*TEKA. COMMISSION OF MOTORIZATION AND ENERGETICS IN AGRICULTURE – 2015, Vol. 15, No.2, 69-74*

# New types of reactors for chemical transformations of organic compounds in terms of aerosol nanocatalysis technology

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*Received June 03 .2015: accepted June 19.2015*

Summary. The possible applications of new technology in the aerosol nanocatalysis for the implementation of the chemical transformations of organic compounds. It given the reaction components of the installations of the technology of aerosol nanocatalysis processes for disposal of industrial and domestic waste. The proposed new design of reactors for performing chemical processes in the conditions of aerosol nanocatalysis with vibrating bed.

Key words: fluidized bed, vibrating bed, rotating bed, aerosol nanocatalysis, waste neutralization.

## INTRODUCTION

There are two technologies of heterogeneous catalysis of chemical transformations of organic substances. One of them is known more than 150 years, which uses a catalyst on carrier. For industrial process catalyst costs in the cost of production does not exceed 1%, but they affect the implementation of most industrial processes. The main factors assessment attribute its activity, selectivity and lifetime. It known that an one-time loading in the reactor is between 10 and 100 tons of catalyst, with its value about 3000-20000$ per ton. This catalyst works in most cases in the stationary bed. For this purpose, it uses the standard of the reactor [1].

In Severodonetsk Technological Institute was opened a new phenomenon for the implementation of heterogeneous catalytic reactions. It was named the aerosol nanocatalysis technology (AnC). The technology uses only active component as catalyst, which is uniformly distributed in the reaction volume. In studying the properties of the technology and basic principles has been studied many chemical reactions. For example, it studied and investigated the reaction of deep oxidation more than 50 individual organic substances. These investigations is found to use for the processes of neutralization about 30 industrial wastes of different productions. It was the first pilot output technologies on industrial level [2, 14,15].

This article discusses about all possible the types of reactor for the processes of chemical transformations of organic compounds. It known that the reaction part for the deep oxidation of organic compounds and their mixtures are well represented by a fluidized bed reactor.

## THE ANALYSIS OF PUBLICATIONS, MATERIALS, METHODS

The principle of aerosol nanocatalysis technology is the use of mechanical and chemical activation (in situ) in reaction volume. It results that the required concentration of catalyst is reduced to 1 - 2 g/m$^3$ of the reactor, and the activity of catalyst increases at $10^5$ - $10^6$ times.

This technology has two lines of development: with fluidized bed catalytic system [3] and with vibrating catalytic systems [4]. The first of them, in laboratory used reactor with fluidized bed. The perceptivity of AnC technologies was highly regarded in the environmental area and was established 4 pilot plant for disposal of various types of industrial and domestic wastes. These were ,built in Severodonetsk (Ukraine), Schekino (Russia), Sayansk (Russia) and Lund (Sweden) with fluidized bed reactor.

However, the reactor with fluidized bed difficult to use for kinetic studies of chemical transformations of organic compounds in the laboratory. But in pilot conditions it was necessary to keep up the conditions of the fluidized bed. Therefore it was decided to create a new direction in the aerosol nanocatalysis technology for study the kinetic characteristics of chemical reactions. A good example was the vibro-impacting bed of the catalytic system. It is completely repeated the properties of the fluidized bed and it can be easily manipulated in the laboratory.

Now the aerosol nanocatalysis technology successfully developed in two directions. Vibro-impacting bed is used to determine the optimal parameters of the chemical processes and the fluidized bed is used to implementation of these processes on an industrial scale [4].

## PURPOSE AND STATEMENT OF THE PROBLEM RESEARCH

Object of research is heterogeneous catalytic transformations of organic compounds in terms of aerosol nanocatalysis technology.

The aim of this work is to consider all possible types of reactors used and proposed for future use in the studied technologies.

Objectives the research activities of this work:

- analysis of existing reactor types for conversion of chemical processes for industry;
- analysis and modernization of laboratory reactors to the research questions;
- proposed reactors for performing chemical transformations in the conditions of aerosol nanocatalysis.

