures; U_{cp} – detriment to environment of i-type of consumed products, in USD.

The comparative analysis of raw materials consumption for coal briquette production on the basis of oil binder and ARPD showed that the proposed recycling technology of ARPD enables to exclude the bituminous binder. The technical recommendations on obtaining briquetted fuel on the basis of ARPD including the technology of coal briquettes were elaborated. The model of fuel briquette was developed and tested.

Results. The feasibility of recycling of waste oil and rice husk as a binder for solid coal briquette were substantiated and proved. The optimal technological parameters for the process of briquetting waste coal from rice husk and waste oil are defined. The next step is deriving the optimal proportion of components for fuel briquettes. As a result, the resource saving technology is developed for briquetted fuel production from waste oil. The working mock-up for fuel briquette production has been developed and successfully tested.

The results of technical and economic analysis demonstrated the cost effectiveness of the developed technology of recycling ARPD as a binder in briquetted fuel. The implementation of this new technology would provide the economic benefit in the amount of around 100 ths USD per year.

Conclusions. The current research is devoted to the issues of using waste oil as the secondary material resource. The research includes the review and analysis of scientific literature in the studied field; the experimental investigation in the laboratory; the development of resource saving technologies; the comparison of theoretical calculations and experimental results. The scientific importance of the research is to expand the usage of briquette fuel based on waste oil as the secondary crude supply in order to solve the environmental problems in oil producing regions.

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