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## Section 1. Biology

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### SEASONAL DYNAMICS OF THE AMOUNT OF AMMONIFYING BACTERIA IN THE SOILS OF DJIZZAK STEPPE

**Abstract:** In this article the results of the investigation of the activity of soil microorganisms in slightly saline and medium saline soils. In spring, when the humidity and temperature are optimal, the number of ammonifying bacteria is higher, while in summer, where there is a decrease in humidity, their number declines sharply. In autumn, the number of bacteria studied increases markedly with a decrease in temperature.

**Keywords:** Saline soils, low salinity, medium salinity, microorganisms, gypsum soils.

#### Introduction

The microbiological and biochemical characteristics of soil are the most complicated features of soil bio-diagnostics. Microorganisms are very sensitive indicators, as they sharply react to any various changes in the environment. This characteristic of the microbes is mostly reported in the literature. It has now been proved that the same group of microorganisms can perform even opposite physiological processes in different conditions, for example, denitrification and nitrogen fixation.

One of the significant environmental factors that have an impact on the effect on the activity of soil microorganisms is a salinization. When a large amount of salts are accumulated in soil because of salinity, it can reach a high salinity up to 6–7%. A large accumulation of salts in soil may cause to die

of microorganisms, which breaks the mechanism of soil fertility. But at the same time, it should be noted that soil microorganisms respond to the levels of salinity in soil in various way.

Microorganisms are an essential component of the biological cycle of energy and substances in the biosphere and in contrast to higher plants and animals, they have universal geochemical functions [11]. Without great and cumulative world of the inhabitant living in soil, there cannot be the soil itself [9; 10]. The knowledge of the patterns of development of microbial populations in soils is of great importance for understanding the true role of soil microflora in the ecosystem, as well as the intensity of its biochemical activity in certain natural conditions [2].

The formation of soil and its fertility is the result of the life activity of organisms which inhabit in

soil. The essence of soil formation is the accumulation and enhancement of fertility in the primitive relatively infertile rock, which changes under the influence of those organisms in soil. Since microorganisms are the mandatory and most active representatives in this process, the problem of fertility is legitimately considered as a microbiological [1].

The work of microorganisms can continuously raise the potential of soil fertility. Human activity can turn the potential wealth of soil into a real fertility that gives a high crop yields. Conditions that can create a high yields would improve soil properties, and make them more favorable for the life of some groups of microorganisms.

Depending on the amount of soil organic matter, certain types and doses of fertilizers affect the soil microorganisms unequally. Favorable conditions for development of soil microbiota can be created when such nutrients as calcium, magnesium, and potassium prevail in the soil. Strengthening of plant nutrition should occur not only through the application of fertilizers, however due to intensification of the activity of specific microorganisms developing in rhizosphere that able to transfer slightly soluble substances into forms that easily assimilated by plants.

Studies the bio-dynamics of soil microorganisms refer to determine the productivity of timely functioning of microorganisms, evaluation of dependence of the amount of microbial cells on environmental factors, setting of the features characterizing the dynamics of the amount of microorganisms, which will ultimately predict microbial productivity, and relative contribution of various groups of microorganisms into the whole biomass in soil.

The dynamics of microorganisms' amount includes short-term and seasonal changes in their functioning over time. There is plenty of information available on the seasonal variability of microorganisms in literature [13]. Issue of studying the dynamics of soil microorganisms suggests both searching of practical approaches and find hypotheses that al-

low to interpreting the origin and nature of various changes in the number of microorganisms.

Major requirement of the need to studying the dynamics of abundance and biomass of soil microorganisms is accuracy and reliability of the data obtained that depend on what components of soil microbial complex are considered and what methods are used in order to count them. In soil fertility, agronomically important groups of soil microorganisms involved in the cycle of nitrogen and carbon play indispensable role. Their amount can be an indication of assessing the soil and identifying of the direction of the processes occurring in it.

Microorganisms can be found in any component of the environment; however most of them are available in the upper soil horizons. Despite the fact that the average mass of bacterial cell is only  $7-9 \times 10^{-14}$  g, their biomass in one hectare of virgin soil is estimated at 3-5 centners while the cultivated layer contains 2-5 tons of microorganisms [5; 6]. It is known that bacteria are the most widespread forms of soils microorganisms. When counting bacteria using direct microscopic calculation method by Vinogradsky, their amount in a gram of soil is estimated at billions. The number of bacteria in soil depends: first of all, on soil type and the period of its use in agricultural practices. This may also change with depth and seasonal fluctuations. Majority of bacteria are in the surface layers of soil (up to 30 cm) while less amounts in subsoil exist. Activity of bacteria is identified according to transformation of both organic (nitrogenous and nitrogen-free) substances and mineral compounds such as nitrogen, sulfur, phosphorus, iron etc. in soil.

Bacteria cause various transformations of mineral and organic substances especially of importance are such processes associated with nutrient release for plants while increasing soil fertility as ammonification, nitrification, nitrogen fixation, cellulose decomposition etc. Activity of bacteria may be restricted by such factors as moisture deficit and unfavorable temperature. Therefore, intensive period

of microbial activity cannot be judged in autumn and spring seasons. But, in summer a significant decrease in the number of bacteria is observable because of moisture lack and high temperature.

It must be noted that all mention above work state the main features of the soils in Mirzachool foot hill plain which are salinized by water soluble salts and gypsum. High salt and gypsum level in the soils develops unfavorable conditions for most soils which makes troubles in their possible amelioration. Obviously they were reported in the recent studies of the researchers from Uzbekistan and Russia [3; 4; 7; 8; 12; 14; 15; 16].

**Research area and methods.** There are sierozem, meadow-sierozem, sierozem-meadow, solonchak, meadow and meadow-marsh soils with different salinity and gypsum level in Zarbdor district. Soil samples were taken from at 0–30, 30–50 and 50–70 cm depths for analyzes. Microbiological analyzes were carried out the day after of sampling day by MPN method.

Soils microfloras determined according to following methods: total number of microorganisms that assimilate organic nitrogen (ammonifiers) by

meat-peptone-mahar (MPA). The research was carried out at the Department of Agrochemistry and Soil Science of Tashkent State Agrarian University. Special biological analyzes in soil samples were done during spring, summer, and autumn periods and were implemented by research group of the Center of AgroEcoBiototechnology at NUUz.

**Results and Discussion.** Ammonification is the first step of nitrogen cycle. Consequent result of vital activity of animals and plants, a large number of nitrogen-containing organic compounds fell on soil, which are susceptible to ammonification accompanied by the release of ammonia. Ammonification is carried out by ammonifying bacteria, as well as actinomycetes and micromycetes that largely dependent on the enrichment of soil with nitrogen-containing organic substances.

In particular conditions, the small amount of bacteria is due to lack of favorable moisture or temperature, on the other hand lack of organic substances may also lead to decrease in microbial activities. Another factor that has much effect on the number of bacteria is geographical distribution of soil type that creates largely dependent on the climate.

Table 1. – Distribution of ammonifying bacteria along the profile of soil of Djizak steppe (thousand per gram of soil)

№ profile	Soil type	Depth, cm	Ammonifying bacteria		
			spring	summer	autumn
1	2	3	4	5	6
Profile I-3	Typical sierozem, nonsaline	0–15	1800	1710	1780
		15–30	1400	1300	1340
		30–50	600	500	550
Profile I-29 a	Sierozem-meadow, strongly saline	0–15	1500	1200	1300
		15–30	1200	930	1100
		30–50	550	400	450
Profile I-79	Sierozem-meadow	0–15	830	680	770
		15–30	600	470	580
		30–50	340	270	300
Profile II-87	Sierozem-meadow	0–15	780	560	690
		15–30	580	400	450
		30–50	320	250	300



1	2	3	4	5	6
Profile I-99	Gray-brown-meadow, medium and strongly saline	0–15	760	545	630
		15–30	520	340	400
		30–50	300	200	285
Profile II-39	Meadow, medium and strongly saline	0–15	670	504	600
		15–30	455	320	390
		30–50	220	130	200
Profile II-79	Meadowsolonchak	0–15	420	350	380
		15–30	290	200	250
		30–50	90	60	80
Profile 41 a	Meadowsolonchak	0–15	230	180	200
		15–30	100	70	80
		30–50	60	30	50

In describing the conditions, we indicated that studied soils of desert zone had sharp difference than the soils of sierozem belt by their agrochemical and physicochemical properties. Extremely unfavorable climatic conditions such as high summer temperature, low relative air humidity, high moisture evaporation from soil surface and low organic matter content are major limiting factors of microbiological processes in soil.

Our results (Table 1) revealed that the largest quantity of ammonifying bacteria growing on MPA medium are belonged to sierozem soils with an estimation in millions. The greatest number of ammonifiers was found in the spring period (Figure 1) that accounted from 600 to 1800 thousand per gram, while in summer under high temperature, this amount decreased slightly to 500–1710 thousand

per gram. Surprising change was in the autumn that there was an increase in the number of bacteria from 550 to 1780 thousand per gram of soil in contrast to the summer period with the affect of the rainfall and new plant residues covered the soil.

The content of this group of microorganisms were greater in sierozem-meadow soils, where their limiting amount in the upper horizons reached at 760–1500 thousand per gram, and the smallest number was 300–550 thousand per gram of soil. A regular decrease in the number of bacteria studied was observed, their number was higher in upper horizons (0–15 cm). Such distribution of ammonifiers through the profile is primarily related to the content of nitrogen-rich organic substances and plant residues, since these compounds are subject to an ammonification.

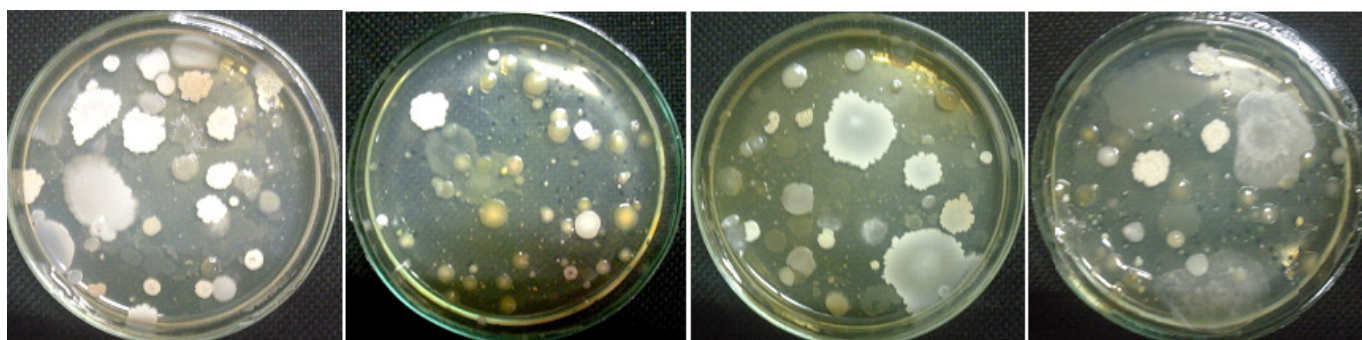


Figure 1. Growth of microorganisms on a MPA medium

The poorest one of the amount of these microorganisms was in solonchaks where their number varied from 230 to 420 thousands per gram even falls from 100–290 to 60–90 thousands per gram of soil. Intermediate place on the number of ammonifiers

are occupied by meadow soils with medium and strong salinity. Their number ranges from 220 to 670 thousand per gram in the soil profile. The largest quantity identified in the spring period while a smaller number is observed in the summer months.

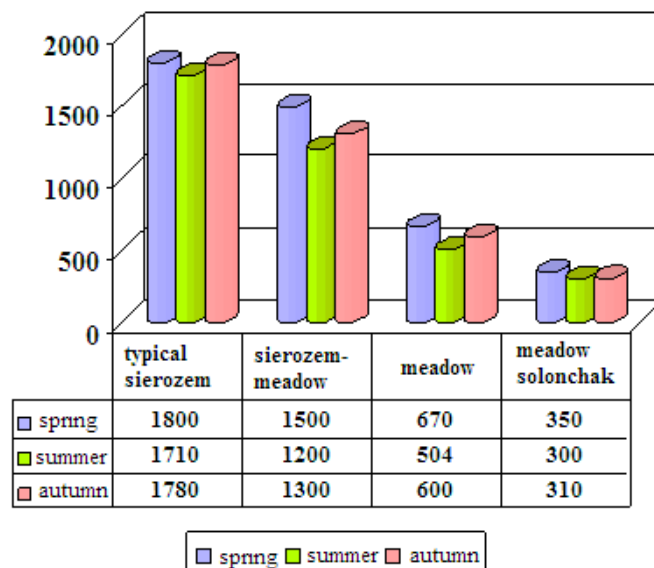


Figure 2. Seasonal dynamics of the amount of ammonifying bacteria in Djizakh steppe soils (thousands COE/per gram soil)

Thus, microbiological studies showed that the seasonal dynamics of the amount of ammonifying bacteria in typical sierozems had similarity in all of studied soils simultaneously.

Such distribution pattern perhaps is depended on the climatic features of the region, as in spring when moisture and temperature are optimal creates conditions for more sustaining of ammonifiers whilst in parallel of the decrease in moisture their number is significantly falls down in summer, but in autumn there can be seen a visible increase in the quantity of the bacteria studied.

**Conclusion.** Distribution of bacteria through the profile has certain pattern. Assessing the amount of bacteria growing on MPA showed that upper horizons are abundant of bacteria. When the depth increases, with a decrease in the number of bacteria are more likely appeared. This is mainly related on the decrease of organic matter content in soil as well as change in air regime etc. According to the pattern of distribution of humus through soil profile the increase in bacterial number are take place. Another last but not least factor which has direct influence on the number of bacteria is plant rooting system.

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## Section 2. Information technology

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### INVESTIGATION OF THE USE OF HYBRID MOBILE APPLICATIONS

**Abstract:** Currently, information technology is actively developing. In this article we investigate the advantages of hybrid mobile applications, the essence of their use, as one of the modern means of communication for business. Successful implementation examples are considered.

**Keywords:** hybrid mobile applications, business, communications, internet.

**Formulation of the problem.** Modern opportunities for expanding business offer owners of small and large companies to invest in the promotion of goods and services on the Internet. The availability of mobile devices and their functionality make you think about why you need to have a mobile application besides a regular website. Through it new ways open not only for direct sales, but also opportunities to build a marketing strategy and establish close contact with the client.

**Analysis of recent research and publications.** The issue of using mobile marketing, including mobile applications, is quite relevant and studied by both domestic and foreign market researchers. In particular, how to apply the mobile marketing toolkit in various business areas and how it can help companies to increase brand awareness and customer loyalty, attract customers to brand communica-

tions, examined in detail researchers such as A. Michael, B. Salter, L. Bugaev, J. Fedorak, V. Mazurenko, N. Matvienko, A. Kust [1].

**Allocation of unresolved parts of a common problem.** Underestimation of mobile applications by Ukrainian companies to improve long-term relationships with customers and improve business processes.

**The purpose of the article** is to generalize and identify the features of using hybrid mobile applications in Ukraine and the world. The emergence of the role of mobile applications in the modern world, as one of the actual ways of analyzing business processes, promoting products and improving customer loyalty.

**The main material of the study.** Mobile Internet every year beats all records of popularity. Already in 2015, the traffic of connecting users to the Internet through mobile devices exceeded the

number of users from stationary computers. In the near future, further growth is projected. This is a signal for all companies to rebuild the strategy in the market of goods and services.

According to the company Clutch [2]:

- 42% of US businesses have applications, and by the end of 2017 this percentage will increase to 67%. Thus, the penetration of mobile applications in the small business environment will grow by one and a half times in just one year;

- After 2017, another 12% of companies plan to make their own applications. Do not plan to do 23% of small and medium-sized enterprises;

- By the end of 2017, demand for the development of mobile applications will grow 5 times faster than the state of IT companies able to meet this demand.

Below is the statistics of the use of various devices and mobile operating systems in the world at the end of 2017 [3]:

Web traffic:

PC – 45%;

Phone – 50%;

Tablet – 5%;

Other device – 0,12%.