## EXPERIMENTAL PART AND DISCUSSION OF RESULTS

An analysis was conducted of the types of reactors for heterogeneous catalytic processes. As a results that the most of them occurs in the reactor with a stationary bed of catalyst. The catalyst in this case consists of the active part, deposited on a solid inert porous carrier or impregnation. The height of the catalyst bed taking with excess as the reaction zone gradually moves relative to the height of the layer. When you reach the end of the catalyst bed the process stop and replace the catalyst. In some cases, the catalyst can be regenerated and back into the process. Later, a similar catalyst it's used in the reactor with a fluidized bed of catalyst. This reactor is used for chemical transformations of organic compounds till now, but it has some limitations. The main ones include so:

– the impossibility of carrying out chemical reactions with the reagent having the composition of solid components;

– the solid components formed during the transformation plugged up the pores of the inert carrier of the catalyst, which leads to its deactivation;

– the solid inert carrier must have some porous structure, strength and thermo stability.

Now, these problems are solved with the aerosol nanocatalysis technology [2]. The basic principles of aerosol nanocatalysis, such as the absence of porous carrier, the creation of catalyst nanoparticles in the reactor by mechanical and chemical activation (in situ) and chemical conversion is carried out in a fluidized bed of the catalytic system [5]. A schematic diagram of a first laboratory setup for deep oxidation of chemical compounds and their mixtures in aerosol nanocatalysis technology with fluidized bed reactor is presented in Fig. 1.

Directly the concept of this laboratory reactor is presented in Fig. 2. The reactor contains three main parts: gas distribution zone, working zone and separation zone. The first zone is used for uniform distribution of the gaseous reaction reagent in the reactor's volume. The second zone contains a catalytic system, which consists of a dispersing material and catalyst. Under the influence of gas distribution flow the catalytic system is distributed across the second working area. There are a mechanical and chemical activation of the catalyst particles and chemical transformations of organic compounds in working part of reactor [1]. The first and second zones limits the gas distribution grid, which also supports the catalytic system in the reactor. Separation zone serves to reduce the speed of movement of catalyst particles and separating them from dispersing particles of the material.

The reactor showed good results during deep oxidation many organic compounds and their mixtures, industrial wastes with any aggregate state of various industries. Upon investigations in the laboratory have been established and proposed processing scheme for the disposal of industrial waste. A schematic diagram of an installation for the disposal of industrial waste is shown in Fig. 3. The process is carried out in conditions of aerosol nanocatalysis technology at 600$^o$C. The scheme envisages the feed zone of raw materials, oxidizing agent and catalyst. In the scheme unit is provided part of catalyst trapping and return them to the cycle. And further purification of exhaust gases from impurities is in the scrubber and is the emissions of gases of natural non-toxic state to the atmosphere [1, 16].

The inorganic synthesis in the laboratory of aerosol nanocatalysis presents the scientific research of obtaining nitrogen oxides by the oxidation of ammonia, than to recovery it in nitric acid and additional oxidation of unreacted oxides. In this case, the fluidized bed reactor is divided into several zones, which are in the process of oxidation, recovery, and final oxidation of the components. This reactor can be used for environmental cleanup of waste gases of the nitric acid production. The scheme of this fluidized bed reactor is presented in Fig. 4 [2].

