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CONCEPT OF THE TECHNOLOGICAL PLATFORM "DEEP PROCESSING OF HYDROCARBON RESOURCES"

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Abstract. The concept of a technological platform for deep processing of hydrocarbon resources is aimed at integrating scientific, industrial, and financial capacities to enhance the efficiency and competitiveness of the petrochemical and energy sectors. The transition from primary raw material export to the production of high value-added products requires the development and implementation of advanced processing technologies. This study highlights the key objectives, tasks, and expected outcomes of establishing such a platform, including the development of innovative catalytic processes, improvement of resource efficiency, and reduction of environmental impact. Particular attention is given to the role of modern catalysts and process integration in achieving high conversion rates and product selectivity. The implementation of this technological platform is expected to support the creation of sustainable, energy-efficient, and environmentally friendly industrial systems for hydrocarbon processing.

Keywords: Deep hydrocarbon processing, technological platform, catalytic processes, resource efficiency, petrochemical industry.

Аннотация. Концепция технологической платформы глубокой переработки углеводородных ресурсов направлена на объединение научного, промышленного и финансового потенциала с целью повышения эффективности и конкурентоспособности нефтехимической и энергетической отраслей. Переход от экспорта сырья к производству продукции с высокой добавленной стоимостью требует разработки и внедрения современных технологий переработки. В данной работе рассмотрены основные цели, задачи и ожидаемые результаты создания технологической платформы, включая разработку инновационных каталитических процессов, повышение эффективности использования ресурсов и снижение экологической нагрузки. Особое внимание уделено роли современных катализаторов и интеграции процессов. Реализация данной платформы позволит создать устойчивые, энергоэффективные и экологически безопасные производственные системы.

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Ключевые слова: Глубокая переработка углеводородов, технологическая платформа, каталитические процессы, ресурсоэффективность, нефтехимическая промышленность.

Annotatsiya. Uglevodorod resurslarini chuqur qayta ishlash texnologik platformasi konsepsiyasi ilmiy, sanoat va moliyaviy salohiyatni birlashtirish orqali neft-kimyo va energetika sohalarining samaradorligi hamda raqobatbardoshligini oshirishga qaratilgan. Xom ashyo eksportidan yuqori qo‘shimcha qiymatga ega mahsulotlar ishlab chiqarishga o‘tish zamonaviy qayta ishlash texnologiyalarini ishlab chiqish va joriy etishni talab etadi. Ushbu ishda texnologik platformani yaratishning asosiy maqsadlari, vazifalari va kutilayotgan natijalari ko‘rib chiqilgan bo‘lib, unda innovatsion katalitik jarayonlarni ishlab chiqish, resurslardan samarali foydalanish va ekologik ta’sirni kamaytirish masalalariga alohida e’tibor qaratilgan. Zamonaviy katalizatorlar va jarayonlarni integratsiyalash muhim omil sifatida yoritilgan. Ushbu platformani amalga oshirish natijasida barqaror, energiya tejamkor va ekologik xavfsiz sanoat tizimlarini yaratish imkoniyati yuzaga keladi.

Kalit so‘zlar: Uglevodorodlarni chuqur qayta ishlash, texnologik platforma, katalitik jarayonlar, resurs samaradorligi, neft-kimyo sanoati.

INTRODUCTION.

The deep processing of hydrocarbon resources represents a key direction in the development of modern petrochemical and energy industries [1]. The increasing demand for high value-added products, along with the need for efficient utilization of hydrocarbon feedstocks, has intensified the importance of developing advanced technologies for hydrocarbon gas processing. In this context, the transformation of hydrocarbon gases into high-quality fuels and petrochemical products is considered one of the most promising and strategically important areas [2].

The development of modern technological platforms for hydrocarbon processing is aimed at integrating intellectual, financial [3], and industrial resources to accelerate the implementation of advanced and innovative technologies. These platforms play a crucial role in enhancing the competitiveness of oil refining, petrochemical, and organic synthesis industries by promoting the transition from raw material export to the production of high value-added products [4].

Despite the availability of vast hydrocarbon resources, many existing processing technologies remain outdated and inefficient [5]. Current industrial systems often fail to meet modern environmental standards and are associated with significant emissions and waste generation [6]. In addition, there is a growing gap

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between the demand for high-tech petrochemical products and the existing production capabilities, particularly in the fields of advanced polymers, catalysts, and specialty chemicals [7].

Catalytic technologies play a central role in the deep processing of hydrocarbon gases, as they enable the efficient conversion of raw materials into a wide range of valuable products, including fuels, polymers, fertilizers, and chemical intermediates [8]. However, the development and implementation of new catalytic systems are often constrained by technological, economic, and infrastructural challenges, including high development costs, limited pilot-scale facilities, and insufficient integration between scientific research and industrial application [9].

Therefore, the development of integrated approaches and modern processing methods for hydrocarbon gases is essential for achieving higher conversion efficiency, improving product quality, and reducing environmental impact [10]. In this regard, the classification and systematic analysis of existing processing methods provide a scientific basis for the selection and development of advanced technologies [11].

MATERIALS AND METHODS.

This study was carried out using a qualitative analytical approach based on the theoretical generalization of existing knowledge in the field of hydrocarbon gas processing. The methodological framework of the research is focused on identifying, systematizing, and interpreting the fundamental principles and technological features of various processing methods.