Mobile operation system:

Android – 71,6%;

iOS – 19,6%;

WindowsPhone – 8,8%;

Depending on the functions to be performed, you should determine what type of application will be used. At the moment, there are three types of applications for mobile devices [4]:

1. native application;
2. hybrid application;
3. web-application

Hybrid mobile applications, which are a combination of native and web applications. They are the golden mean in terms of time and financial costs, it is most suitable for choosing.

A mobile application of a hybrid type is a cross-platform model designed to work with phone software. It combines certain options of native and web

applications, which makes it a universal development. This application has the function of updating information. In the hands of entrepreneurs it will become a valuable marketing tool for attracting and retaining customers, as well as solving potentially important tasks [5].

Among the obvious advantages of this application, it should be noted:

- affordability;
- high speed of creation;
- adapted for changes due to independent updating;
- Ability to apply immediately for multiple platforms;
- reuse of code from the website;
- saving memory on the phone, because the software product is stored on separate servers.

It is important to remember that to solve specific tasks and the effective operation of the application, the customer must intelligibly communicate the main goals that he wants to achieve with his help in a particular market segment. At the same time, due attention should be paid to the design of the product and to satisfy all customer needs.

**Benefits of a hybrid mobile business application:**

A) Additional resource for business expansion

Regardless of the scope of your services or the level of popularity of products, mobile applications will be an additional resource for expanding the company's capabilities. With its help, you can at times increase the turnover and find new potential customers. The mobile application takes you away from local attachment to one territory and opens up to you a large sales market, the dimensions of which are not limited to the territorial scope. This platform can serve not only as a direct channel for the sale of goods and services, but also a field where the buyer will receive reliable information, and a potential business partner will study the conditions and establish contact with you for joint cooperation.

### B) Effective marketing channel for online stores

A hybrid mobile application allows you to create an effective marketing channel. If people use mobile devices as a tool for buying goods, then why not provide this opportunity for him. Users who installed a mobile application on a smartphone will be obviously interested in buying exactly your product. They will receive timely and useful information about:

- holding of shares;
- discounts;
- special offers;
- changes in prices;
- expansion of the range.

### C) Optimal platform for contact with the client

Installing the application on the mobile phone of potential customers and displaying the icon on the monitor will allow it to establish advertising contact with a long-term perspective. To access your products, the user will only need to do one click on the screen. With the installed application, a person is directed to make repeated purchases, because for this you need to perform simple actions.

The mobile device is always with the user, which ensures constant contact with customers. You only need to correctly send text notifications to your audience, which will allow you to establish effective communication with direct benefit to your business. To send messages, you need to organize the correct strategy. The user should only get really useful data that will correspond to current trends and time.

### D) Involving clients in your business

With the help of a hybrid mobile application, you can better monitor your business, actively monitor the mood of your target audience and adjust the company's work. For customers, this is a resource through which they can use loyalty programs and other beneficial offers. It will allow you to keep feedback with the customer and get feedback about the work of employees and the quality of the product. You will also be given control over the application and the ability to improve its functionality, depending on user behavior.

### E) An effective tool for controlling business performance

For the owner it is a chance to get a ready-made tool for the analysis of electronic commerce, because there is an opportunity for convenient collection of information about purchased goods, their quantity and value. Settings allow you to select the desired metrics for you, which will be displayed in real time. Knowledge of specific numbers will allow for more effective meetings with the company's management. Based on this information, you can build a strategy for more successful promotion of the company in the market.

### F) Convenient resource for the exchange of corporate data

The mobile application will secure corporate information and will allow it to be transmitted quickly through various departments. With its help with the data you can do any actions:

- browse;
- Edit;
- download;
- share with other employees.

All this is done with a convenient device, which everyone always has with him. This also increases the efficiency of the work, if the subordinates are out of the office or went on a long business trip.

### G) Advantage over competitors

Developing and implementing a mobile application is the first step on the road to building a strategy that will be uniquely successful than any attempt to improve the market position of your competitors. With its help, you will soon achieve the loyalty of the target audience, as you can offer them a service much better and more convenient than other companies. At a time when more and more buyers prefer to make purchases without leaving home, the mobile application will improve your performance and give a prompt impetus for future development and prosperity.

### Examples of the most popular hybrid applications [7]:

1. HeartCamera for iOS – allows you to decorate a photo with hand-drawn figurines:

- installation from the store;
- requires the use of a phone camera;
- for work necessary access to the Internet, if there is a desire to share the result of their work;

2. TripCase organizer for travel planning:

- download from the store;
- You can use geolocation;
- Internet connection is required;
- You can use a cellular network;

**Conclusions and offers.** Thus, from the above analysis it can be seen that hybrid applications have the least drawbacks, while they organically combine the advantages of two other categories – native and web applications. There is no doubt that the market for hybrid applications will grow rapidly and grow, and the study of the development tools for such applications is an important and urgent task.

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## Section 3. Mathematics

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### CREATION OF THE INFINITE ALGEBRAIC K-FUNCTORS OF THE P. I

**Abstract:** For the solution of various problems of algebraic topology it is useful to have a design of the universal object in algebraic K – theories, i. e. the classifying space [1, 81–83].

In language of simplicial sets creation of a functor from category of nilpotent subalgebras is carried out to category of conditionally minimum flags. The theorem is proved that the set of flags simplexes meets a condition of completeness [7, 24–27].

**Keywords:** category, a simplex, subalgebras, an endomorphism, an epimorphism, a morphism, a retraction, a flag.

Let  $\Delta$  – category which objects are serially ordered sets:  $[n] = \{0, 1, 2, \dots, n\}, n \in \mathbb{N}$ , a morphisms – nondecreasing univalent mappings. Let's define morphisms of this category:  $d_n^i : [n-1] \rightarrow [n]$  the increasing univalent mapping not accepting value  $i \in [n]$ ,  $s_n^i : [n+1] \rightarrow [n]$  the nondecreasing univalent mapping which is twice accepting value  $i \in [n]$ . Can be shown [7, 24–27] that any nondecreasing  $\alpha : [m] \rightarrow [n]$  display is presented in the form of superposition of a finite number of the main displays  $s^i$  and  $d^i$ .

**Definition 1.** Let  $C$  – the arbitriest category, a simplicial object of category  $C$  is called the arbitriest contravariant functor  $X : \Delta \rightarrow C$ , morphisms of simplicial objects the corresponding functorial morphisms are considered [2, 7–12].

We will designate an image  $[n]$  of an object of category  $\Delta$  at a functor  $X$  a symbol  $X_n$  –  $n$  a layer of a simplicial object  $X$ . Similar to morphisms  $X(d_n^i)$  and  $X(s_n^i)$  are designated, as  $d_n^i$  well  $s_n^i$  as (or  $d^i, s^i$ ). Morphisms:  $d^i$  – operators of capture of sides,  $s^i$  – operators of degeneration.

By the simplicial scheme as it is defined in [6, 20–22] the arbitriest set of tops together with such family of its terminating subsets (simplexes) is called that any subset of any simplex is a simplex and any subset consisting of the single top there is a simplex.

Let  $\sigma^n = (a_0, a_1, a_2, \dots, a_n)$  –  $n$  the measuring simplex consisting  $n+1$  of top  $a_0, a_1, a_2, \dots, a_n$  and  $\sigma^n \supset \sigma^k$ , then  $\sigma^k$  – under a simplex or a side of a simplex  $\sigma^n$ .



Let  $\sigma^k$  – a simplex side  $\sigma^n$ , then the investment is defined  $i: \sigma^k \rightarrow \sigma^n$ , it is an investment it is transitive:  $(i_1: \sigma^{k_1} \rightarrow \sigma^{k_2}, i_2: \sigma^{k_2} \rightarrow \sigma^n \Rightarrow i_2 \circ i_1: \sigma^{k_1} \rightarrow \sigma^n)$ .

Let's define display  $\tilde{F}$  from the simplicial scheme  $X$  in some category  $C$  of sets as follows: for each  $\sigma^n$  simplex from  $X$ ,  $\tilde{F}(\sigma^n)$  is an object in  $C$  and for any investment of simplexes in  $X: i: \sigma^k \rightarrow \sigma^n$  the morphism is defined in  $C: \tilde{F}(i): \tilde{F}(\sigma^n) \rightarrow \tilde{F}(\sigma^k)$  meeting a transitivity condition.

Let's call display  $\tilde{F}$  a contravariant functor  $X$  from in  $C$  being associated with the simplicial scheme  $X$ . Let's  $\tilde{X}$ , construct the simplicial sets associated with a functor  $\tilde{F}$ . Let's define a **design 1**. it agrees [6, 20–22].

At the same time the commutability of the following charts is supposed:

$$\begin{array}{ccccc} \tilde{F}_1(\sigma^n) & \xrightarrow{\tilde{F}_1(i_2)} & \tilde{F}_1(\sigma^{k_2}) & \xrightarrow{\tilde{F}_1(i_1)} & \tilde{F}_1(\sigma^{k_1}) \\ p \downarrow & & p \downarrow & & p \downarrow & \text{and,} \\ \tilde{F}_2(\sigma^n) & \xrightarrow{\tilde{F}_2(i_2)} & \tilde{F}_2(\sigma^{k_2}) & \xrightarrow{\tilde{F}_2(i_1)} & \tilde{F}_2(\sigma^{k_1}) \\ & & \tilde{\sigma}_1^{n} \xrightarrow{\tilde{d}_1(i_2)} \tilde{\sigma}_1^{k_2} \xrightarrow{\tilde{d}_1(i_1)} \tilde{\sigma}_1^{k_1} & & \\ & & p \downarrow & p \downarrow & p \downarrow \\ & & \tilde{\sigma}_2^{n} \xrightarrow{\tilde{d}_2(i_2)} \tilde{\sigma}_2^{k_2} \xrightarrow{\tilde{d}_2(i_1)} \tilde{\sigma}_2^{k_1} & & \end{array}$$

where  $i_1: \sigma^{k_1} \rightarrow \sigma^{k_2}, i_2: \sigma^{k_2} \rightarrow \sigma^n$  investments of simplexes in  $X$ .

**Definition 2.** Let  $Q$  – some projective  $A$  module, a flag  $\mathcal{F}$  in the module  $Q$  we will call terminating filtration the free  $Q$  – submodules:  $Q = Q_0 \supseteq Q_1 \supseteq \dots \supseteq Q_l \supseteq 0$ , such that everyone either  $Q_i$  coincides with  $Q_{i+1}$ , or is a direct item in  $Q_{i+1}$ , we will call  $l$  – length of a flag we  $\mathcal{F}$ . Will designate  $\Phi$  through a set of all flags  $\mathcal{F}$  of the free  $\mathcal{A}$  – the module  $\leftrightarrow \mathcal{A}^n$ . Let  $\mathcal{F}^n = \{A^N \supseteq \mathcal{F}_1 \dots \supseteq \mathcal{F}_n \supseteq 0\}$  length flag  $n$  in the module  $\mathcal{A}^n$ . Let's designate through  $X_n$  a set of flags of length  $n$  in the module we  $\mathcal{A}^n$ . Will define operators  $d_i$  and  $s_i$  on  $X_n$  subsets from  $\Phi: d_i: X_n \rightarrow X_{n-1}$  operators of deletion  $i$  – an item  $\mathcal{F}_i$

in flags  $X_n$ , i.e. any flag  $\mathcal{F}^n = \{A^N \supseteq \mathcal{F}_1 \dots \supseteq \mathcal{F}_i \supseteq \dots \supseteq \mathcal{F}_n \supseteq 0\}$ , passes into a flag  $\mathcal{F}^{n-1} = \{A^N \supseteq \mathcal{F}_1 \dots \supseteq \hat{\mathcal{F}}_i \supseteq \dots \supseteq \mathcal{F}_n \supseteq 0\}$ ,  $s_i: X_n \rightarrow X_{n+1}$  – the operator of a gemination  $i$  – the module  $\mathcal{F}_i$ , i.e.  $\forall \mathcal{F}^n = \{A^N \supseteq \mathcal{F}_1 \supseteq \dots \supseteq \mathcal{F}_{i-1} \supseteq \mathcal{F}_i \supseteq \mathcal{F}_{i+1} \supseteq \dots \supseteq \mathcal{F}_n \supseteq 0\}$  passes into a flag  $\mathcal{F}^{n+1} = \{A^N \supseteq \mathcal{F}_1 \supseteq \dots \supseteq \mathcal{F}_{i-1} \supseteq \mathcal{F}_i \supseteq \mathcal{F}_i \supseteq \mathcal{F}_{i+1} \supseteq \dots \supseteq \mathcal{F}_n \supseteq 0\}$ . It is possible to show [3, 103–109] that display  $[n] \rightarrow X_n$  sets a category morphism  $\Delta$  in category of all flags  $\Phi$  of the free module  $\mathcal{A}^n$ , i.e. we have a functor from category  $\Delta$  in category  $\Phi$ . This functor sets structure of a simpitsonny set on at the same time  $\Phi$ .  $X_n$  – is a set of  $n$  – dimensional simplexes in  $\Phi$ .

The operator  $d_i: X_n \rightarrow X_{n-1}$  is captures of  $(n-1)$  sides in dimension simplexes  $n$ .

Let  $\sigma^n$  are  $n$  – measuring simplexes – flags from  $X_n$ , where  $\sigma^n = \{A^N \supseteq \mathcal{F}_1 \supseteq \dots \supseteq \mathcal{F}_n \supseteq 0\}$ , modules  $A^N$  and  $\mathcal{F}_1, \mathcal{F}_2, \dots, \mathcal{F}_n$  – we will call simplex tops. So, sides of various dimension of a simplex  $\sigma^n$  turn out application of one or larger number of times of operators of capture of sides  $d_i$  to  $\sigma^n$ .

Let  $\sigma^{n_1}, \dots, \sigma^{n_k}$  simplex subsimplexes sides  $\sigma^N \in \Phi$ . Join:  $\bigcup_{i=1}^k \sigma^{n_i}$  these subsimplexes  $\sigma^n$ , the simplex tops of which is all such modules  $\mathcal{F}_j$ , which are tops at least of one simplex  $\sigma^{n_i}, i = 1, \dots, k$ , and frequency rate of top  $\mathcal{F}_j$  in a simplex  $\sigma^n$  are it is equal to the maximal frequency  $\mathcal{F}_j$  rate in simplexes of  $\sigma^{n_i}, i = 1, \dots, k$ . Top  $\mathcal{F}_j$  are regulated the same as they are ordered in a simplex  $\sigma^N$ .

**Definition 3.** The subset  $D \subset \Phi$  is called the complete if  $\forall \sigma^n \in D$  simplex and any its subsimplexes  $(\sigma^{n_1}, \dots, \sigma^{n_k}) \subset D$ , we have  $\bigcup_{i=1}^k \sigma^{n_i} \in D$  (a completeness condition).

**Definition 4.** Let then the subsimplex be minimum for in if any side  $\sigma^n$  does not belong  $D$ .

If  $\sigma^N \in D \subset \Phi$  and  $\sigma^{n_1}, \dots, \sigma^{n_k}$  – various minimum simplexes for  $\sigma^N \in D$ ,

then  $\sigma^n = \bigcup_{i=1}^k \sigma^{n_i} \subset \sigma^N$  we will call conditionally minimum simplex (flag) for  $\sigma^N \in D$ , i. e. to each simplex  $\sigma^N \in D$  there corresponds some simplex  $\sigma^n$  and if  $D$  the complete that  $\sigma^n \in D$ .

**Remark 1.**  $\sigma^n \in D$  he corresponds to any conditionally minimum simplex, at  $\sigma^n = \bigcup_{i=1}^k \sigma^{n_i}$ ,  $\sigma^{n_i}, i = 1, \dots, k$  various minimum simplexes for  $\sigma^n$  in  $D$ .

Let  $D \subset \Phi$  meets a completeness condition, then all conditionally minimum flags  $\tilde{D} \subset D$ . there Is a display:  $p: D \rightarrow \tilde{D}$  being an epimorphism, it compares to each flag  $\sigma^N \in D$  conditionally minimum flag for it  $\sigma^n \in D$ , thus to each subset  $D \subset \Phi$  to the meeting completeness condition, there corresponds the subset of its conditionally minimum flags  $\tilde{D}$ .

