

Keywords: "green" metallurgy, direct reduction of iron, electrometallurgy, coal gasification, ferroalloy production.

УДК 662.73; 662.67

OVERVIEW OF MODERN OIL SHALE PROCESSING METHODS AND ENVIRONMENTAL ASPECTS OF THEIR USE

V. M. Kushnarenko¹, O. V. Bohoyavlenska²

National Technical University 'Kharkiv Polytechnic Institute', 2, Kyrpychova str., Kharkiv, 61002, Ukraine

¹*Kushnarenko Vitalii Mykolaiovych, magister of the Department of Oil, Gas and Solid Fuel Processing Technologies, e-mail: vetalakush@gmail.com*

²*Bohoyavlenska Olena Volodymyrivna, Candidate of Technical Sciences, Associate Professor of the Department of Oil, Gas and Solid Fuel Processing Technologies, e-mail: evsob@gmail.com*

A review of modern technologies for the development and application of complex processing of oil shale, which is a raw material for energy, chemical, medical, construction industries, agriculture and other sectors, is carried out

Keywords: *oil shale, oil shale chemistry, oil shale, solid ash residues, thermal technologies*

Oil and natural gas are currently the main raw materials for the energy and chemical industries. At the same time, the constant growth of energy consumption amid depletion of conventional oil and gas fields, relocation of production centres to hard-to-reach regions with high investment costs require an assessment of the possibilities of developing the raw material base and organising the production of new unconventional hydrocarbon raw materials, including oil shale.

The resources of these minerals are significant and most deposits are located at easily accessible depths, which greatly facilitates their search, exploration and exploitation. That is why many countries have now started developing shale hydrocarbons. Based on the experience and accumulated scientific research, it is necessary to conduct theoretical and experimental studies aimed at the development and practical implementation of shale processing and shale chemistry in Ukraine.

The combustible part of oil shale is sapropel or humus-sapropel. The organic matter is evenly distributed in the rock, which is usually clayey. When oil shale is heated without air access to 5000 °C or with air access to 10000 °C, the organic matter decomposes with the release of shale oil, dry combustible gases and resinous water. Resin yield from kerogen-poor shales is 5-10% by weight of dry rock, and up to 30-50% from the richest shales [1].

As for the use of oil shale by other countries, the largest oil companies in America, Exxon Mobil and Chevron, as well as the Anglo-Dutch Royal Dutch Shell, spend about \$100 million annually testing new methods of shale oil extraction.

China also pays considerable attention to shale carbonaceous rocks, and the average annual production of shale tar now reaches 390-400 thousand tonnes.

Much attention is paid to the development of the oil shale industry in Brazil. Since the 1980s, the country's energy needs have been met by alternative energy

sources for 35%. The country produces less than 2 million tonnes of oil per year from shale.

One of the oldest oil shale processing plants is located in Germany. The plant extracts oil shale and uses it to produce cement. The annual output of the mine is approximately 400 thousand tonnes. Oil shale is used in two ways: most of it is burned to generate electricity and ash, while a smaller part is used as raw material and fuel directly in the cement kiln.

Other countries involved in oil shale extraction and processing include Australia, Jordan, Israel, and Morocco.

The current practice of oil shale development can be divided into the following main areas

- extraction and combustion as boiler fuel;
- extraction and use as a raw material for cement production with associated energy generation;
- extraction and processing into more valuable energy and chemical raw materials.

The first option is actively practiced in Estonia, where most of the extracted oil shale is burned as boiler fuel at Narva and Baltic thermal power plants. The development of this area is limited by the growing level of requirements to industrial and environmental safety, which leads to a deterioration in the economic performance of the energy use of raw oil shale.

The second direction of industrial development of oil shale is developing where the kerogen content in the shale rock is relatively low, but its mineral composition allows producing cement clinker of acceptable quality (Germany) [2]. However, the scale of oil shale use as a raw material for the cement industry is incomparable with the size of its reserves, so the main vector of development of oil shale industrial development will be directed towards obtaining high-quality energy and chemical raw materials [3].

The third direction is related to the processing of oil shale into the most valuable energy and chemical raw materials. In this case, one of the main target products of shale processing is shale oil [4].

Abroad, in particular, in the United States, it is believed that a full-scale industrial shale oil plant should have a daily capacity of at least 50 thousand barrels (about 8 thousand m³), and preferably 100 thousand barrels (about 16 thousand m³). To ensure such productivity of shale oil, 25 million tonnes of shale rock should be extracted annually. [5].