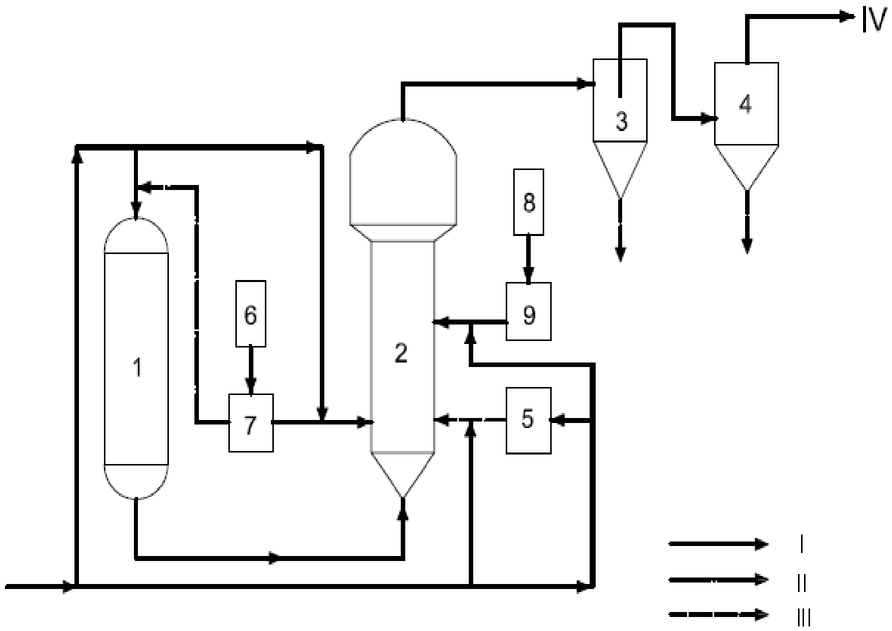


**Fig. 1.** A schematic diagram of the laboratory setup of deep oxidation of chemical compounds. 1 – electric heater; 2 – reactor; 3 – cyclone; 4 – filter; 5 – catalyst feeder; 6 – capacity for organics; 7, 9 – peristaltic pump; 8 – capacity for additional organics

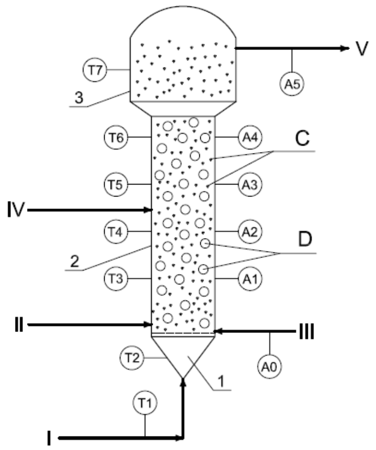


**Fig. 2.** The laboratory reactor of aerosol catalysis with fluidized bed (ACFB). 1. gas distribution zone; 2. the reaction zone; 3. separation zone; $T_1$-$T_7$ – thermocouple; $A_0$-$A_6$ – analysis point; C – catalyst particles; D – dispersed material; Flows: I – air; II – reagent; III - the catalyst; IV – reducing agent (if necessary); V – exhaust gases and the catalyst.

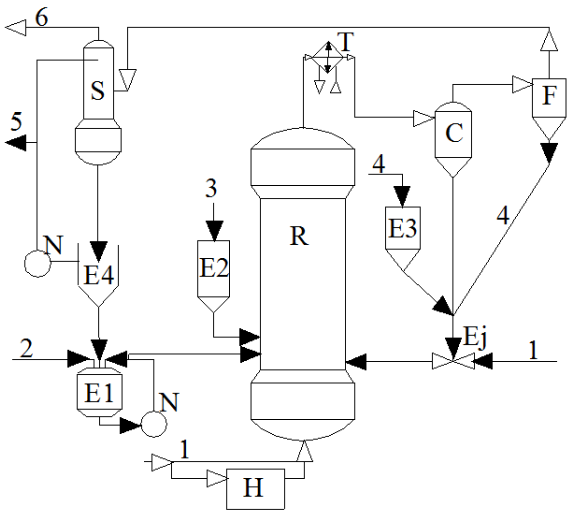


**Fig. 3.** The process flow diagram of industrial waste neutralization by ACFB technology: R – reactor; C – cyclone; F – filter; T – heat-exchanger, S – scrubber; H – preheating; N – pump; E1-3 – containers for liquid waste, solid waste and catalyst; E4 – settler; Ej – ejector; 1 – air; 2 – liquid waste; 3 – solid waste; 4 – catalyst; 5 – purified water; 6 – gases in the atmosphere

The development of aerosol nanocatalysis technology is took its place in the environmental area of chemical and oil-refining industry. Created a mobile pilot unit for disposal of industrial wastes in the aerosol catalyst has shown perspective in this direction. A schematic diagram of a mobile pilot plant with a fluidized bed reactor by aerosol nanocatalysis technology presented in Fig. 5 [6].