Let  $i: D \rightarrow \tilde{D}$  an investment,  $\sigma^n \in \tilde{D}$ , then owing to a remark 1.:  $i(\sigma^n) = \sigma^n, p(\sigma^n) = \sigma^n$  then  $p(i(\sigma^n)) = \sigma^n$ . Thus composition  $p \circ i$  – an identity mapping:  $p: D \rightarrow \tilde{D}$  – a retraction on a subset.

Let  $i_1: D_1 \rightarrow D$  – an investment, then the following chart is commutative:

$$\begin{array}{ccc} D_1 & \xrightarrow{i_1} & D \\ p_1 \downarrow & p \downarrow & \\ \tilde{D}_1 & \xrightarrow{\tilde{i}_1} & \tilde{D} \\ p \circ i_1 \circ j_1 = \tilde{i}_1 & & \end{array}$$

and if  $j_1: \tilde{D}_1 \rightarrow D_1$  – an investment, then

Thus, if  $\{D\}$  – category of subsets with a completeness condition from  $\Phi$  with investment morphisms  $i$ ,  $\{D\}$  – category of subsets with displays  $\tilde{i}$ , that compliance  $D \rightarrow \tilde{D}$  is a covariant functor  $F_1: \{D\} \rightarrow \{\tilde{D}\}$ . It is possible to show that the follow-

ing chart is commutative:  $p_2 \downarrow \quad p_1 \downarrow \quad p \downarrow$ , really, in

$$\begin{array}{ccc} D_2 & \xrightarrow{i_2} & D_1 \xrightarrow{i_1} D \\ p_2 \downarrow & p_1 \downarrow & p \downarrow \\ \tilde{D}_2 & \xrightarrow{\tilde{i}_2} & \tilde{D}_1 \xrightarrow{\tilde{i}_1} \tilde{D} \end{array}$$

force commutabilities of the left-hand and right side of a square of the chart takes place it commutability,

then  $p \circ i_1 \circ i_2 = \tilde{i}_1 \circ \tilde{i}_2 \circ p_2$  on  $D_2$  if  $j_2$  designates an investment  $\tilde{D}_2$  in  $D_2$  that on  $j_2(D_2)$  fairly:  $p \circ i_1 \circ i_2 \circ j_2 = \tilde{i}_1 \circ \tilde{i}_2 \circ p_2 \circ j_2 = \tilde{i}_1 \circ \tilde{i}_2$ , since  $p_2 \circ j_2$  – an identity mapping, then the commuting diagram:

$$\begin{array}{ccc} D_2 & \xrightarrow{i_2} & D_1 \xrightarrow{i_1} D \\ j_2 \uparrow & p_1 \uparrow & p \uparrow \\ \tilde{D}_2 & \xrightarrow{\tilde{i}_2} & \tilde{D}_1 \xrightarrow{\tilde{i}_1} \tilde{D} \end{array}$$

Let's designate through  $END(\mathcal{A}^N)$  algebra  $\mathcal{A}$  – endomorphisms of the free module  $\mathcal{A}^N$ .

**Definition 5.**  $\Phi \supset D$  – an admissible set for a subalgebra  $NA \subset END(\mathcal{A}^N)$ , if for each flag  $\mathcal{F} = \{A^N \supseteq \mathcal{F}_1 \dots \supseteq \mathcal{F}_l \supseteq 0\} \in D$  and for any  $b \in NA$  endomorphism the condition is fair:  $b(\mathcal{F}_j) \subset \mathcal{F}_{j+1}, j = 0, 1, \dots, l, \mathcal{F}_0 = A^N, \mathcal{F}_{l+1} \equiv 0$  for all tops  $\mathcal{F}_j$  a flag  $\mathcal{F}$ . Let  $D \neq \emptyset$ , then  $END(\mathcal{A}^N) \supset NA$  – we will call a subalgebra nilpotent [4, 567–572].

**Theorem 1.** The set  $D$  admissible flags – simplexes from  $\Phi$  meets a completeness condition [7, 24–27].

**Proof**

Let  $\sigma^N$  a flag from  $D$  and  $\sigma^{n_1}, \dots, \sigma^{n_k}$  its admissible subsimplexes.

Let's consider a simplex

$\sigma^n = \bigcup_{i=1}^k \sigma^{n_i} = \{A^N \supseteq \mathcal{F}_1 \dots \supseteq \mathcal{F}_j \supseteq \mathcal{F}_{j+1} \supseteq 0\}$  each top  $\mathcal{F}_j$  a flag  $\sigma^n$  contains in a flag  $\sigma^{n_i} = \{A^N \supseteq \mathcal{F}_1^i \dots \supseteq \mathcal{F}_m^i \supseteq \mathcal{F}_{j+1} \supseteq \dots \supseteq 0\}, i \in [1, k]$  i. e.  $\mathcal{F}_j = \mathcal{F}_m^i$  for some  $m$ .

Since a flag  $\sigma^{n_i}$  admissible,  $b(\mathcal{F}_m) \subset \mathcal{F}_{m+1}^i$  for any  $b \in NA$ , and as on creation of a flag  $\sigma^n$ ,  $\mathcal{F}_{m+1}^i = \mathcal{F}_{j+1}$  or  $\mathcal{F}_{m+1}^i \subset \mathcal{F}_{j+1}$   $b(\mathcal{F}_j) \subseteq \mathcal{F}_{m+1}^i \subseteq \mathcal{F}_{j+1}$ , then flag  $\sigma^n$  – admissible.

Let  $END$  designates category of all nilpotent subalgebras of algebra  $END(\mathcal{A}^N)$  with morphisms of an investment of subalgebras.

To everyone nilpotent  $NA \subset END(\mathcal{A}^N)$  a subalgebra there corresponds the set of admissible flags  $D$ , meeting a completeness condition: i. e. we have compliance  $f: NA \rightarrow D$ . The commuting diagram

takes place:  $NA_1 \xrightarrow{i_1} NA$   
 $f_1 \downarrow \quad f \downarrow$  where the investment is de-

defined as follows: if  $\mathcal{F} \in D$  – an admissible flag for a subalgebra

$NA$ , then it is admissible, apparently, and for a subalgebra  $NA_1 \subset NA$ .

Let  $i_2 : NA_2 \rightarrow NA_1$  – an investment of a nilpotent subalgebra  $NA_2$  in  $NA_1$ , that the following chart

be commutative [5, 118–126]:  $NA_2 \xrightarrow{i_2} NA_1 \xrightarrow{i_1} NA$   
 $f_2 \downarrow \quad f_1 \downarrow \quad f \downarrow$

really, since left-hand and right side of a square of the chart are commutative,  $f_2 = \tilde{i}_2 \circ \tilde{i}_1 \circ f \circ i_1 \circ i_2$ .

Thus we have a contravariant functor:  $F_2 : \{NA\} \rightarrow \{D\}$  from category of nilpotent subalgebras of algebra  $END(\mathcal{A}^N)$  with the morphisms enclosed in category  $\{D\}$  of subsets of a set  $\Phi$ , meeting a completeness condition.

If  $\tilde{D}$  designates a set of conditionally minimum flags for  $D$ , then on proved above  $p : D \rightarrow \tilde{D}$  is a retraction, and  $\tilde{D}$  – a retractor. Earlier we proved existence of a covariant functor  $F_1 : \{D\} \rightarrow \{\tilde{D}\}$  from category of the complete subsets of a set  $\Phi$  in category of conditionally minimum flags  $\tilde{D}$  for sets  $D$ . Superposition of these functors  $F_1 \circ F_2$  sets a contravariant functor  $F = F_1 \circ F_2$  from category of nilpotent subalgebras  $\{NA\}$  in category of retractors of admissible flags, t. e  $F : \{NA\} \rightarrow \{\tilde{D}\} \leftrightarrow FNA$  – image of a subalgebra  $NA$ . The theorem is proved.

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## ON A CERTAIN PROBLEM OF A SINGULAR PERTURBATION OF THE WAVE EQUATION

**Abstract:** A complete asymptotic expansion with respect to a small parameter of the solution of a singularly perturbed Cauchy problem with initial jump for a multidimensional hyperbolic equation of the second order degenerating into a linear hyperbolic equation of the first order is constructed.

**Keywords:** optimal control, perturbation method, internal transition layers, singular perturbation, asymptotic approximations.

### Introduction

Many applied problems of physics, mechanics, engineering, chemistry and biology are described by means of differential equations containing small or large parameters called perturbed equations [1, 627–654; 2, 127–128; 3, 720–730; 4, 10–126]. Depending on the nature of the perturbation, such problems are subdivided into regularly perturbed and singularly perturbed problems. In comparison with regularly perturbed problems, the study of singularly perturbed problems presents a great difficulty. In such problems, the degenerate problem belongs to a different type than the original problem, and difficulties arise in qualitative investigation of the behavior of the solution of a non-degenerate problem. One of the difficult problems in the theory of singularly perturbed problems for differential equations is the construction of asymptotic expansions with respect to a small parameter of solutions for the problems under consideration. The solutions of

singularly perturbed problems for differential equations with a small parameter for the highest derivatives depend on the parameter both in a regular way and in a singular way.

### 1. Statement of the problem

Consider the following singularly perturbed hyperbolic equation of the second order:

$$\varepsilon \left( \frac{\partial^2 V}{\partial t^2} - \Delta V \right) = A(t, x) \frac{\partial V}{\partial t} + \sum_{j=1}^n B_j(t, x) \frac{\partial V}{\partial x_j} + F(t, x), \quad (1)$$

where  $\varepsilon > 0$  – small parameter,  $x = (x_1, x_2, \dots, x_n)$  –  $n$  – dimensional vector,

$$\Delta V = \frac{\partial^2 V}{\partial x_1^2} + \frac{\partial^2 V}{\partial x_2^2} + \dots + \frac{\partial^2 V}{\partial x_n^2}$$

– Laplace operator.

Necessary to consider the behavior of the solution of equation (1) when  $\varepsilon \rightarrow 0$  with initial conditions

$$V_{t=0} = \varphi(x), \quad \varepsilon \frac{\partial V}{\partial t}_{t=0} = \psi(x). \quad (2)$$

The following conditions must be fulfilled:

1) Functions  $A(t, x), B_j(t, x), j = \overline{1, n}, F(t, x)$  are sufficiently smooth in the domain

$$D = \{(t, x) : t \geq 0, x \in R^n\}.$$

2) Functions  $\varphi(x), \psi(x)$  smoothly enough  $R^n$ .

### 2. Calculation of the initial change

To determine the initial jump [5, 145–171]  $\Delta(x)$  multiply equation (1) by  $\varepsilon$  and  $t = \varepsilon\tau$ . Then from (1), (2)

$$\begin{aligned} \frac{\partial^2 V}{\partial \tau^2} - \varepsilon^2 \Delta V &= A(\varepsilon\tau, x) \frac{\partial V}{\partial \tau} + \\ + \varepsilon \left[ \sum_{i=1}^n B_i(\varepsilon\tau, x) \frac{\partial V}{\partial x_i} + F(t, x) \right] \end{aligned} \quad (3)$$

$$V_{\tau=0} = \varphi(x), \quad \frac{\partial V}{\partial \tau}_{\tau=0} = \psi(x).$$

From (3) when  $\varepsilon = 0$

$$\frac{\partial^2 V}{\partial \tau^2} = A(0, x) \frac{\partial V}{\partial \tau}, \quad (4)$$

$$V_{\tau=0} = \varphi(x), \quad \frac{\partial V}{\partial \tau}_{\tau=0} = \psi(x).$$

From (4)

$$\varepsilon \frac{\partial^2 V}{\partial t^2} = A(0, x) \frac{\partial V}{\partial t}, \quad (5)$$

$$V(0, x, \varepsilon) = \varphi(x), \quad \varepsilon \frac{\partial V}{\partial t}(0, x, \varepsilon) = \psi(x),$$

then

$$\frac{\partial V}{\partial t}(t, x, \varepsilon) = \frac{\psi(x)}{\varepsilon} \exp\left(A(0, x) \frac{t}{\varepsilon}\right).$$

Let  $t = t_\varepsilon = -(\varepsilon \ln \varepsilon) / \xi$ . Then from the expression  $\partial V / \partial t$  considering the properties 1), 2) when  $\varepsilon \rightarrow 0$

$$\left| \frac{\partial V}{\partial t}(t_\varepsilon, x, \varepsilon) \right| \leq M, M = \text{const} > 0 \quad (6)$$

for any bounded subset  $G \in R^n$ .

Suppose that  $\lim_{\varepsilon \rightarrow 0} V(t_\varepsilon, x, \varepsilon) = \varphi(x) + \Delta(x)$  for any  $x \in G$ . Integrating both sides of expression (5) from 0 to  $t_\varepsilon$ :

$$\varepsilon \frac{\partial V}{\partial t}(t_\varepsilon, x, \varepsilon) - \psi(x) = A(0, x)(V(t_\varepsilon, x, \varepsilon) - \varphi(x)). \quad (7)$$

Passing to the limit in (7) when  $\varepsilon \rightarrow 0$  considering (6), for any  $x \in G$

$$\Delta(x) = -\frac{\psi(x)}{A(0, x)}. \quad (8)$$

Thus, the initial jump for  $V$  defined. Then it is necessary to construct the asymptotics of the solution of problem (1), (2).

### 3. Construction of the asymptotics of the solution

The asymptotic expansion in the small parameter for the solution of the singularly perturbed problem (1), (2) is considered as the sum

$$V(t, x, \varepsilon) = V_\varepsilon(t, x) + W_\varepsilon(\tau, x), \quad (9)$$

where function  $V_\varepsilon(t, x)$  – the regular part of the asymptotics is representable in the form of a series in powers of  $\varepsilon$

$$V_\varepsilon(t, x) = \sum_{k \geq 0} \varepsilon^k V_k(\tau, x), \quad (10)$$

function  $W_k(\tau, x)$  – the singular part of the asymptotics is representable in the form of a series in powers of  $\varepsilon$

$$W_\varepsilon(\tau, x) = \sum_{k \geq 0} \varepsilon^k W_k(\tau, x), \quad (11)$$

The regular part of the asymptotics  $V_\varepsilon(t, x)$  is determined by means of the initial singularly perturbed differential equation (1)

$$\begin{aligned} \varepsilon \left( \frac{\partial^2 V_\varepsilon}{\partial t^2} - \Delta V_\varepsilon \right) &= A(t, x) \frac{\partial V_\varepsilon}{\partial t} + \\ + \sum_{i=1}^n B_i(t, x) \frac{\partial V_\varepsilon}{\partial x_i} + F(t, x), \end{aligned} \quad (12)$$

and the singular part of the asymptotics  $W_\varepsilon(\tau, x)$  is determined by means of the homogeneous equation corresponding to equation (1) (13):

$$\begin{aligned} \frac{\partial^2 W_\varepsilon}{\partial \tau^2} - \varepsilon^2 \Delta W_\varepsilon &= \\ = A(\varepsilon\tau, x) \frac{\partial W_\varepsilon}{\partial t} + \varepsilon \sum_{i=1}^n B_i(\varepsilon\tau, x) \frac{\partial W_\varepsilon}{\partial x_i}. \end{aligned} \quad (13)$$

Substituting the expansions (10), (11) respectively in (12), (13) and expanding the functions  $A(\varepsilon\tau, x), B_i(\varepsilon\tau, x)$  in the series of degrees  $\varepsilon$  and equating the coefficients for the same powers of  $\varepsilon$  in both sides of equations (12), (13), obtain a sequence



of differential equations for determining the coefficients of the expansions (10), (11).