The ash residue formed during the thermal processing of oil shale is a huge reserve of cheap raw materials for the production of a diverse range of construction materials, primarily binders. Energy clinker production based on oil shale ash is well developed. This method is used to produce building blocks and panels, autoclaved porous and heavy concrete, silicate bricks, and high-grade Portland cement [6].

Oil shale is a source of over 60 (table 1).

Practical development of these resources is not widespread due to their low exploration, lack of proven technologies, and low competitiveness compared to the country's traditional hydrocarbon resources - oil and especially natural gas.

Therefore, the structure of the resource base of the shale hydrocarbon balance sheet should take into account a phased scheme of involving these energy carriers in the national economic circulation.

Table 1

Products that can be obtained from oil shale processing

Industry	Products.
Fuel and energy	Gas, fuel oil, diesel oil, petrol, wood impregnation oil, bitumen, kerosene, fuel oil, road surface oil, softeners, fixatives, lubricants, additives
Shale chemical	Benzene, toluene, thiophene, solvents, varnishes, adhesives, sulphur, acids, duplicators, dyes, mastics, sulphanol, plasticisers
Plastic and rubber engineering	Automotive blocks, cladding boards, linoleum, artificial leather, rubber softeners, etc.
Medicines	Ichthyol, sodium-ichthyol, sulfichthon, albichthol
Building materials	Cement, lime, mineral wool, facing materials, crushed stone for construction works, stone casting products, concrete aggregates, heavy and lightweight concrete
Agricultural preparations	Herbicides, urea, nerosin, plant growth stimulants, lime flour, etc.
Non-metallic	Alumina, soda ash, phosphorus, potassium, sodium, magnesium sulphates, sulphuric acid
Rare metal	vanadium, germanium, cobalt, molybdenum, nickel, uranium

Practical development of these resources is not widespread due to their low exploration, lack of proven technologies, and low competitiveness compared to the country's traditional hydrocarbon resources - oil and especially natural gas. Therefore, the structure of the resource base of the shale hydrocarbon balance sheet should take into account a phased scheme of involving these energy carriers in the national economic circulation.

At present, certain experience has been gained in the field of oil shale processing using underground and surface thermal methods to produce liquid hydrocarbons and fuel gas. At the same time, any industrial technology should ensure environmental safety of the region during the development of the field and after the oil shale processing is stopped for a long time.

There is a fairly large number of thermal technologies for oil shale processing in ground-based units, where two sources of oil shale heating are used

- solid heat carrier (oil shale ash, ceramic balls) - Haloter, Estonia, Narva; Enefit, Estonia, Auver village; Alberta Tasiuk, Australia, Stewart Point;
- gas coolant (internally heated - Union A, Parajo Direct, Kiviter, Superior Direct, KentortII processes and externally heated - Union B, Parajo Indirect, Petrosix, Superior Indirect, Fushun).

Existing pyrolysis methods have a number of disadvantages: increased consumption of raw materials, low specific reactor productivity. Analysis of the shale

chemical industry development shows that the main reserve for increasing the integrated use of shale raw materials is the replacement of the energy source.

It is also advisable to assess the environmental safety of onshore thermal methods of oil shale processing, taking into account the technology used. To this end, researchers have formed the following groups:

- Engineering (yield of target products; corrosion safety; versatility of the technological process; efficiency of the coolant);

- environmental (requirements for raw materials: possibility of processing oil shale of a certain fractional and chemical composition, use of other types of hydrocarbon raw materials; dependence of the technological process on the quality of raw materials;

- generation of additional solid and gaseous waste; possibility of closing gaseous and solid flows in technological cycles; water consumption; reliability and trouble-free operation) [7].

Based on the selected criteria, it was found that the Enefit process is the most modern, as it has a minimal environmental impact and maximum yield of target products (90-95 %). The minimal environmental impact is likely to be explained by the use of potential heat from the fly ash, the possibility of processing oil shale with a fine fraction of oil shale production reaching 30%, high yield of shale oil, and low water consumption.

The complete combustion of the carbon residue ensures relative safety of groundwater and leads to the possibility of using ash that can replace clinker in cement production. In addition, the use of waste heat for electricity generation also prevents carbon dioxide emissions.