The aerosol nanocatalysis reactor with fluidized bed is well used in the environmental industrial complex. However the process of studying the kinetic characteristics and management factors in chemical transformations was difficult. So we created a new direction of the aerosol nanocatalysis technology with vibrating bed of catalytic systems. Now this direction is well developed in the laboratory. It studied many oxidative and refining processes for fuels obtaining, and sorption processes of flue gases of thermal power plants. A schematic diagram of this laboratory unit are presented in Fig. 6 [7, 8, 17].

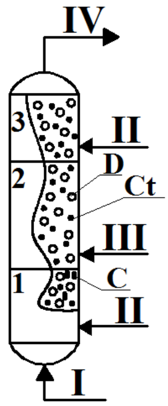


**Fig. 4.** The schematic diagram of the aerosol nanocatalysis reactor for catalytic purification of waste gases of nitric acid production. 1 – oxidation zone; 2 – reduction zone; 3 – the final oxidation zone; D – dispersed material; Ct – catalyst particles; C – particles of ash and chalk. Flows: I – flue gases; II - air; III - fuel; IV – to the atmosphere.

This scheme consists of several parts. There are the feed of the reagent, the reaction part and the receiving unit and the separation of the finished product. In laboratory conditions the unit of reagent feed includes the laboratory dispenser of raw materials. The raw materials for refining process is fed up of the laboratory reactor. The reaction products is withdrawn from the bottom and collect in a container. Further the products will separate into two benzene and diesel fractions and than go to analyze the composition.

The aerosol nanocatalysis technology with vibrating bed successfully is found its part in the chemical and refining industry. To study the kinetic characteristics of the processes of chemical transformations of organic compounds revealed that the technology with vibrating bed is better in ten times than the technology with fluidized bed. However, there are some difficulties with the implementation of vibrating bed in to the industry. We'll propose one of variant, which presented in Fig. 7. This principal scheme combines both variants of the aerosol nanocatalysis technology. The reactor with vibrating bed is used as a preliminary activation of the catalyst and than to flow into the reactor with fluidized-bed [6, 9-11].

To study the properties and characteristics of fluidized and vibrating beds were offered new designs of reactors. One of the reaction unit is shown in Fig. 8. It combines the vibration and rotational motion of a catalytic system. This is to allow ease mixing of the gaseous and solid systems located in the reactor. This construction can be provided for processes of refining gas oil to obtained gasoline and diesel fractions. In this principal technological scheme can be provided the part of formed coke burning. The products after container of products sent to distillation on fractions [12,13].