For  $V_0(t, x)$ ,  $W_0(\tau, x)$

$$A(t, x) \frac{\partial V_0}{\partial t} + \sum_{i=1}^n B_i(t, x) \frac{\partial V_0}{\partial x_i} + F(t, x) = 0, \quad (14)$$

$$\frac{\partial^2 W_0}{\partial \tau^2} = A(0, x) \frac{\partial W_0}{\partial \tau}, \quad (15)$$

and for  $V_k(t, x)$ ,  $W_k(\tau, x)$

$$A(t, x) \frac{\partial V_k}{\partial t} + \sum_{i=1}^n B_i(t, x) \frac{\partial V_k}{\partial x_i} = \Phi_k(t, x), \quad (16)$$

$$\frac{\partial^2 W_k}{\partial \tau^2} = A(0, x) \frac{\partial W_k}{\partial \tau} + \Psi_k(\tau, x), \quad (17)$$

where  $\Phi_k$  already defined function  $V_i(t, x)$ ,  $i < k$ :

$$\Phi_k(t, x) = \frac{\partial^2 V_{k-1}}{\partial t^2} - \Delta V_{k-1},$$

and function  $\Psi_k$  expressed by

$$W_i(\tau, x), \quad i < k:$$

$$\begin{aligned} \Psi_k(\tau, x) = & -\Delta W_{k-2} + \sum_{i=0}^{k-1} \left[ \frac{\tau^{i+1}}{(i+1)!} A_t^{(i)}(0, x) \frac{\partial W_{k-i-1}}{\partial \tau} \right] + \\ & + \sum_{j=1}^n \sum_{i=0}^{k-1} \frac{\tau^i}{i!} B_j^{(i)}(0, x) \frac{\partial W_{k-i-1}}{\partial x_j}. \end{aligned}$$

To uniquely determine the coefficients of the expansions (10), (11), it is necessary to specify the initial conditions. To determine these conditions, we substitute the expansion (9) with (10), (11) into the initial conditions (2) and equate the coefficients for the same powers of  $\varepsilon$  in the expressions obtained. Then

$$W_0(0, x) = \varphi(x) - V_0(0, x), \quad (18)$$

$$\frac{\partial W_0}{\partial \tau}(0, x) = \psi(x),$$

$$W_k(0, x) = -V_k(0, x), \quad (19)$$

$$\frac{\partial W_k}{\partial \tau}(0, x) = -\frac{\partial V_{k-1}}{\partial t}(0, x), \quad k = 1, 2, \dots$$

Initial condition for  $V_0(t, x)$

$$V_0(0, x) = \varphi(x) + \Delta(x), \quad (20)$$

where the initial jump is determined by means of formula (8).

Solution  $V_0(t, x)$  of (14), (20) is constructed as follows [6, 235–236]. Integration of the equation

(14) is equivalent to integrating the characteristic system:

$$\begin{aligned} \frac{dV_0}{dt} &= -\frac{F(t, x)}{A(t, x)}, \quad \frac{dx_1}{dt} = \frac{B_1(t, x)}{A(t, x)}, \quad \dots \\ \dots \frac{dx_n}{dt} &= \frac{B_n(t, x)}{A(t, x)}. \end{aligned} \quad (21)$$

Let

$$x_1 = X_1(t, x_1^0, \dots, x_n^0), \quad x_n = X_n(t, x_1^0, \dots, x_n^0),$$

$V_0 = \tilde{V}_0(t, x_1^0, \dots, x_n^0, \varphi(x_0) + \Delta(x_0))$  – solution of the system of equations (21), satisfying the condition

$$X_1(0, x_1^0, \dots, x_n^0) = x_1^0, \dots, X_n(0, x_1^0, \dots, x_n^0) = x_n^0,$$

$$\tilde{V}_0(0, x_1^0, \dots, x_n^0, \varphi(x_0) + \Delta(x_0)) = \varphi(x_0) + \Delta(x_0).$$

Then the unique solution  $V_0(t, x)$  of the problem (14), (20) will be written in the form of an implicit formula  $V_0(t, x) = \tilde{V}_0(t, x_0, \varphi(x_0) + \Delta(x_0))$ . The system of equations  $x_1 = X_1(t, x_0), \dots, x_n = X_n(t, x_0)$  is uniquely solvable with respect to  $x_0 = (x_1^0, \dots, x_n^0)$  when  $t \geq 0$ . For this it suffices to show that

$$\begin{aligned} \det \left\{ \frac{\partial X}{\partial x_0}(t, x_0) = \frac{\partial(X_1, \dots, X_n)}{\partial(x_1^0, \dots, x_n^0)}(t, x_0) \right\} = \\ = \begin{vmatrix} \frac{\partial X_1}{\partial x_1^0} & \dots & \frac{\partial X_1}{\partial x_n^0} \\ \dots & \dots & \dots \\ \frac{\partial X_n}{\partial x_1^0} & \dots & \frac{\partial X_n}{\partial x_n^0} \end{vmatrix} (t, x_0) \neq 0. \end{aligned}$$

For this consider the system of identities

$$\frac{dX}{dt} = \frac{B(t, X)}{A(t, X)},$$

where

$$\begin{aligned} X &= (X_1(t, x_0), \dots, X_n(t, x_0)), \quad B(t, X) = \\ &= (B_1(t, X), \dots, B_n(t, X)). \end{aligned}$$

Differentiating this system by  $x_i^0$ ,

$$\frac{d}{dt} \frac{\partial X}{\partial x_i^0} = \sum_{k=1}^n \frac{B_{x_k} A - A_{x_k} B}{A^2} \frac{\partial X_k}{\partial x_i^0}, \quad i = 1, 2, \dots, n$$

or in matrix form

$$\frac{d}{dt} \frac{\partial X}{\partial x_0} = \frac{B_x A - A_x B}{A^2} \frac{\partial X}{\partial x_0}. \quad (22)$$

The solution of the matrix equation (22), satisfying the initial condition

$$\frac{\partial X}{\partial x_0}(0, x_0) = E = \begin{pmatrix} 1 & \cdots & 0 \\ \vdots & \ddots & \vdots \\ 0 & \cdots & 1 \end{pmatrix}$$

will

$$\frac{\partial X}{\partial x_0}(t, x_0) = \exp \left[ \int_0^t \frac{B_x A - A_x B}{A^2}(\tau, X(\tau, x_0)) d\tau \right],$$

from where follows

$$\det \frac{\partial X}{\partial x_0}(t, x_0) \neq 0.$$

Let  $x_0 = x_0(t, x)$  – solution of equation  $x = X(t, x_0)$ , then  $V_0(t, x) = \tilde{V}_0(t, x_0(t, x), \varphi(x_0(t, x)) + \Delta(x_0(t, x)))$  gives an explicit formula for solving the problem (14), (20).

Turn to the problem (15), (18). Integrating both sides of equation (15) from 0 to  $\tau$  and taking into account (18), (20) and (8),

$$\begin{aligned} \frac{\partial W_0}{\partial \tau} &= A(0, x)W_0, \quad W_0(0, x) = \\ &= \varphi(x) - V_0(0, x) = -\Delta(x) = \frac{\psi(x)}{A(0, x)}. \end{aligned}$$

The trivial solution of this equation is asymptotically stable when  $\tau \rightarrow +\infty$ , i.e.  $\lim_{\tau \rightarrow +\infty} W_0(\tau, x) = 0$ . Then equation implies that

$$\lim_{\tau \rightarrow +\infty} \frac{\partial W_0}{\partial \tau}(\tau, x) = 0.$$

Thus, the zeroth approximation  $V_0(t, x), W_0(\tau, x)$  constructed.

Turn to the definition

$V_k(t, x), W_k(\tau, x), k = 1, 2, \dots$  Equation (16) is solved by the method of characteristics. To determine the initial condition for  $V_k(t, x)$  consider (19). Suppose that  $W_k(\tau, x), \partial W_k(\tau, x) / \partial \tau$  limits to zero when  $\tau \rightarrow +\infty$ . Then integrating both sides of (17) by  $\tau$  from 0 to  $+\infty$  and considering (19),

$$\frac{\partial V_{k-1}}{\partial t}(0, x) = A(0, x)V_k(0, x) + \int_0^{\infty} \Psi_k(\tau, x) d\tau.$$

Because  $A(0, x) \neq 0$ , then the initial condition for  $V_k(t, x)$ :

$$V_k(0, x) = \frac{\frac{\partial V_{k-1}}{\partial t}(0, x) - \int_0^{\infty} \Psi_k(\tau, x) d\tau}{A(0, x)}, \quad (23)$$

Integrating now both sides of equation (17) from 0 to  $\tau$  with considering (19), (23),

$$\begin{aligned} \frac{\partial W_k}{\partial \tau}(\tau, x) &= A(0, x)W_k(\tau, x) - \int_{\tau}^{\infty} \Psi_k(\tau, x) d\tau, \quad (24) \\ W_k(0, x) &= -V_k(0, x). \end{aligned}$$

The trivial solution of the homogeneous equation corresponding to (24), asymptotically stable with  $\tau \rightarrow +\infty$ . Thus, the formal expansion (9) for the solution of the original problem (1), (2) is constructed.

#### 4. The validity of asymptotic expansions

Defining the terms of the expansions (10), (11)  $n, n+1$  inclusive and denote by  $\bar{V}_n(t, x, \varepsilon)$  the corresponding partial sum of the expansion (9),

$$\bar{V}_n(t, x, \varepsilon) = V_{n, \varepsilon}(t, x) + W_{n, \varepsilon}(\tau, x), \quad (25)$$

where

$$V_{n, \varepsilon}(t, x) = \sum_{k=0}^n \varepsilon^k V_k(t, x), \quad W_{n, \varepsilon}(\tau, x) = \sum_{k=0}^{n+1} \varepsilon^k W_k(\tau, x),$$

and the coefficients  $V_0(t, x)$  and  $W_0(\tau, x)$  are uniquely determined from problems (14), (20) and (15), (18), coefficients  $V_k(t, x)$  and  $W_k(\tau, x)$  respectively, from problems (16), (23) and (17), (19), and the coefficient  $W_{n+1}(\tau, x)$  is uniquely determined from equation (17) under the initial conditions

$$W_{n+1}(\tau, x) = 0, \quad \frac{\partial W_{n+1}}{\partial \tau}(0, x) = -\frac{\partial V_n}{\partial t}(0, x). \quad (26)$$

Suppose  $R_n(t, x, \varepsilon) = V(t, x, \varepsilon) - \bar{V}_n(t, x, \varepsilon)$ , where function  $V(t, x, \varepsilon)$  – exact solution of the problem (1), (2) and function  $\bar{V}_n(t, x, \varepsilon)$ , expressed by the formula (25),

$$\bar{V}_n(t, x, \varepsilon) = \sum_{k=0}^n \varepsilon^k V_k(t, x) + \sum_{k=0}^{n+1} \varepsilon^k W_k(\tau, x). \quad (27)$$

Function  $\bar{V}_n(t, x, \varepsilon)$  in any characteristic cone  $Q$  equations (1) satisfies equation (1) with an accuracy of order  $\varepsilon^{n+1}$ ,

$$\begin{aligned} \varepsilon \left( \frac{\partial^2 \bar{V}_n}{\partial t^2} - \dots - \bar{V}_n \right) - A(t, x) \frac{\partial \bar{V}_n}{\partial t} \\ - \sum_{i=1}^n B_i(t, x) \frac{\partial \bar{V}_n}{\partial x_i} - F(t, x) = Q(\varepsilon^{n+1}). \end{aligned} \quad (28)$$

The following is valid **Theorem** Suppose that the following conditions are satisfied:

- 1) functions  $A(t, x), B_i(t, x),$   
 $i = 1, n; F(t, x) \in C^{n+2}(D);$
- 2)  $\varphi(x), \psi(x) \in C^{n+\lfloor \frac{n}{2} \rfloor + 3}(R^n),$  and  $\psi(x) \neq 0;$

Then problem (1), (2) in  $Q$  – characteristic cone of equation (1) has a unique solution  $V(t, x, \varepsilon),$  which admits the following asymptotic expansion [7, 377–384]:

$$V(t, x, \varepsilon) = \sum_{k=0}^n \varepsilon^k V_k(t, x) + \sum_{k=0}^{n+1} \varepsilon^k W_k(\tau, x) + R_n(t, x, \varepsilon), \tag{29}$$

where the coefficients  $V_k(t, x), W_k(\tau, x), k = 0, 1, \dots, n$  are successively determined from problems (16), (23) and (17), (19), and the coefficient  $W_{n+1}(\tau, x)$  from the task (17), (26), and for the remainder term  $R_n$  and  $Q$  for sufficiently small  $\varepsilon$  the estimate

$$R_n(t, x, \varepsilon)_{N_2^1(Q)} = \left( \int \dots \int_Q \left[ R_n^2 + \left( \frac{\partial R_n}{\partial t} \right)^2 + \sum_{i=1}^n \left( \frac{\partial R_n}{\partial x_i} \right)^2 \right] dt dx \right)^{\frac{1}{2}} = O(\varepsilon^{n+1}). \tag{30}$$

**Proof** According to the conditions of the theorem, in any characteristic cone  $Q$  equation (1) when  $\varepsilon \neq 0$  exists [8, 178–179] the unique solution of problem (1), (2), having continuous derivatives appearing in equation (1).

To prove the estimate (30) we subtract from equation (1) the equation (28). Then, taking (27), (29) we obtain an equation for  $R = R_n(t, x, \varepsilon)$

$$\varepsilon \left( \frac{\partial^2 R}{\partial t^2} - \text{''} R \right) = A \frac{\partial R}{\partial t} + \sum_i B_i \frac{\partial R}{\partial x_i} + g \tag{31}$$

with zero initial conditions

$$R(0, x, \varepsilon) = 0, \frac{\partial R}{\partial t}(0, x, \varepsilon) = 0, \tag{32}$$

where function  $g = g(t, x, \varepsilon)$  at sufficiently small  $\varepsilon$  in  $Q$  has an estimation

$$g(t, x, \varepsilon) = O(\varepsilon^{n+1}). \tag{33}$$

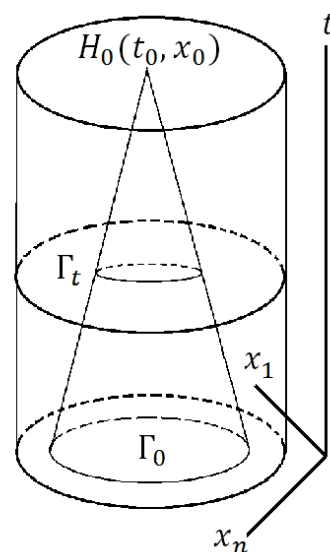


Figure 1.