One of the thermally promising methods of integrated oil shale processing is the plasma-chemical method. Plasma-chemical technology has wider possibilities, as the temperature of the coolant can reach 3000÷5000 K, and at high temperatures, chemical transformations of hydrocarbons are accelerated. In this process, the destruction of organic substances is carried out using the low-temperature energy of the plasma of the reducing gas (hydrogen, mixtures of hydrogen and methane)

Favourable geological conditions, in particular, the depth of the ground, are a prerequisite for the underground industrial processing method. For example, in the US, commercial production of shale oil by underground methods began in 1985, and in the Piceance Creek basin (Colorado), the maximum capacity of shale oil

Thus, the task of developing and applying integrated processing of oil shale, which is a raw material for the energy, chemical, medical, construction, agricultural and other industries, is relevant and timely.

Bibliography

1. Осипов А.М., Шендрик Т.Г., Грищук С.В., Попов А.Ф. Горючі сланці – перспективний ресурс природної органічної сировини в Україні (Огляд) // Енерготехнології та ресурсозбереження. – 2013. – № 6. – С. 3-9.

2. Awni Y. Al-Otoom. Utilization of oil shale in the production of Portland clinker // Cement and Concrete Composites. – 2006. – 28 (1). – P. 3-11.
3. Kang Z.; Zhao Y.; Yang D. Review of Oil Shale in-Situ Conversion Technology. Applied Energy. – 2020. – 269 (C), DOI: 10.1016/j.apenergy.2020.115121
4. Oja V., Suuberg E.M. (2012). Oil Shale Processing , Chemistry and Technology. In: Meyers, R.A. (eds) Encyclopedia of Sustainability Science and Technology. Springer, New York, NY. https://doi.org/10.1007/978-1-4419-0851-3_102
5. Oil Shale Development in the United States. CHAPTER THREE Oil Shale Technologies. – 2005, pp. 11-24 <https://www.jstor.org/stable/10.7249/mg414netl.10>
6. Hussain Azeez Mohamed, Leonel Campos. Oil shale ash utilization in industrial processes as an alternative raw material // Master of Science. Thesis Stockholm. – 2016 <https://www.diva-portal.org/smash/get/diva2:1052716/FULLTEXT01.pdf>
7. Bao Jia, Jianzheng Su. Advancements and Environmental Implications in Oil Shale Exploration and Processing // Applied Sciences. – 2023. – 13(13), P. 7657.

Overview of modern oil shale processing methods and environmental aspects of their use

Kushnarenko Vitalii Mykolaiovych, magister,
Bohoyavlenska Olena Volodymyrivna, Candidate of Technical Sciences, Associate Professor
(National Technical University Kharkiv Polytechnic Institute)

A review of modern technologies for the development and application of complex processing of oil shale, which is a raw material for energy, chemical, medical, construction industries, agriculture and other sectors, is carried out

Keywords: oil shale, oil shale chemistry, oil shale, solid ash residues, thermal technologies

УДК 338.3:620.9:662.74

ДОСЛІДЖЕННЯ ВПЛИВУ СКЛАДУ ГАСИЛЬНОГО ГАЗУ НА ЯКІСНІ ПОКАЗНИКИ КОКСУ ПРИ СУХОМУ ГАСІННІ (ЕТАП 1)

А. А. Когтін¹, Д. В. Мирошніченко²

¹*Когтін Артем Анатолійович, головний інженер проекту Державне підприємство "Державний інститут по проектуванню підприємств коксохімічної промисловості" (ДП "ГИПРОКОКС"), аспірант кафедри технологій переробки нафти, газу та твердого палива НТУ «ХП». e-mail: kogtin.giprokoks@gmail.com*

²*Мирошніченко Денис Вікторович, докт. техн. наук, проф., завідувач кафедри технологій переробки нафти, газу та твердого палива Національний Технічний Університет «Харківський Політехнічний Інститут», e-mail: dvmir79@gmail.com*

Наведено отримані результати по впливу газу різного складу на показники реакційної здатності CRI (Coke Reactivity Index) та гарячої міцності коксу CSR (Coke Strange after Reaction).

Ключові слова: *сухе гасіння коксу, якість коксу, реакційна здатність CRI (Coke Reactivity Index), гаряча міцність коксу CSR (Coke Strange after Reaction)*

Як відомо, пріоритетними для дослідження фізико-хімічних властивостей коксу в даний час виділяють реакційну здатність CRI (Coke Reactivity Index) і гарячу міцність коксу CSR (Coke Strange after Reaction), що