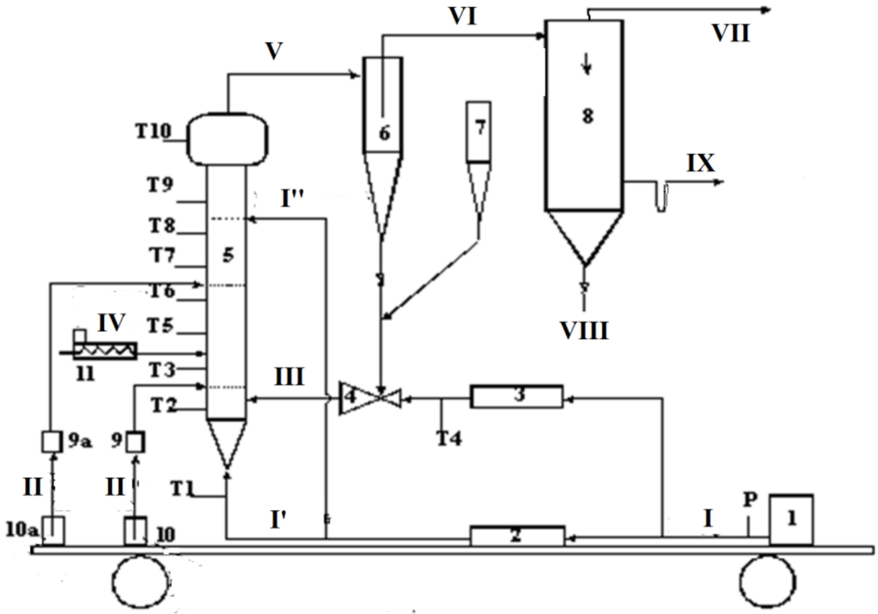


**Fig. 5.** The principal scheme of mobile pilot unit for catalytic neutralization of pollutants different classes of organic and inorganic compounds on the catalyst $Fe_2O_3$: 1 – air compressor, 2, 3, 9, 9a – flowmeter, 4 – ejector, 5 – reactor, 6 – cyclone, 7 – bunker catalyst, 8 – scrubber, 10, 10A – tanks with diesel fuel, 11 – solid waste dispenser. Flow I, I',I'' - air, II -diesel fuel, III - catalyst, IV - solid waste, V - reaction products, VI - gas-off products, VII - to the atmosphere, VIII - water, IX - the drain

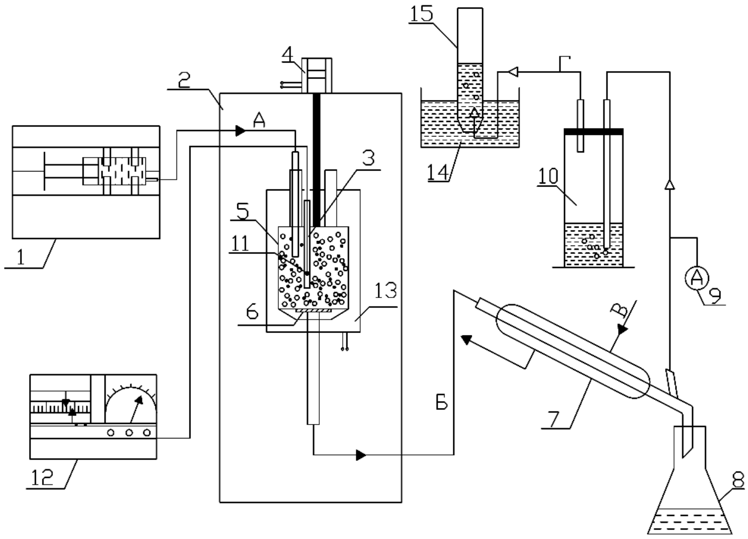


**Fig. 6.** The laboratory setup for studying the cracking process of vacuum gasoil on the aerosol nanocatalysis technology with vibrating bed. 1 – reagent dispenser; 2 – heat chamber; 3, 11 – thermocouple; 4 – vibro device; 5 – reactor; 6 – metal and felt filter; 7 – water refrigerator; 8 – receiver liquid fraction; 9 – analysis point; 10 –gas cracking washout; 12 – device for control of frequency vibration and temperature; 13 – furnace; 14 – water tank; 15 – gas phase receiver

We having considered the many types of reactors from grinding mills, reels, various types of crushers. It was found that the necessary conditions for the catalytic system, the best you can create in colloid mills [19].

In this embodiment, it is proposed to use a reactor with a rotating bed as commonly used in practice, particle size reduction. The reactor is located and rotates within a stationary heater, ends with a filter that keeps the nanoparticles in the reactor.

In Fig. 9 the schematic diagram of the proposed disposal of organic compounds by AnC technology with a completely new type of reactor [18, 20].

The reaction products leaving the reactor, flows through the heat exchanger into the cyclone, where it is separated from the catalyst, which is returned through the ejector into the reactor. Then through the scrubber non-toxic reaction products are directed into the atmosphere, and the residual return to the reactor. This reactor is characterized in that it served a mixture of: organic compounds, oxidizing agent (air) and the catalyst [21].