Let  $Q$  the characteristic cone of equation (1) with vertex at point  $H_0(t_0, x_0).$  Let put the cone  $Q$  in the cylinder with the upper and lower bases  $\Gamma_{t_0}$  and  $\Gamma_0,$  lying respectively on hyperplanes  $t = t_0$  and  $t = 0$  and with a lateral surface  $S,$  lying on a cylindrical hypersurface  $\sum_{i=1}^n (x_i - x_i^0)^2 = \beth^2,$  where  $\beth > t_0$  – arbitrary positive number, and  $\Gamma_t$  – arbitrary section of the cylinder  $Z$  hyperplane  $t \in [0, t_0] = const.$   $Z_t$  – part of the cylinder enclosed between the bases  $\Gamma_0$  and  $\Gamma_t.$

Multiplying both sides of (31) by  $2(AR_t + \sum_i B_i R_{x_i})$  after elementary transformations we obtain the following identity

$$\begin{aligned} & \varepsilon \frac{\partial}{\partial t} \left[ A \left( R_t^2 + \sum_i R_{x_i}^2 \right) + 2 \sum_i B_i R_t R_{x_i} \right] - \\ & - \varepsilon \sum_i \frac{\partial}{\partial x_i} \left[ B_i \left( R_t^2 + R_{x_i}^2 \right) + 2 A R_t R_{x_i} \right] - \\ & - \varepsilon \sum_{i,j (i \neq j)} \frac{\partial}{\partial x_j} \left[ 2 B_i R_{x_i} R_{x_j} - B_j R_{x_i}^2 \right] \tag{34} \\ & = 2 \left( A R_t + \sum_i B_i R_{x_i} \right)^2 + 2g \cdot \left( A R_t + \sum_i B_i R_{x_i} \right) + \\ & + \varepsilon (R_t, R_{x_1}, \dots, R_{x_n}) M (R_t, R_{x_1}, \dots, R_{x_n})^T, \end{aligned}$$

where the matrix  $M$

$$M = \begin{pmatrix} A_t - \sum_i B_{ix_i} & \cdots & B_{nt} - A_{x_n} \\ \vdots & \ddots & \vdots \\ B_{nt} - A_{x_n} & \cdots & A_t - \sum_i B_{ix_i} \end{pmatrix} = (m_{ij})(t, \mathbf{x}).$$

$$= \left( \sum_i (x_i - x_i^0)^2 \right)^{\frac{1}{2}}.$$

We integrate the relation (34) by area  $Z_t$

$$2 \iint_{Z_t} \left\{ \frac{\partial}{\partial t} \left[ A \left( R_t^2 + \sum_i R_{x_i}^2 \right) + 2 \sum_i B_i R_t R_{x_i} \right] - \sum_{i,j(i \neq j)} \frac{\partial}{\partial x_j} (2B_i R_{x_i} R_{x_j} - B_j R_{x_i}^2) \right\} dt dx =$$

$$= 2 \iint_{Z_t} \left( AR_t + \sum_i B_i R_{x_i}^2 \right)^2 dx dt + \quad (35)$$

$$+ 2 \iint_{Z_t} \int g \cdot (AR_t + \sum_i B_i R_{x_i}) dx dt +$$

$$+ \varepsilon \iint_{Z_t} \int (R_t, R_{x_1}, \dots, R_{x_n}) M (R_t, R_{x_1}, \dots, R_{x_n})^T dx dt.$$

Transforming the integral on the left-hand side of (35) by the Ostrogradsky-Gauss formula,

$$2 \iint_{\Gamma_t} \left[ A \left( R_t^2 + \sum_i R_{x_i}^2 \right) + 2 \sum_i B_i R_t R_{x_i} \right] dx -$$

$$- \varepsilon \iint_{\Gamma_0} \left[ A \left( R_t^2 + \sum_i R_{x_i}^2 \right) + 2 \sum_i B_i R_t R_{x_i} \right] dx +$$

$$+ \varepsilon \iint_{S_t} \left\{ \left[ \sum_i (B_i (R_t^2 + R_{x_i}^2) + 2A R_t R_{x_i}) \right] \frac{x_i - x_i^0}{x - x_0} + \right.$$

$$+ \sum_{i,j(i \neq j)} (2B_i R_{x_i} R_{x_j} - B_j R_{x_i}^2) \frac{x_j - x_j^0}{x - x_0} \left. \right\} ds =$$

$$= 2 \iint_{Z_t} \left( AR_t + \sum_i B_i R_{x_i}^2 \right)^2 dx dt +$$

$$+ 2 \iint_{Z_t} \int g \cdot (AR_t + \sum_i B_i R_{x_i}) dx dt + \quad (36)$$

$$+ \varepsilon \iint_{Z_t} \int (R_t, R_{x_1}, \dots, R_{x_n}) M (R_t, R_{x_1}, \dots, R_{x_n})^T dx dt$$

where  $ds$  – surface element  $S_t$ , integration into  $S_t$  is produced on the outside of the surface  $S_t$ , determined by the direction of the normal to  $S_t$ :

$$\bar{n} = \left\{ 0, -\frac{x_1 - x_1^0}{x - x_0}, \dots, -\frac{x_n - x_n^0}{x - x_0} \right\}, x - x_0 =$$

The integral over  $\Gamma_0$  on the left-hand side of (36) is equal to zero, since from (32) follows that  $R_t|_{\Gamma_0} = 0$ , it remains to show

$$\iint_{\Gamma_0} AR_{x_i}^2 dx = 0$$

$$\iint_{\Gamma_0} AR_{x_i}^2 dx = \iint_{\Gamma_0} AR_{x_i}^2 dx_1 \dots dx_n =$$

$$= \int \left( \int_{\Gamma_0} AR_{x_i}^2 dx_i \right) dx_1 \dots dx_{i-1} dx_{i+1} \dots dx_n.$$

Integrating by parts of the inner integral gives

$$\int AR_{x_i}^2 dx_i = ARR_{x_i} - \int R (AR_{x_i})_{x_i} dx_i,$$

hence, by (32) obtain that

$$\iint_{\Gamma_0} \sum_{i=1}^n AR_{x_i}^2 dx = 0.$$

Let  $\square = t_0 + 2\delta$ , where  $\delta$  any positive number, and  $\tilde{\psi}(x) \in C^2(R^n)$  such function that  $0 \leq \tilde{\psi}(x) \leq 1$ ,

$$\tilde{\psi}(x) = \begin{cases} 1, & \|x - x_0\| \leq t_0, \\ 0, & \|x - x_0\| \geq t_0 + \delta. \end{cases}$$

Instead of a function  $R(t, x, \varepsilon)$  consider the function  $\tilde{R} = \tilde{R}(t, x, \varepsilon) = R(t, x, \varepsilon) \tilde{\psi}(x)$ . Obviously,

$$\tilde{R}(t, x, \varepsilon) = \begin{cases} R(t, x, \varepsilon) & \text{in } Q, \\ 0 & \text{on } Z_{side}. \end{cases}$$

Rewriting the equality (36) for function  $\tilde{R} = \tilde{R}(t, x, \varepsilon)$  in the following way [9, 5–12]

$$\varepsilon \iint_{\Gamma_0} \left[ -A(\tilde{R}_t^2 + \sum_i \tilde{R}_{x_i}^2) - 2 \sum_i B_i \tilde{R}_t \tilde{R}_{x_i} \right] dx +$$

$$+ 2 \iint_{Z_t} \int \left( A\tilde{R}_t + \sum_i B_i \tilde{R}_{x_i} \right)^2 dx dt = \quad (37)$$

$$= -2 \iint_{Z_t} \int g \cdot \left( A\tilde{R}_t + \sum_i B_i \tilde{R}_{x_i} \right) dx dt$$

$$- \iint_{Z_t} \int (\tilde{R}_t, \tilde{R}_{x_1}, \dots, \tilde{R}_{x_n}) M (\tilde{R}_t, \tilde{R}_{x_1}, \dots, \tilde{R}_{x_n})^T dx dt.$$

From the inequality  $2cd \leq \delta c^2 + d^2 / \delta, \delta > 0$  and

$$\pm 2g \cdot \left( A\tilde{R}_t + \sum_i B_i \tilde{R}_{x_i} \right) \leq \frac{g^2}{2} + 2 \left( A\tilde{R}_t + \sum_i B_i \tilde{R}_{x_i} \right)^2.$$

Then from (37)

$$\varepsilon \int \int_{\Gamma_t} \left[ -A(\tilde{R}_t^2 + \sum_i \tilde{R}_{x_i}^2) - 2 \sum_i B_i \tilde{R}_t \tilde{R}_{x_i} \right] dx \leq \quad (38)$$

$$\leq \varepsilon \int \int_{Z_t} \int (\tilde{R}_t, \tilde{R}_{x_1}, \dots, \tilde{R}_{x_n}) M(\tilde{R}_t, \tilde{R}_{x_1}, \dots, \tilde{R}_{x_n})^T dx dt + \\ + \int \int_{Z_t} \int \frac{g^2}{2} dx dt.$$

Quadratic form

$$W(\tilde{R}_t, \tilde{R}_{x_i}) = -A(\tilde{R}_t^2 + \sum_i \tilde{R}_{x_i}^2) - 2 \sum_i B_i \tilde{R}_t \tilde{R}_{x_i}$$

is positive definite. We denote by

$$\mu = \min \left\{ \inf_Q \left( |A(t, x)| - \sum_i |B_i(t, x)| \right), \inf_Q |A(t, x)| - B \right\}, \\ B = \max_i \sup_Q |B_i(t, x)|.$$

Then

$$W(\tilde{R}_t, \tilde{R}_{x_i}) \geq \mu \left( \tilde{R}_t^2 + \sum_i \tilde{R}_{x_i}^2 \right). \quad (39)$$

Quadratic form  $(\tilde{R}_t, \tilde{R}_{x_1}, \dots, \tilde{R}_{x_n}) M(\tilde{R}_t, \tilde{R}_{x_1}, \dots, \tilde{R}_{x_n})^T$  is estimated from above in the following way [10, 181–191]

$$(\tilde{R}_t, \tilde{R}_{x_1}, \dots, \tilde{R}_{x_n}) M(\tilde{R}_t, \tilde{R}_{x_1}, \dots, \tilde{R}_{x_n})^T \leq \\ \leq \lambda \left( \tilde{R}_t^2 + \sum_i \tilde{R}_{x_i}^2 \right), \quad (40)$$

where

$$\lambda = (n+2)m, \quad m = \max_{i,j} \sup_Q |m_{i,j}(t, x)|.$$

Introducing the notation

$$J(t) = \int \int_{\Gamma_t} \left( \tilde{R}_t^2 + \sum_i \tilde{R}_{x_i}^2 \right) dx$$

and taking into account (39), (40) from (38)

$$\varepsilon \mu J(t) \leq \varepsilon \lambda \int_0^t J(t) dt + \frac{1}{2} \int \int_{Z_t} \int g^2 dx dt. \quad (41)$$

Applying the Bellman-Gronwall lemma to (41), we have

$$J(t) \leq \int \int_{Z_t} \int \frac{g^2}{\varepsilon} dx dt \cdot e^{\frac{\lambda t}{\mu}} \leq \frac{1}{2} \int \int_{Z_t} \int \frac{g^2}{\varepsilon} dx dt \cdot e^{\frac{\lambda t_0}{\mu}},$$

hence, taking into account the estimate (33)

$$J(t) = \int \int_{\Gamma_t} \left( \tilde{R}_t^2 + \sum_i \tilde{R}_{x_i}^2 \right) dx = O(\varepsilon^{2n+1}). \quad (42)$$

Then necessary to prove, that for  $\tilde{R}(t, x, \varepsilon)$  with small  $\varepsilon$  follows

$$\int \int_{Z_t} \int \tilde{R}^2 dx dt \leq \tilde{C} \int \int_{Z_t} \int \tilde{R}^2 dx dt, \quad \tilde{C} = const > 0. \quad (43)$$

Considering the properties (32), for  $\tilde{R}$  in  $Q$  follows

$$\tilde{R}^2 = \left( \int_0^t \tilde{R}^2 dt \right)^2 \leq t \int_0^t \tilde{R}^2 dt.$$

Integrating it sequentially first on  $\Gamma_t$ , then on  $t$  from  $t = const$ ,

$$\int \int_{Z_t} \int \tilde{R}^2 dt \leq \int_0^t \left( \int \int_{Z_t} \int \tilde{R}^2 dt dx \right) ds \leq \frac{t^2}{2} \int \int_{Z_t} \int \tilde{R}^2 dt dx$$

From (42) using (43)

$$\int \int_{Z_t} \int \tilde{R}^2 dt dx = O(\varepsilon^{2n+1}). \quad (44)$$

From (42), (44)

$$\int \int_{Z_t} \int (\tilde{R}_t^2 + \tilde{R}^2 + \sum_i \tilde{R}_{x_i}^2) dt dx = O(\varepsilon^{2n+1}).$$

For  $R$  in  $Q$

$$\|R_n(t, x, \varepsilon)\|_{N_2^1(Q)} = \\ = \left( \int \int_Q \int (R_t^2 + R^2 + \sum_i R_{x_i}^2) dt dx \right)^{\frac{1}{2}} = O(\varepsilon^{2n+1}).$$

Considering  $R = R_n$ , for number  $n+1$

$$\|R_{n+1}(t, x, \varepsilon)\|_{N_2^1(Q)} = O(\varepsilon^{n+1.5}). \quad (45)$$

Because

$R_n = R_{n+1} + (\bar{V}_{n+1} - \bar{V}_n) = R_{n+1} + \varepsilon^{n+1} (V_{n+1} + \varepsilon W_{n+2})$ , then from  $R_n^2 \leq 2(R_{n+1}^2 + (\bar{V}_{n+1} - \bar{V}_n)^2)$  using (45) followed the estimation

$$\|R_n(t, x, \varepsilon)\|_{N_2^1(Q)} = O(\varepsilon^{n+1}).$$

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## INTERNAL LAYERS FOR A SINGULARLY PERTURBED SECOND-ORDER QUASILINEAR DIFFERENTIAL EQUATION WITH DISCONTINUOUS RIGHT-HAND SIDE WITH NEUMANN AND DIRICHLET BOUNDARY CONDITIONS

**Abstract:** In this work we research a singularly perturbed boundary value problem for a quasi-linear ordinary differential equation of the second order with Neumann and Dirichlet boundary conditions. We have considered new class of problems, in which nonlinearities undergo discontinuities, which leads to the appearance of sharp transition layers in the vicinity of the discontinuity points. The existence is proved and an asymptotic expansion of solutions with an internal transition layer is constructed.

**Keywords:** singular perturbations, asymptotic approximations.

### Introduction

In this paper we study the boundary value problem for a singularly perturbed ordinary differential equation of the second order, which can be regarded as a stationary equation of the reaction-advection-diffusion type with discontinuous reactive and advective terms. Problems of this type belong to the class of discontinuous dynamical systems, which are widely used as mathematical models in the field of mechanics, electronics, biology, etc. [1, 5–22] Boundary problems are of particular interest for applications whose solutions exhibit large gradients in the neighborhood of any of the interior points of the domain of definition. In this case one speaks of the existence of an inner transition layer. Here consider a differential equation that contains a term with the first derivative having the meaning of advection. To this type is the Burgers equation known from the acoustics problems [2, 100–105].

### 1. Formulation of the problem

Consider the following boundary-value problem:

$$\begin{cases} \varepsilon y'' = A(y, t)y' + f(y, t), & 0 \leq t \leq 1, \\ y(0, \varepsilon) = y^0, & y'(1, \varepsilon) = y^1, \end{cases}$$

where  $\varepsilon > 0$  is a small parameter. We assume that the functions  $A(y, x)$  and  $f(y, x)$  are defined everywhere in the domain  $\bar{D} = \{(y, x) \mid I_y \times [0; 1]\}$ , where  $I_y$  is the permissible interval for changing the function  $y(x)$  and sufficiently smooth in  $\bar{D}$ , except for the part of the line  $y \in I_y, x = x_0$ , where  $x_0$  is the interior point of  $[0; 1]$ , which lies inside the domain  $\bar{D}$ , and divides the domain  $\bar{D}$  into two parts:

$$\begin{aligned} \bar{D}^{(-)} &= \{(y, x) \mid y \in I_y, 0 \leq x \leq x_0\}, \bar{D}^{(+)} = \\ &= \{(y, x) \mid y \in I_y, x_0 \leq x \leq 1\}. \end{aligned}$$

Also suppose that the following conditions are satisfied:

$$A(y, t) = \begin{cases} A^{(-)}(y, t), & (y, t) \in D^{(-)}, \\ A^{(+)}(y, t), & (y, t) \in D^{(+)}, \end{cases} f(y, t) =$$

$$= \begin{cases} f^{(-)}(y,t), & (y,t) \in D^{(-)}, \\ f^{(+)}(y,t), & (y,t) \in D^{(+)}, \end{cases}$$

$$A^{(-)}(y,t_0) \neq A^{(+)}(y,t_0), f^{(-)}(y,t_0) \neq f^{(+)}(y,t_0).$$

Suppose that on a segment  $0 \leq x \leq x_0$  there exists a solution  $y = \varphi_1(x) \in I_y$  of the Cauchy problems  $A^{(-)}(y,x)y' + f^{(-)}(y,x) = 0$ ,  $y(0) = y^0$  and on the segment  $x_0 \leq x \leq 1$  there exists a solution  $y = \varphi_2(x) \in I_y$  of the Cauchy problem  $A^{(+)}(y,x)y' + f^{(+)}(y,x) = 0$ ,  $y'(1) = y^1$  and we will assume:  $\varphi_1(x_0) < \varphi_2(x_0)$ ,

$$A^{(-)}(\varphi_1(x),x) > 0, A^{(+)}(\varphi_2(x),x) < 0, 0 \leq x \leq 1.$$

### 2. Attached system

Consider the auxiliary system

$$\frac{d\tilde{y}}{d\tau} = \tilde{z}, \quad \frac{d\tilde{z}}{d\tau} = A^{(\mp)}(\tilde{y},x_0)\tilde{z}, \quad -\infty < \tau < +\infty. \quad (1)$$

We divide each of the second equations of systems (1) by the first, and we arrive at differential equations of the first order with respect to the functions  $\tilde{z}(\tilde{y})$ , which determine the phase trajectories of these systems on the plane  $(\tilde{y},\tilde{z})$ ,  $d\tilde{z}/d\tilde{y} = A^{(\mp)}(\tilde{y},x_0)$ . Points  $(\varphi_1(x_0),0)$ ,  $(\varphi_2(x_0),0)$  on the phase plane  $(\tilde{y},\tilde{z})$  are the rest points, and because functions  $A^{(\mp)}(\tilde{y},x_0)$  is continuous in  $\varphi_1(x_0) < \tilde{y} < \varphi_2(x_0)$ , then there exist the phase trajectory:

$$\tilde{z}^{(\mp)}(\tilde{y}) = \int_{\varphi_{1,2}(x_0)}^{\tilde{y}} A^{(\mp)}(s,x_0) ds.$$

### 3. Asymptotic representation of the solution

The asymptotic approximation of the solution of our problem will be constructed separately from left and right of the point  $x_0$  and denote it as  $y^{(-)}(x,\varepsilon)$  on the interval  $[0,x_0]$  and  $y^{(+)}(x,\varepsilon)$  on the interval  $[x_0,1]$ . We continuously associate the functions  $y^{(-)}$  and  $y^{(+)}$ , and also their derivatives [3, 109–122]

$$z^{(-)} = \frac{dy^{(-)}}{dx}, z^{(+)} = \frac{dy^{(+)}}{dx}$$

at the point  $x_0$ :

$$\begin{aligned} y^{(-)}(x_0,\varepsilon) &= y^{(+)}(x_0,\varepsilon) = p(\varepsilon), \\ z^{(-)}(x_0,\varepsilon) &= z^{(+)}(x_0,\varepsilon) = z(\varepsilon). \end{aligned} \quad (2)$$

The values of  $p(\varepsilon)$  and  $z(\varepsilon)$ , respectively, of the functions  $y^{(\mp)}(x,\varepsilon)$  and  $z^{(\mp)}(x,\varepsilon)$  at the point  $x_0$  are unknown and will be determined in the course of constructing the asymptotic expansion of our problem.