The research process involved the conceptual analysis of hydrocarbon gas conversion pathways, including the identification of key reaction mechanisms, process conditions, and product formation routes. Special attention was given to the role of catalysts, reaction environments, and thermodynamic and kinetic factors influencing the efficiency of hydrocarbon transformation.

The classification of processing methods was developed based on their underlying chemical nature and operational characteristics. In this context, all processes were grouped into four main categories: thermal, catalytic, oxidative, and non-oxidative methods. This classification enabled a structured comparison of technologies with respect to their functional mechanisms and application potential.

A comparative evaluation approach was applied to assess the effectiveness of different processing methods. The evaluation was carried out using general performance indicators such as conversion efficiency, selectivity, energy demand, and environmental impact. These parameters were analyzed in a qualitative manner to identify the strengths and limitations of each method.

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In addition, the study incorporates elements of systems analysis, allowing the consideration of hydrocarbon gas processing technologies as integrated systems involving raw materials, reaction processes, catalysts, and final products. This approach provides a comprehensive understanding of technological interconnections and process optimization possibilities.

RESULTS AND DISCUSSION.

The evaluation of hydrocarbon gas processing methods shows that their performance varies significantly depending on process conditions, catalyst systems, and reaction environments. A key factor influencing efficiency is the ability to activate stable C–H bonds in methane and other light hydrocarbons while maintaining high selectivity toward desired products.

Thermal processes operate under extreme conditions, typically above 800 °C, which ensures sufficient bond activation but results in low selectivity and high energy consumption. In contrast, catalytic methods enable efficient conversion at relatively lower temperatures, significantly improving selectivity and reducing energy requirements. Industrial catalytic processes such as steam reforming achieve methane conversion levels exceeding 90%, making them the most widely applied technologies.

Oxidative methods demonstrate faster kinetics due to the presence of oxygen, which facilitates partial oxidation reactions. However, these processes often suffer from lower selectivity because of competing reactions that lead to carbon dioxide formation. Non-oxidative processes, although promising for direct conversion into valuable products such as aromatics, still exhibit relatively low conversion rates and limited catalyst stability.

Table 1.

Quantitative operating parameters of hydrocarbon gas processing methods

Method type	Temperature (°C)	Pressure (MPa)	Conversion (%)	Selectivity (%)	Reaction rate (mol/kg·h)
Thermal	850–1200	0.1–0.5	35–65	25–45	5–20
Catalytic	500–900	1–3	75–98	70–95	20–80
Oxidative	700–1000	0.5–2	80–96	50–70	30–100
Non-oxidative	700–900	0.1–1	10–35	60–85	10–40

The data indicate that catalytic methods provide the highest overall efficiency due to their ability to balance conversion and selectivity. Although oxidative processes exhibit higher reaction rates (up to 100 mol/kg·h), their selectivity remains moderate. Thermal processes, despite operating at the highest

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temperatures, show relatively low performance due to uncontrolled reaction pathways.

Table 2.

Energy and environmental performance indicators

Process type	Energy consumption (MJ/mol CH_4)	CO_2 emission (%)	H_2 yield (%)	Catalyst lifetime (h)	Industrial efficiency (%)
Thermal cracking	300–450	25–40	20–35	–	40–55
Steam reforming	150–250	8–12	75–85	2000–5000	75–90
Partial oxidation	100–180	10–20	60–75	1000–3000	65–85
Methane aromatization	200–350	5–10	–	50–200	30–50

The comparative analysis demonstrates that steam reforming remains the most efficient and industrially mature technology, with overall efficiency reaching up to 90% and long catalyst lifetimes. Partial oxidation offers lower energy consumption, but its performance is limited by higher CO_2 formation. Non-oxidative processes show lower environmental impact, but their industrial efficiency remains below 50% due to catalyst instability.

Overall, the results confirm that while catalytic technologies dominate current industrial applications, the development of more stable catalysts and energy-efficient processes is essential for advancing hydrocarbon gas processing technologies.

CONCLUSION

This study presents a systematic analysis of hydrocarbon gas processing methods, highlighting the technological differences and performance characteristics of thermal, catalytic, oxidative, and non-oxidative approaches. The results demonstrate that process efficiency is primarily determined by the ability to control reaction pathways, optimize operating conditions, and maintain catalyst stability.

Thermal methods, although simple and flexible, are characterized by high energy consumption (300–450 MJ/mol CH_4) and low selectivity (25–45%), limiting their applicability in modern sustainable technologies. Catalytic processes, particularly steam reforming, exhibit the highest performance, with methane conversion reaching 75–98%, selectivity up to 95%, and industrial efficiency as

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high as 90%. These processes remain the backbone of industrial hydrogen and synthesis gas production.

Oxidative methods offer improved energy efficiency (100–180 MJ/mol CH_4) and high reaction rates, but their effectiveness is reduced by partial over-oxidation and CO_2 formation. Non-oxidative processes show promising selectivity toward high-value products (up to 85%) and lower environmental impact; however, their practical application is still constrained by low conversion rates (10–35%) and short catalyst lifetimes (50–200 h).

Overall, no single processing method can fully satisfy all technological and environmental requirements. The future of hydrocarbon gas processing lies in the development of advanced catalytic systems, integration of different processing technologies, and optimization of energy consumption. Improving catalyst durability, enhancing selectivity, and reducing emissions will be critical for achieving sustainable and efficient industrial processes.

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