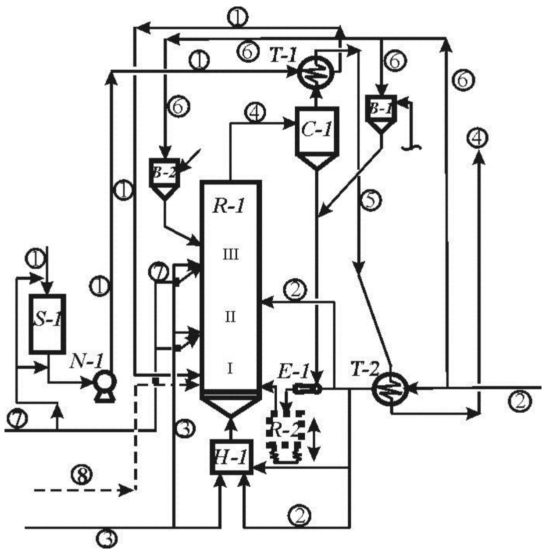


**Fig. 7.** The principal technological scheme of the reactor with fluidized bed of catalytic system and used the reactor with vibrating bed. H-1 - preheating; N-1 - pump; R-1 - reactor; E-1- ejector; C-1 - cyclone; S-1 - scrubber; T-1, T-2 - heat-exchangers; B-1, B-2 - containers for dispersed materials and catalyst. Flow: 1 – liquid and gaseous reagent; 2 – air; 3 – fuel gas; 4 – products of reaction; 5 – gaseous reaction products after refrigerator; 6 – air for dispersed materials flow; 7 – nitrogen for expulsion lines; 8 – solid reagent flow.

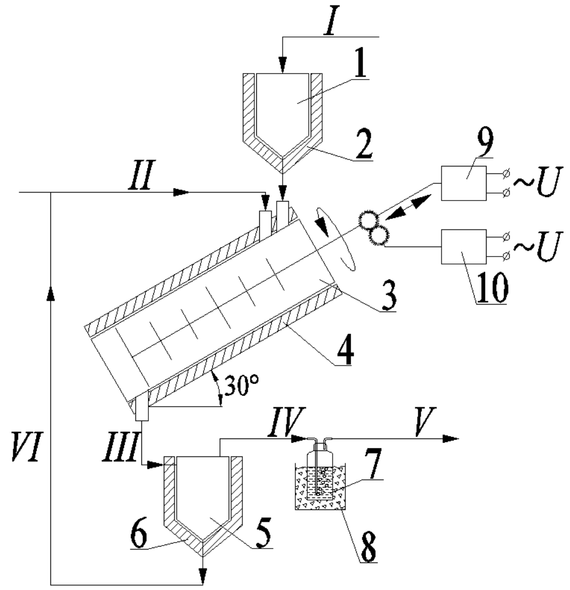


**Fig. 8.** The principal scheme of the aerosol nanocatalysis reactor with vibrating bed 1 – container for liquid reagents; 2 – heater of initial reagents; 3 – reactor; 4 – electro-heater; 5 – cyclone; 6 – heater of the reaction products; 7 – container for the reaction products; 8 – refrigerator of reaction products; 9, 10 – a device for producing vibrations vibrating impulses; I – flow initial reagents; II – submission of the catalyst; III – the reaction products and the catalyst; IV – products of the reaction; V – gaseous reaction products; VI – the recycle of the catalyst