On each of the segments  $[0,x_0]$  and  $[x_0,1]$  we construct asymptotic approximations of the solutions of the following boundary-value problems (3):

$$\begin{cases} \varepsilon y''^{(\mp)} = A^{(\mp)}(y^{(\mp)},x)y'^{(\mp)} + f^{(\mp)}(y^{(\mp)},x), & 0 \leq x \leq x_0, \\ y^{(-)}(0,\varepsilon) = y^0, y^{(-)}(x_0,\varepsilon) = p(\varepsilon), \\ \varepsilon y''^{(+)} = A^{(+)}(y^{(+)},x)y'^{(+)} + f^{(+)}(y^{(+)},x), & x_0 < x \leq 1, \\ y^{(+)}(x_0,\varepsilon) = p(\varepsilon), y'^{(+)}(1,\varepsilon) = y^1. \end{cases} \quad (3)$$

Problems (3) for the ordinary differential equations of the second order are equivalent to the following problems for systems of equations of the first order:

$$\begin{cases} y'^{(\mp)} = z^{(\mp)}, \varepsilon z'^{(\mp)} = A^{(\mp)}(y^{(\mp)},x)z^{(\mp)} + f^{(\mp)}(y^{(\mp)},x), \\ 0 \leq x \leq x_0, y^{(-)}(0,\varepsilon) = y^0, y^{(-)}(x_0,\varepsilon) = p(\varepsilon), \\ y'^{(+)} = z^{(+)}, \varepsilon z'^{(+)} = A^{(+)}(y^{(+)},x)z^{(+)} + f^{(+)}(y^{(+)},x), \\ x_0 \leq x \leq 1, y^{(+)}(x_0,\varepsilon) = p(\varepsilon), z^{(+)}(1,\varepsilon) = y^1. \end{cases} \quad (4)$$

For a detailed description of the behavior of the solution in the vicinity of the transition point layer and boundary parts we introduce an extended variables:  $\tau_0 = x/\varepsilon$ ,  $\tau = (x-x_0)/\varepsilon$ ,  $\tau_1 = (1-x)\varepsilon$ .

Asymptotic expansions of the solutions of each of the problems (4) will be constructed in the form of sums of three terms:

$$\begin{aligned} y^{(-)}(x,\varepsilon) &= \bar{y}^{(-)}(x,\varepsilon) + Ly(\tau_0,\varepsilon) + Q^{(-)}y(\tau,\varepsilon), \\ z^{(-)}(x,\varepsilon) &= \bar{z}^{(-)}(x,\varepsilon) + Lz(\tau_0,\varepsilon) + Q^{(-)}z(\tau,\varepsilon), \\ y^{(+)}(x,\varepsilon) &= \bar{y}^{(+)}(x,\varepsilon) + Q^{(+)}y(\tau,\varepsilon) + Ry(\tau_1,\varepsilon), \\ z^{(+)}(x,\varepsilon) &= \bar{z}^{(+)}(x,\varepsilon) + Q^{(+)}z(\tau,\varepsilon) + Rz(\tau_1,\varepsilon), \end{aligned} \quad (5)$$

where  $y^{(\mp)}(x,\varepsilon)$  and  $z^{(\mp)}(x,\varepsilon)$  is the regular part of the expansion that approximates the solution far from the region of the transition layer, and the functions  $Q^{(\mp)}y(\tau,\varepsilon)$  and  $Q^{(\mp)}z(\tau,\varepsilon)$  describe the behavior of the solution in the neighborhood (from the left and the right) of the discontinuity point  $x = x_0$ ,  $Ly(\tau_0,\varepsilon)$  and  $Lz(\tau_0,\varepsilon)$  – the boundary part of the asymptotics near the point  $x = 0$ ,  $Ry(\tau_1,\varepsilon)$  and

$Rz(\tau, \varepsilon)$  – the boundary part of the asymptotics near the point  $x = 1$ .

Each term in (5) will be sought in the form of an expansion in powers of  $\varepsilon$ :

$$\begin{aligned}\bar{y}^{(\mp)}(x, \varepsilon) &= \bar{y}_0^{(\mp)}(x) + \varepsilon \bar{y}_1^{(\mp)}(x) + \dots, \\ \bar{z}^{(\mp)}(x, \varepsilon) &= \bar{z}_0^{(\mp)}(x) + \varepsilon \bar{z}_1^{(\mp)}(x) + \dots; \\ Q^{(\mp)}y(\tau, \varepsilon) &= Q_0^{(\mp)}y(\tau) + \varepsilon Q_1^{(\mp)}y(\tau) + \dots, \\ Q^{(\mp)}z(\tau, \varepsilon) &= \varepsilon^{-1}Q_{-1}^{(\mp)}z(\tau) + Q_0^{(\mp)}z(\tau) + \varepsilon Q_1^{(\mp)}z(\tau) + \dots \\ Ly(\tau_0, \varepsilon) &= L_0y(\tau_0) + \varepsilon L_1y(\tau_0) + \dots, \quad (6) \\ Lz(\tau_0, \varepsilon) &= \varepsilon^{-1}L_{-1}z(\tau_0) + L_0z(\tau_0) + \varepsilon L_1z(\tau_0) + \dots \\ Ry(\tau_1, \varepsilon) &= R_0y(\tau_1) + \varepsilon R_1y(\tau_1) + \dots, \\ Rz(\tau_1, \varepsilon) &= \varepsilon^{-1}R_{-1}z(\tau_1) + R_0z(\tau_1) + \varepsilon R_1z(\tau_1) + \dots\end{aligned}$$

The unknown values  $p(\varepsilon)$  and  $z(\varepsilon)$  of the functions  $y^{(\mp)}(x, \varepsilon)$  and  $z^{(\mp)}(x, \varepsilon)$  at  $x_0$  also will be sought in the form of expansions in powers of  $\varepsilon$ :

$$p(\varepsilon) = p_0 + \varepsilon p_1 + \dots, \quad z(\varepsilon) = \varepsilon^{-1}z_{-1} + z_0 + \varepsilon z_1 + \dots \quad (7)$$

We write down the joining conditions (2) with allowance for the expansions (6) – (7):

$$\begin{aligned}\bar{y}_0^{(-)}(x_0) + \varepsilon \bar{y}_1^{(-)}(x_0) + \dots + Q_0^{(-)}y(0) + \varepsilon Q_1^{(-)}y(0) + \dots = \\ = \bar{y}_0^{(+)}(x_0) + \varepsilon \bar{y}_1^{(+)}(x_0) + \dots + Q_0^{(+)}y(0) + \varepsilon Q_1^{(+)}y(0) + \dots = \\ = p_0 + \varepsilon p_1 + \dots; \quad (8)\end{aligned}$$

$$\begin{aligned}\bar{z}_0^{(-)}(x_0) + \varepsilon \bar{z}_1^{(-)}(x_0) + \dots + \varepsilon^{-1}Q_{-1}^{(-)}z(0) + \\ + Q_0^{(-)}z(0) + \varepsilon Q_1^{(-)}z(0) + \dots = \\ = \bar{z}_0^{(+)}(x_0) + \varepsilon \bar{z}_1^{(+)}(x_0) + \dots + \varepsilon^{-1}Q_{-1}^{(+)}z(0) + \\ + Q_0^{(+)}z(0) + \varepsilon Q_1^{(+)}z(0) + \dots = \\ = \varepsilon^{-1}z_{-1} + z_0 + \varepsilon z_1 + \dots \quad (9)\end{aligned}$$

#### 4. The regular terms of asymptotic representation

Problems for the terms of the regular part we obtain by substituting the functions  $y^{(\mp)}(x, \varepsilon)$  and  $z^{(\mp)}(x, \varepsilon)$  in the form (6) into the system of equations:

$$\frac{d\bar{y}^{(\mp)}}{dx} = \bar{z}^{(\mp)}, \quad \varepsilon \frac{d\bar{z}^{(\mp)}}{dx} = A^{(\mp)}(\bar{y}^{(\mp)}, x)\bar{z}^{(\mp)} + f(\bar{y}^{(\mp)}, x)$$

and by substituting the additional conditions for  $x = 0$  and  $x = 1$ , respectively, of problem (4), and

equating the terms for the same powers of  $\varepsilon$  in both parts of the obtained equalities. As a result, in each  $i$  – th order,  $i=0,1,\dots$ , we will determine functions  $\bar{y}_i^{(\mp)}(x)$  as solutions of the Cauchy problem for the differential equations of the first order, and then find expressions for their derivatives – functions  $\bar{z}_i^{(\mp)}(x)$ .

Thus in the 0 – th approximation we obtain the following Cauchy problems:

$$\begin{aligned}A^{(-)}(\bar{y}_0^{(-)}, x)\frac{d\bar{y}_0^{(-)}}{dx} + f(\bar{y}_0^{(-)}, x) &= 0, \\ \bar{y}_0^{(-)}(0) &= y^0, \quad 0 \leq x \leq x_0, \\ A^{(+)}(\bar{y}_0^{(+)}, x)\frac{d\bar{y}_0^{(+)}}{dx} + f(\bar{y}_0^{(+)}, x) &= 0, \\ \frac{d\bar{y}_0^{(+)}}{dx}(1) &= y^1, \quad x_0 \leq x \leq 1.\end{aligned}$$

We set  $\bar{y}_0^{(-)}(x) = \varphi_1(x)$ ,  $\bar{y}_0^{(+)}(x) = \varphi_2(x)$ , and  $\bar{z}_0^{(-)}(x) = \varphi_1'(x)$ ,  $\bar{z}_0^{(+)}(x) = \varphi_2'(x)$ .

The regular terms  $\bar{y}_i^{(\mp)}(x)$  are defined as solutions of problems:

$$\begin{aligned}A^{(\mp)}(\bar{y}_i^{(\mp)}(x), x)\frac{d\bar{y}_i^{(\mp)}}{dx} &= -W^{(\mp)}(x)\bar{y}_i^{(\mp)} + F_i^{(\mp)}(x), \\ \bar{y}_i^{(-)}(0) &= 0, \quad \frac{d\bar{y}_i^{(+)}}{dx}(1) = 0,\end{aligned}$$

where

$$W^{(\mp)}(x) = \frac{\partial A^{(\mp)}}{\partial y}(\varphi_{1,2}(x), x)\varphi_{1,2}'(x) + \frac{\partial f^{(\mp)}}{\partial y}(\varphi_{1,2}(x), x)$$

and  $F_i^{(\mp)}(x)$  are known functions that depend on  $\bar{y}_j^{(\mp)}(x), \bar{z}_j^{(\mp)}(x)$ ,  $0 \leq j \leq i-1$ . Function with the superscript “–”, defined for  $0 \leq x \leq x_0$ , and with the superscript “+” for  $x_0 \leq x \leq 1$ . It is not difficult for them to obtain explicit expressions, for that we will make a replacement

$$P^{(\mp)}(x) = \frac{W^{(\mp)}(x)}{A^{(\mp)}(\bar{y}_0^{(\mp)}(x), x)},$$

$$Q^{(\mp)}(x) = \frac{F_i^{(\mp)}(x)}{A^{(\mp)}(\bar{y}_0^{(\mp)}(x), x)},$$

$$\frac{d\bar{y}_i^{(\mp)}}{dx} + P^{(\mp)}(x)\bar{y}_i^{(\mp)} = Q^{(\mp)}(x).$$

We solve last equation with the help of an integrating factor and the final values  $\bar{y}_i^{(-)}(x)$  and  $\bar{y}_i^{(+)}(x)$  can be represented as:

$$\begin{aligned}\bar{y}_i^{(-)}(x) &= \exp \int_1^x -P^{(-)}(s) ds \\ \bar{y}_i^{(-)}(x) &= \exp \int_1^x -P^{(-)}(s) ds \left( \int_1^x Q^{(-)}(s') \times \right. \\ &\quad \times \exp \left( -\int_1^{s'} -P^{(-)}(s) ds \right) ds' - \\ &\quad \left. - \int_1^0 Q^{(-)}(s') \exp \left( -\int_1^{s'} -P^{(-)}(s) ds \right) ds' \right), \quad 0 \leq x \leq x_0, \\ \bar{y}_i^{(+)}(x) &= \exp \int_1^x -P(s) ds \times \\ &\quad \times \left( \int_1^x Q(s') \exp \left( -\int_1^{s'} -P(s) ds \right) ds' - 1 \right), \\ &\quad x_0 \leq x \leq 1\end{aligned}$$

and then we can calculate:  $\bar{z}_i^{(\mp)} = d\bar{y}_i^{(\mp)} / dx$ .

### 5. Construction of the transition layer

Equations for the coefficients  $Q_i^{(\mp)} y(\tau)$ ,  $i = 0, 1, \dots$  and  $Q_i^{(\mp)} z(\tau)$ ,  $i = -1, 0, 1, \dots$  will be obtained by substituting the expansions (6) into systems of equations

$$\begin{aligned}\frac{dQ^{(\mp)} y}{d\tau} &= \varepsilon Q^{(\mp)} z, \\ \frac{dQ^{(\mp)} z}{d\tau} &= A^{(\mp)} \left( \bar{y}^{(\mp)}(x_0 + \varepsilon\tau) + Q^{(\mp)} y, x_0 + \varepsilon\tau \right) \\ &\quad \left( \bar{z}^{(\mp)}(x_0 + \varepsilon\tau) + Q^{(\mp)} z \right) + \\ &\quad + f^{(\mp)} \left( \bar{y}^{(\mp)}(x_0 + \varepsilon\tau) + Q^{(\mp)} y, x_0 + \varepsilon\tau \right) - \\ &\quad - A^{(\mp)} \left( \bar{y}^{(\mp)}(x_0 + \varepsilon\tau), x_0 + \varepsilon\tau \right) \bar{z}^{(\mp)}(x_0 + \varepsilon\tau) - \\ &\quad - f^{(\mp)} \left( \bar{y}^{(\mp)}(x_0 + \varepsilon\tau), x_0 + \varepsilon\tau \right). \quad (10)\end{aligned}$$

We require that the transition conditions of the standard condition decrease at infinity:  $Q_i^{(\mp)} y(\mp\infty) = 0, i \geq 0$ . Equating the coefficients of  $\varepsilon_0$  in the first equations (10) and in the conditions (8), and also the coefficients of  $\varepsilon_{-1}$  in the second equations (10), we obtain the following problems for the principal terms of the expansions (6):

$$\begin{cases} \frac{dQ_0^{(\mp)} y}{d\tau} = Q_{-1}^{(\mp)} z, \quad \frac{dQ_{-1}^{(\mp)} z}{d\tau} = A^{(\mp)} \left( \varphi_{1,2}(x_0) + Q_0^{(\mp)} y, x_0 \right) Q_{-1}^{(\mp)} z, \\ Q_0^{(\mp)} y(0) = p_0 - \varphi_{1,2}(x_0), \quad Q_0^{(\mp)} y(\mp\infty) = \varphi_{1,2}(x_0). \end{cases} \quad (11)$$

Problems for functions with the index “-” will be solved for  $\tau \leq 0$ , and with the index “+” – for  $\tau \geq 0$ .

We introduce the notation

$\tilde{y}_0(\tau) = \varphi_{1,2}(x_0) + Q_0^{(\mp)} y(\tau)$  and rewrite the tasks (11) with their use:

$$\begin{cases} \frac{dQ_0^{(\mp)} y}{d\tau} = Q_{-1}^{(\mp)} z, \quad \frac{dQ_{-1}^{(\mp)} z}{d\tau} = A^{(\mp)} \left( \tilde{y}_0(\tau), x_0 \right) Q_{-1}^{(\mp)} z, \\ \tilde{y}_0(\tau) = p_0, \quad \tilde{y}_0^{(\mp)}(\mp\infty) = \varphi_{1,2}(x_0). \end{cases} \quad (12)$$

The systems of equations (12) coincident with the adjoint systems (1), therefore, for  $\varphi_1(x_0) \leq \tilde{y}_0^{(\mp)} \leq \varphi_2(x_0)$  functions defined:

$$Q_{-1}^{(\mp)} z = \int_{\varphi_{1,2}(x_0)}^{\tilde{y}_0^{(\mp)}} A^{(\mp)}(s, x_0) ds. \quad (13)$$

From the sewing conditions (9) in the order  $\varepsilon^{-1}$ , taking into account the conditions for  $\tau = 0$  of problems (12), we obtain equalities

$$\int_{\varphi_1(x_0)}^{p_0} A^{(-)}(s, x_0) ds = \int_{\varphi_2(x_0)}^{p_0} A^{(+)}(s, x_0) ds = z_{-1}. \quad (14)$$

The first of these equations represents the equation for determining the unknown quantity  $p_0$ . From the second equation (14), we can determine the coefficient  $z_{-1}$ . After the expressions (13) are obtained for the functions  $Q_{-1}^{(\mp)} z$ , we can return to the system (12) and put the Cauchy problems for the functions:  $\tilde{y}_0^{(\mp)}(0) = p_0$ ,

$$\frac{d\tilde{y}_0(\tau)}{d\tau} = \int_{\varphi_{1,2}(x_0)}^{\tilde{y}_0^{(\mp)}} A^{(\mp)}(s, x_0) ds.$$

From the inequalities (13) and the expressions (12) it follows that for the functions  $Q_0^{(\mp)} y$  we have the following exponential estimates:

$$\left| Q_0^{(\mp)} y(\tau) \right| \leq c \exp(-k|\tau|), \quad (15)$$

where  $c$  and  $\kappa$  are some positive numbers.

The transition layer functions  $Q_k^{(\mp)} y(\tau)$ ,  $Q_{k-1}^{(\mp)} z(\tau)$ ,  $k \geq 1$  are determined from the following systems of linear equations:



$$\left\{ \begin{array}{l} \frac{dQ_k^{(\mp)}y}{d\tau} = Q_{k-1}^{(\mp)}z, \\ \frac{dQ_{k-1}^{(\mp)}z}{d\tau} = \tilde{A}^{(\mp)}(\tau) \cdot Q_{k-1}^{(\mp)}z + \tilde{A}_y^{(\mp)}(\tau) \cdot Q_{-1}^{(\mp)}z \cdot Q_k^{(\mp)}y + G_{k-1}^{(\mp)}(\tau), \\ Q_k^{(\mp)}y(0) = p_k - \bar{y}_k^{(\mp)}(x_0), \quad Q_k^{(\mp)}y(\mp\infty) = 0, \end{array} \right. \quad (16)$$

where  $G_{k-1}^{(\mp)}(\tau)$  are known functions that are recurrently expressed in terms of  $Q_j^{(\mp)}z$ ,  $-1 \leq j \leq k-2$  and  $Q_j^{(\mp)}y$ ,  $0 \leq j \leq k-1$ , and introduced designations

$$\tilde{A}^{(\mp)}(\tau) = A^{(\mp)}(\tilde{y}_0^{(\mp)}(\tau), x_0), \quad \tilde{A}_y^{(\mp)}(\tau) = A_y^{(\mp)}(\tilde{y}_0^{(\mp)}(\tau), x_0).$$

The tasks for functions with the superscript “-” are solved on the half-line  $\tau \leq 0$ , and with the superscript “+” – on the half-line  $\tau \geq 0$ .

Using equalities

$$\begin{aligned} \frac{d}{d\tau} \left( \tilde{A}^{(\mp)}(\tilde{y}_0^{(\mp)}(\tau), x_0) \cdot Q_k^{(\mp)}y \right) &= \\ &= \tilde{A}^{(\mp)}(\tilde{y}_0^{(\mp)}(\tau), x_0) \cdot \frac{dQ_k^{(\mp)}y}{d\tau} + \\ &+ \tilde{A}_y^{(\mp)}(\tilde{y}_0^{(\mp)}(\tau), x_0) \cdot \frac{d\tilde{y}_0^{(\mp)}}{d\tau} \cdot Q_k^{(\mp)}y = \\ &= \tilde{A}^{(\mp)}(\tau) \cdot Q_{k-1}^{(\mp)}z + \tilde{A}_y^{(\mp)}(\tau) \cdot Q_{-1}^{(\mp)}z \cdot Q_k^{(\mp)}y. \end{aligned} \quad (17)$$

Second equations (16) can be reduced to the following form:

$$\frac{dQ_{k-1}^{(\mp)}z}{d\tau} = \frac{d(\tilde{A}^{(\mp)}(\tau) \cdot Q_k^{(\mp)}y)}{d\tau} + G_{k-1}^{(\mp)}(\tau).$$

Integrating in the range from  $\mp\infty$  to  $\tau$  taking into account the conditions of problems (16) as  $\tau \rightarrow \mp\infty$ , we obtain expressions for the functions  $Q_{k-1}^{(\mp)}z(\tau)$ :

$$Q_{k-1}^{(\mp)}z = \tilde{A}^{(\mp)}(\tau) \cdot Q_k^{(\mp)}y(\tau) + \int_{\mp\infty}^{\tau} G_{k-1}^{(\mp)}(s) ds. \quad (18)$$

We substitute these expressions in the first equation (16) and integrate it with allowance for the initial conditions. Then we obtain the functions  $Q_k^{(\mp)}y(\tau)$  in an explicit form:

$$Q_k^{(\mp)}y(\tau) = \left( p_k - \bar{y}_k^{(\mp)}(x_0) \right) e^{\int_{\mp\infty}^{\tau} \tilde{A}^{(\mp)}(s) ds} +$$

$$+ \int_0^{\tau} e^{\int_0^s \tilde{A}^{(\mp)}(q) dq} ds \int_{\mp\infty}^s G_{k-1}^{(\mp)}(q) dq.$$

For functions  $G_{k-1}^{(\mp)}(\tau)$  exponential estimates of type (17) are valid; therefore, similar estimates are also valid for the functions  $Q_k^{(\mp)}y(\tau)$  and  $Q_{k-1}^{(\mp)}z(\tau)$ . From the matching conditions (9) in the order  $\varepsilon^{k-1}$ , we have the equalities:

$$\bar{z}_{k-1}^{(\mp)}(x_0) + Q_{k-1}^{(\mp)}z(0) = \bar{z}_{k-1}^{(+)}(x_0) + Q_{k-1}^{(+)}z(0) = z_{k-1}, \quad k \geq 1.$$

Substituting the expressions (18) in these equations, we obtain equations for the unknown quantities  $p_k$  and  $z_{k-1}$ , solving which we find [4, 200–205]

$$\begin{aligned} p_k &= \left( A^{(-)}(p_0, x_0) - A^{(+)}(p_0, x_0) \right)^{-1} \left( \bar{z}_{k-1}^{(+)}(x_0) - \bar{z}_{k-1}^{(-)}(x_0) + \right. \\ &+ A^{(-)}(p_0, x_0) \bar{y}_k^{(-)}(x_0) - A^{(+)}(p_0, x_0) \bar{y}_k^{(+)}(x_0) + \\ &+ \int_{+\infty}^0 G_{k-1}^{(+)}(\tau) d\tau - \int_{-\infty}^0 G_{k-1}^{(-)}(\tau) d\tau, \\ z_{k-1} &= \bar{z}_{k-1}^{(-)}(x_0) + A^{(-)}(p_0, x_0) \left( p_k - \bar{y}_k^{(-)}(x_0) \right) + \\ &+ \int_{-\infty}^0 G_{k-1}^{(-)}(\tau) d\tau. \end{aligned}$$

## 6. Construction of left boundary functions

For  $L_0y(\tau_0)$  we have a problem

$$\left\{ \begin{array}{l} \frac{dL_0y}{d\tau_0} = f_2(0, \phi_2(x) + L_0y, 0), \\ L_0y(0) = y^0 + \phi_2(x), \quad L_0y(\infty) = 0. \end{array} \right. \quad (19)$$

Making the change of variables  $\bar{y} = \phi_2(0) + L_0y(\tau_0)$ ,  $z = \bar{y}'$  in (19) we get

$$\left\{ \begin{array}{l} \frac{d\bar{z}}{d\tau_0} = f_2(0, \bar{y}, 0), \quad \frac{d\bar{y}}{d\tau_0} = \bar{z}, \\ \bar{y}(0) = y^0, \quad \bar{y}(\infty) = \phi_2(0). \end{array} \right. \quad (20)$$

We write the problem for  $L_ky(\tau_0)$ ,  $k \geq 1$  in the following form

$$\left\{ \begin{array}{l} \frac{d^2 L_k y}{d\tau_0^2} = f_{2y}(\tau_0) L_k y + \bar{h}_k(\tau_0), \\ L_k y(0) = \bar{y}_k^{(-)}, \quad L_k y(\infty) = 0, \end{array} \right.$$

where  $f_{2y}(\tau_0) = f_{2y}(\phi_2(0) + L_0y, 0, 0)$ , and  $\bar{h}_k(\tau_0)$  – known functions that are recruited through  $\bar{y}_j^{(-)}(0)$  ( $k \geq j$ ),  $L_k y(\tau_0)$  ( $k-1 \geq j$ ).

We can express a solution  $L_k y(\tau_0)$  in the following form

$$L_k y(\tau_0) = \bar{y}^{(-)}(0) \frac{\tilde{z}(\tau_0)}{\tilde{z}(0)} + \tilde{z}(\tau_0) S_k^{(+)}(\tau_0), \quad (21)$$

where

$$S_k^{(+)}(\tau_0) = \int_0^{\tau_0} \tilde{z}^{(-)}(\eta) d\eta \int_{-\infty}^{\eta} \tilde{z}(s) \tilde{h}_k(s) ds$$

and  $\tilde{z}(s)$  we can find from (20). And from (21) we obtain an exponential estimate for  $L_k y(\tau_0)$ .

### 7. Construction of right boundary functions

The terms of the boundary layer  $Ry(\tau_1, \varepsilon)$  are represented in the following form:

$$Ry(\tau_1, \varepsilon) = \sum_{i=0}^{\infty} \varepsilon^i R_i(\tau_1), \quad \tau_1 = \frac{1-x}{\varepsilon}.$$

To determine boundary functions, we need boundary conditions.

Substituting the expressions (5) for  $y(x, \varepsilon)$  into the boundary conditions, we obtain equalities

$$\frac{d\bar{y}^{(+)}}{dx}(1, \varepsilon) + \frac{1}{\varepsilon} \frac{dQ^{(+)}}{d\tau} \left( \frac{1}{\varepsilon}, \varepsilon \right) + \frac{1}{\varepsilon} \frac{dR}{d\tau_1}(0, \varepsilon) = y^1. \quad (22)$$

We substitute the desired expansions for  $\bar{y}^{(+)}$ ,  $R$ ,  $Q^{(+)}$  in this equation and equate terms with identical powers of  $\varepsilon$  in both sides of the equalities. Since the boundary condition is given at the point  $x=1$ , the term  $dQ^{(+)}/d\tau(1/\varepsilon, \varepsilon)$  on the right-hand side of equation (22) can be dropped. Thus we obtain:

$$\begin{aligned} \frac{dR_0}{d\tau_1}(1, \varepsilon) = 0, \quad \frac{dR_1}{d\tau_1}(1, \varepsilon) = y^1 - \frac{d\bar{y}_0^{(+)}}{dx}(1), \\ \frac{dR_i}{d\tau_1}(1, \varepsilon) = -\frac{d\bar{y}_{i-1}^{(+)}}{dx}(1), \quad i = 1, 2, 3, \dots \end{aligned} \quad (23)$$

We also add conditions for the vanishing of boundary functions at infinity:

$$R_i(\tau_1, \varepsilon)(\infty) = 0, \quad i = 1, 2, 3, \dots \quad (24)$$

Equating terms with equal powers of  $\varepsilon$  in both parts of equalities, as a result we obtain an equation for the function  $R_0(\tau_1)$ :

$$\frac{d^2}{d\tau_1^2} R_0(\tau_1) = R_0 f = f(\phi(1) + R_0, 0, 0) - f(\phi(1), 0, 0),$$

where  $f(\phi(1), 0, 0) = 0$ .

The equations (23), (24) follow the boundary conditions

$$\frac{dR_0}{d\tau_1}(1) = 0, \quad R_0(+\infty) = 0, \quad y(\tau_1) = \phi(1) + R_0(\tau_1),$$

$$y'' = \frac{d^2 R_0}{d\tau_1^2}, \quad y' = 0.$$

We introduce a change of variable

$$\begin{cases} y' = v, & y(+\infty) = 0, \\ v' = y'' = f(y, 0, 0), & v(0) = 0. \end{cases}$$

We form the characteristic equation

$$\begin{vmatrix} 0 - \lambda & 1 \\ f_y(\phi(1), 0, 0) & 0 - \lambda \end{vmatrix} = 0.$$

Hence we obtain  $\lambda^2 - f_y(\phi(1), 0, 0) = 0$  – where  $\lambda = \sqrt{f_y(\phi(1), 0, 0)}$ . As  $f_y(\phi_i(x), x, 0) > 0$  (stability condition) is a rest point of the saddle type  $y(\tau_1) = \phi(1)$ ,  $v(\tau_1) = 0$ , it follows that  $R_0(\tau_1) = 0$ . Thus, in the boundary-value Neumann problem under boundary conditions, the boundary function in the zeroth approximation  $R_0$  is zero. For  $i=1$  we obtain the equation for determining  $R_1(\tau_1)$ :

$$\frac{d^2 R_1}{d\tau^2} = R_1 f = \bar{f}_y(1) R_1, \quad \tau_1 > 0.$$

From (23) the boundary conditions follow

$$\frac{dR_1}{d\tau_1}(1) = y^1 - \frac{d\bar{y}_0^{(+)}}{dx}(1), \quad R_1(\infty) = 0.$$

From here  $R_1(\tau_1) = h_0 \exp(-k_0 \tau_1) / k_0$ ,  $\tau_1 > 0$ , where  $h_0 = d\bar{y}_0^{(+)}/dx - y^1$ ,  $k_0 = \sqrt{\bar{f}_y(1)} > 0$ . Thus, the function  $R_1(\tau_1)$  has an exponential estimate  $|R_1(\tau_1)| \leq c \exp(-k\tau_1)$ ,  $\tau_1 \geq 0$ , where  $c, k$  are positive numbers not depending on  $\varepsilon$ . In different assessments, they can be different [5, 2042–2048]. Similarly, the coefficients are found. Then the remaining coefficients of the expansion for the boundary function  $R_i$ , when  $i \geq 2$

$$\frac{d^2 R_i}{d\tau_1^2} = R_i f = \bar{f}_u(1) R_i + r_i(\tau_1), \quad \tau_1 > 0,$$

$$\frac{dR_i}{d\tau_1}(1) = -\frac{d\bar{y}_{i-1}^{(+)}}{dx}(1), \quad R_i(\infty) = 0,$$

where  $r_i(\tau_1)$  recurrently expressed in terms of the function  $R_j(\tau_1)$  with numbers  $j < i$ .