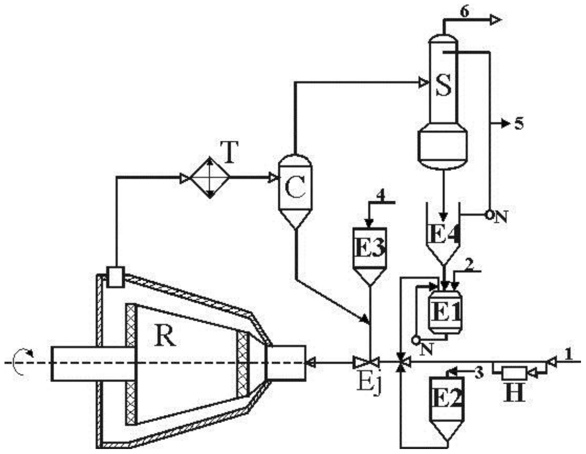


**Fig. 9.** The schematic diagram of neutralization of organic compounds with a rotating catalyst bed by AnC technology: R – reactor; C – cyclone; T – heat-exchanger, S – scrubber; H – preheating; N – pump; E1-3 – containers for liquid, solid waste and catalyst; E4 – settler; Ej – ejector; 1 – air; 2 – liquid waste; 3 – solid waste; 4 – catalyst; 5 – purified water; 6 – gases in the atmosphere

## CONCLUSIONS

1. To educating advantages and disadvantages of fluidized bed reactor in the technology for heterogeneous catalysis using a catalyst.
2. It considered a new promising aerosol nanocatalysis technology and some types of units with fluidized bed reactor for processes of treatment of various types of industrial waste.
3. It shows a more advanced version of the aerosol nanocatalysis technology using the reactor with vibrating bed.
4. A new reactor with vibrating catalytic system that can turn high boiled organic compounds into the products of synthesis. The device combines vibro system to activate the surface of catalyst particles with rotational movements catalytic system for uniform air distribution throughout the volume of the reactor.
5. It proposed a new variant of the rotating reactor that can turn any organic compounds in the target products. In the apparatus containing dispersed material is a mixture of organic compounds oxidizing agent and catalyst. The rotation of the reactor allows to evenly distribute the catalytic system throughout the volume of the reactor and speeds up the access of the reagent molecules to the active surface of the catalyst.

## REFERENCES

1. **Glikin M., Kutakova D., Prin E., Glikina I. and Volga A., 2000.** Heterogeneous catalysis on porouse carrier and in aerosol (Catalysis and oil-chemistry). Nr5-6. 92-101 (in Russian)
2. **Glikin M., Kutakova D. and Prin E., 1999.** Unsteady processes and aerosol catalysis (Chemical Engineering Science), 54. 4337-4342.
3. **Glikin M.A., Kutakova D.A., Glikina I.M., Volga A.I., 2000.** New way to increase catalyst activity.

Collection of abstracts V Ukrainian-Polish Symposium. Odessa. 57-58.
4. **Glikin M.A., Glikina I.M., Kauffeldt E., 2005**. Investigations and Applications of Aerosol Nano-catalysis in a Vibrofluidized (Vibrating) Bed. (Adsorption Science & Technology). Vol. 23, Nr. 2. 135-143.
5. **Glikin M.A., Kutakova D.A., Pavlyuk E.A., Glikina I.M., Perestoronina R.Eu., 2001**. Aerosol catalysis: a new way in industrial wastes disposal. Collection of abstracts XV International Conference on Chemical Reactors. Helsinki, Finland. 215-217 (in English)
6. **Glikin M.A., Kutakova D.A., Glikina I.M., Volga A.I., 2001**. A new way to increase catalytic activity. (Adsorption science and technology). Vol. 19. Nr. 2. 101-115.
7. **Glikin M.A., Glikina I.M., Kudryavtsev S.A., 2009.** Specific control parameters in the technology of aerosol nanocatalysis. (ANNALES Universitatis Mariae Curie-Sklodowska). sectio AA CHEMIA. Vol. LXIV. 218-226.
8. **Glikin Marat, Porkuian Olga, Amer Habib Alsooz and Kudryavtsev Sergey, 2013.** Using the aerosol of SiO2/ZrO2 catalyst nanoparticles to obtain gasoline and diesel from vacuum gasoil (TEKA). Vol. 13. Nr3. 56-62.
9. **Porkuian O.V.**, **Glikin M.A.**, **Tomson A.V. and Eremenko T.Yu., 2012.** The principal automation recommendations of reaction part of catalytic cracking process by aerosol nanocatalysis (Vestnik SNU). Nr.17(188). part 1. 240-244. (in Ukrainian).
10. **Glikin M.A., Kudryavtsev S.A. and Saif Mohammed A., 2012**. The application aerosol nanocatalysis technology for steam conversation of $C_3$-$C_4$ hydrocarbons process. (Vestnik KhPI). Nr.68(974). 173-176. (in Russian).
11. **Glikin M.A. and Saif Mohammed A., 2013.** The study of the kinetics of steam reforming of hydrocarbons C3-C4 aerosol nanocatalysis (East European journal of advanced technologies) Nr.2/6(62).,11-15. (in Russian).
12. **Glikin M.A., Kudryavtsev S.A., Магди Х.А., Амер А.Х., 2013.** The composition of cracking products in aerosol nanocatalysis for the modified Si/Zr catalyst (Technology audit and production reserves). Nr.6.2. 16-18. (in Russian).
13. **Glikin M.A., Kudryavtsev S.A., Kascheev A.S., 2013**. The mechanism of catalytic cracking of vacuum gasoil in terms of aerosol nanocatalysis technology (Vestnik SNU). Nr.14(203). 47-52. (in Ukrainian).
14. **Glikin M.A., 2014**. The search for alternative catalytic technologies. Aerosol nanocatalysis. (East European journal of advanced technologies). Nr.5/6(71). 4-11. (in Russian).
15. **Glikin M.A., 2014**. The Aerosol nanocatalysis is a new technology industrial catalysis. The history of development in Ukraine. (Chemical industry of Ukraine). Nr.2(121).14-23. (in Russian).
16. **Mamedov B.B., Baranova L.A., 2014.** The processing of industrial chlorinated wastes (Vestnik SNU). Nr.9(216). 121-123. (in Ukrainian).
17. **Leonenko S.V., Kudryavtsev S.A., Kutakova D.A., 2014**. Recycling fuel oil to hydrocarbons by aerosol nanocatalysis technology (Vestnik SNU). Nr.10(217). 79-82. (in Russian).
18. **Medvedev Eu.Eu., Shershnev S.A., Glikin M.A**., **2014**. The Aerosol nanocatalysis in a rotating layer. The study of the elements of the kinetics on the example of a test of the oxidation reaction of acetic acid (Vestnik SNU). Nr.10(217). 83-87. (in Russian).
19. **Anna Nikolaenko, Alsayyad Taha Hussein, 2014**. Modelling of vibrating machine-tool with improved construction (TEKA). Vol.1. T.XIV. 174-182. (in English).
20. **Medvedev Eu.Eu., Glikin M.A**. **2012**. Catalytic oxidation of glycerol on the technology of aerosol catalysis Collection of abstracts International scientific-technical conference "Technology-2012". Severodonetsk. Ukraine. 12-13. (in Russian).
21. **Kudryavtsev S.A., 2008**. Alternative energy and resource saving technology of production of ethylene from hydrocarbons is aerosol nanocatalysis Proceedings of the V International conference "Strategy of quality in industry and education". Varna-Dnepropetrovsk. Bulgaria-Ukraine. 152-154. (in Russian).

## НОВЫЕ ТИПЫ РЕАКТОРОВ ДЛЯ ХИМИЧЕСКИХ ПРЕВРАЩЕНИЙ ОРГАНИЧЕСКИХ СОЕДИНЕНИЙ НА АЭРОЗОЛЬ С ТОЧКИ ЗРЕНИЯ НАНОКАТАЛИТИЧЕСКОЙ ТЕХНОЛОГИИ

И. Гликина

Аннотация. Возможные применения новой аэрозольной нанокаталитической технологии для осуществления химических превращений органических соединений. Это учитывая реакции компоненты установок технологии аэрозольных нанокаталитических процессов утилизации промышленных и бытовых отходов. Предлагаемая новая конструкция реакторов для осуществления химических процессов в условиях аэрозольного нанокатализатора с вибрирующем слоем.

Ключевые слова: кипящий слой, вибрирующий слой, аэрозоль нанокатализатор, нейтрализации отходов.