### 8. Numeric Example

We consider the boundary-value problem

$$\varepsilon y'' = \begin{cases} (1-x)y' + 6(1-x), & 0 \leq x \leq \frac{1}{2}, \\ (x-3)y' - 2(x-3), & \frac{1}{2} < x \leq 1, \end{cases} \quad y(0) = 0, y'(1) = 1,$$

using the boundary conditions and the results obtained above, as a result of simple transformations, we obtain:

$$y(x) = \begin{cases} 6 \left( e^{\frac{x-x^2}{2}} - 1 \right), & 0 \leq x \leq \frac{1}{2}, \\ 2 \left( e^{\frac{x^2-3x}{2}} + 1 \right), & \frac{1}{2} < x \leq 1. \end{cases}$$

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## Section 4. Materials Science

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### **DEVELOPMENT OF TECHNOLOGY FOR METAL LAYERED COMPOSITIONS WITH CASTING METHOD ON GASIFIED MODELS**

**Abstract:** The paper is development of technology for metal layered compositions with casting method on gasified models.

**Keywords:** Metal layered compositions, casting method on gasified models, a metalworking tools, dies – matrices, steels, carbide and molybdenum, and their alloys.

#### **1. Introduction**

Scientific research on development of metal layered compositions are being carried out in more than 30 countries of the world. A ten-fold increase in the speed of processing metal-working on machine-tools (3500–50000 rev/m), increase the impact of the internal stresses in the machining of components leads to higher quality requirements of the tool - tools and parts, in the whole improvement of production. This intern requires the high performance properties from the materials of details. As static information demonstrates that, every year in the world for the development of high-quality materials spent US\$ 5–6 billion, including Europe and the CIS countries is the number of 1–2 billion US dollars, and in the production in the highly countries 4–5 billion spent in US dollars. Currently, under the conditions of production intensification when manufacturing the quality products the development of metal and non-metal

compositions with high mechanical properties is one of the important production tasks.

In the years of independence our country focuses on producing high-quality and competitive engineering products in the global market. The development of the engineering industry, its products, which must meet modern requirements to increase the reliability, safety and life of the manufactured machinery, apparatus and equipment and materials, improving their quality have led to significant results.

Nowadays, it is important to increase the economic efficiency of industries, on the development of a new composition of the materials produced, as well as the efficient and cost-effective improvement of technologies for the production of products by casting in order to enhance the performance of economic: in this aspect the purposeful scientific -research work is the very improvement, as well as the carryinj out of scientific-research in the direction

of the development of composite materials using special metal layered compositions ensures product quality; development of technology for metal layered compositions; improvement of theoretical and technological bases of thermal treatment enhancing the strength of the metal layered compositions; creation and production of new energy and material saving metal layered compositions based on the latest scientific and technological achievements, which economize scarce tool materials and increase productivity. The above-mentioned research areas, and the results of research carried out in these areas are the justification of the relevance of the topic of this thesis.

## 2. Statement of A Problem

Analysis of the current and prospective estimation of the possibilities of offered technology application have allowed to choose as objects:

– ametalworking tools (*machine-building direction*), the most representative and widely used rigid tools: round die type M18h2 and M42; side-and-face milling cutters; grooved stamps; matrices for various purposes [1].

The main goal of metal layered compositions development is to reduce the consumption of scarce alloyed steels, labor, creating a high level of compressive stress in the operating member of metal layered compositions both at the manufacture and at thermal treatment.

Taking into consideration the selected method for obtaining the metal layered compositions the casting on gasified models, as well as the fact that the basis for metal layered compositions should serve the cast metal alloys, as a tool component metal materials are taken.

It should be noted that the above group of materials performs the main role in tool production. It includes tool steels and hard alloys. The paper presents the chemical composition of the used tool steels, carbide and molybdenum, and their alloys.

For the manufacture of metal layered compositions it is necessary to perform the following basic technological methods: preparing of foam polystyrene for the production of foam model; manufacturing of tool's foam model; preparation of the working element; preparing and obtaining of casting; getting tool [1–3].

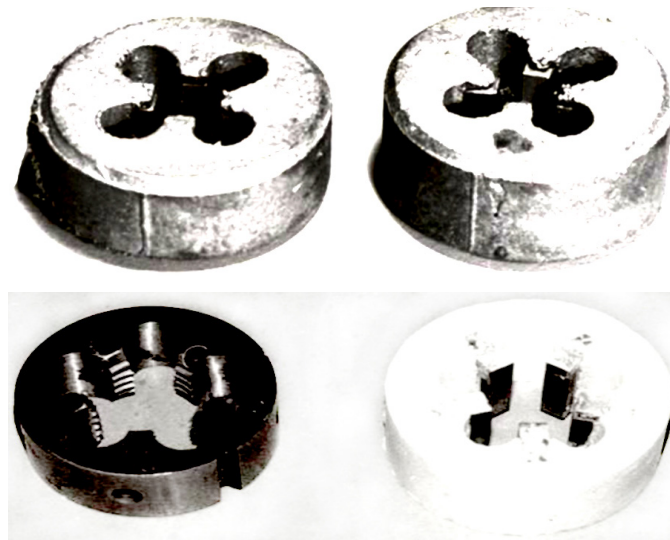


Figure 1. Metal layered compositions “9HC steel-cast structural steel 40HL” – cast circular dies

Obtaining of metal layered compositions of a type cast structural steel – work paste is possible in the case of the comparability of physical and mechanical properties of materials. The compositions

of this type are a connection between the tool and cast structural steel. The main advantage of this class of compounds is the reducing of the consumption of alloy tool steels, due to the partial replacement



of their more affordable structural steel and reducing the complexity of manufacturing punching and multi-edge cutter of a complex profile [1; 3].

The composition cold work tool steel - cast structural steel was selected for the manufacture of circular dies–matrices (Figure 1).

Analysis of the ratio of the geometric parameters of the working elements and the tool bodies allowed to establish that for this class of instrument the paste thickness in the contact area with the melt should be 2–5 mm.

### 3. The Concept of the Problem Decision

Microstructural studies were conducted on the use of metal layered compositions with hard working element made of the cold work tool steel. The study of the metal layered composition steel 9HC–steel 40HL the round dies M18 × 2 and M42 have been tried to manufacture. The various flux ( $\text{Na}_2\text{B}_2\text{O}_7$  and others) were used in the compositions as an intermediate layer.

As previously was indicated, for the manufacture of complex multi-edge cutter the compositions of hot-work, high-speed steels - cast structural steel were used. The specificity of the operation of a given class of tool is due to the high requirements to the tool body, operating under the dynamic and cyclic loads (steel 40HL, 40HGL, 40HGFIL). As hot-work tool steels the steels: R6M5, 10R6M5-MP, R6M5K5 and others were selected [1; 3].

Variant with an intermediate layer is practically the unique for compositions, the components of which have very different physical characteristics. These compositions are solid alloys - steel, molybdenum alloys - steel. For punching tools (matrices for hot metal pressing) and drilling tools (drill bits, chisels, and milling cutters) the pastes made of hard alloys intended for brazed tool were used. To create compositions as a material of the intermediate layer the alloys of Cu-Ni-Mn system, Cu-Ni with a thickness of 0.2–0.6 mm, sprayed by the plasma-method, were used [1; 3].

As indicated above, for the tools body casting structural steel was used, and as its main working

part molybdenum and its alloys (MCH VM and Mo-TiC), as well as the hard alloys of VC and TC group.

The mechanism of the formation, composition, structure, physical and mechanical properties of metal layered compositions of a type “cold work steel – structural steel”, “hot-work steel – structural steel”, “hard metal – structural steel” and “molybdenum and its alloys – structural steel” were fully studied (Figure 2) [1; 3].

Study of metal layered compositions of a type “tool material-structural steel” confirmed the obtaining of continuous compounds.

The proposed version of the MLC production technology with low-melting working element was intended mainly for the manufacturing of tillage tools of different types. In this case the powder hard alloys in the binder are applied in the form of a paste or are placed in the form of premanufactured pastes in a cavity specially prepared. The melting temperature at the time of pouring 1650-1700°C. The use of boron compounds for the manufacture of various composite materials having a high level of mechanical, thermal, electrical and other properties, gets quite widespread, above all, by the use of boron compounds themselves [1; 3].

As a result, consideration of the mechanism and characteristics of the formation of all types of connections allowed to predict the course of the process and select the technological conditions for the creation of this sort compositions.

The results of macro- and microstructural studies of the compositions showed that the discontinuity in the transition zone is not detected. Indicators of microprobe analyzes of the compositions have high depths of mutual penetration of elements Cr, Ni, W up to 300 microns and deep. Distribution of microhardness over the cross section of the compositions showed that the highest hardness (1100-1400 HV) has a carbide sub-zone, then the curve monotonically decreases in hardness of the eutectic and hypoeutectic subzones and reaches a minimum in the area of the sinter skin and carburizing, 250 ... 350 HV [1; 3].

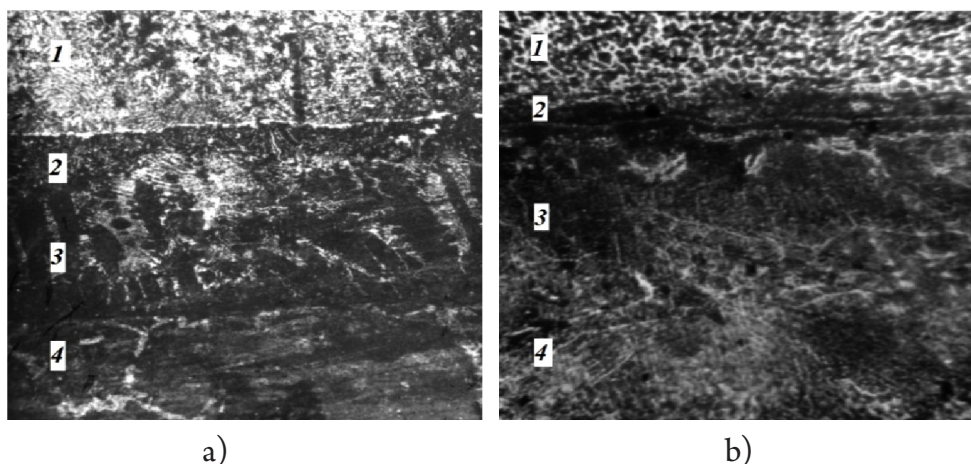


Figure 2. Microstructure of transition zone of metal layered compositions: “sintered alloy of Mo–TiC–PR N58F – cast structural steel 40HNML” (a), a layered metal composition “sintered alloy Mo–TiC–Ni – cast structural steel 40HNML” (b). X150 1 – area of migration; 2, a zone on the base of transition layer material; 3 – sinter skin; 4 – carburizing zone

Taking into account and summarizing the results of the research of all types of compositions, one can imagine the mechanism and features of connections formation between the elements of the composition with the participation of the intermediate layer.

There has been determined the mechanism and installed the features of forming a connection between elements of metal layered compositions, in which the contact of the melt of structural steel with the paste surface - working, cutting element crystallizes to form a solid sinter skin followed by melting the material of the intermediate layer and the interaction of the resulting melt with limiting it solid surfaces: on the one side of the tool material, on the other – of steel. The result is a transition zone of composition having a complex structure and phase composition comprising the interaction products between the elements of the melt and the basic constituents of the composition. Based on these studies there

has been developed a production technology for a number of metal layered compositions for metal-cutting and tillage tools. Analysis of the mechanism and characteristics of the formation of all obtained types of compounds of metal layered compositions allows to predict the course of the process and select the process conditions for the creation the layered metal compositions with desired properties.

### 5. Conclusions

There have been worked out the bases of working elements preparing from the tooling materials, necessary and sufficient for the forming of a reliable and efficient composition. These technological basics play an important role in the obtaining of metal layered compositions.

On the basis of a carried out research there have been developed the original technologies of obtaining of some metal layered compositions of the end use for metal working, soil cultivating and drilling tools.

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## Section 5. Technical sciences

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### METHOD DRYING MEDICINAL HERBAL USING A HELIO ACCUMULATION DRYING EQUIPMENT

**Abstract:** In this work, a method for drying medicinal herbal (*Allium motor*) using a helio accumulation drying plant is considered. During the drying process, the temperature was held at 46-54 °C and the drying time was 13 hours. With these parameters, the engine is well dried and it is well preserved vitamins. In appearance you can determine that the color and taste has not changed.

**Keywords:** energy, drying, accumulation, motor, helio dryer, quality.

Drying is a complex technological (physico-chemical: 1) process that should ensure not only the preservation of quality indicators of the material, but in some cases, the improvement of these indicators. Therefore, the choice of methods and rational process regimes should be based on the scientific principles of drying technology from the study of the properties of the product as a drying object – to the selection of the method and the justification of the process regimes and on this basis to the creation of rational designs for drying plants [1].

The increase in air temperature increases the rate of drying, which, according to some authors, leads to an increase in the coefficient of heat transfer between the body and moist air. However, increasing the temperature, as a rule, limiting the thermal sensitivity of most herbs, fruits and vegetables leads to an increase in the coefficient of heat transfer between the body and moist air [2]. High temperatures can lead to irreversible changes in the components of colloidal tissue, as well as to increased heat loss and reduce the effectiveness of the entire system [3–4].

Most medicinal plants undergo drying. Some of them, such as lily of the valley and fern, are some-

times used fresh. But these cases are an exception to the general procedure for the use of medicinal plants in pharmaceuticals.

The drying process is used to obtain and store raw materials that are more stable during storage, more economical in transportation and more convenient for further operations with it.

When preparing medicinal herbs, the drying process is a very important and important operation. Having exposed the wrong regime of drying medicinal herbs, you can not only significantly reduce, but completely destroy the medicinal substances contained in raw materials.

In each plant, continuous physical, biological and biochemical processes take place throughout life. There is the formation of carbohydrates, proteins, fats, organic acids, alkaloids, glycosides, the processes of cleavage and formation of new compounds [5–6].

Drying as a way of preserving food is known since ancient times. This method is based on dehydration of plant material to a moisture content of 8–14% in it and a high concentration of solids [5–7]. For the development of microorganisms, water is needed: bacteria require at least 30% moisture for



life, 15% for molds. Microorganisms use substances found in cell sap in relatively low concentrations, and all biochemical reactions take place in aqueous solutions. With the removal of moisture, the concentration of these substances increases, and they are already inhibitors of the life of microorganisms, which, although not dying, but due to unfavorable conditions do not develop [5].

The main task of drying medicinal plants is to create conditions for the maximum speed of the process with minimum energy consumption and the most complete preservation of the qualitative and quantitative composition of biological active substances.

When choosing the optimal regime of the drying process, first of all, one should be guided by the requirements of normative documentation for a specific kind of medicinal plant raw materials, taking into account those properties of plants that will influence the nature of the drying process.

In any living plant, there are simultaneously thousands of different chemical reactions, the sum of which is called metabolism. In all chemical reactions of cells, enzymes – catalysts and regulators of metabolic processes participate. There are two directions of metabolism – anabolism (the sum of chemical reactions involved in the synthesis of substances) and catabolism (a set of reactions leading to the disintegration of substances). In living medicinal plants the processes of anabolism prevail, in the medicinal raw material immediately after the preparation, catabolism begins to predominate.

In the process of drying the raw material, when it is heated to a temperature of 45–60 °C, enzymes that accelerate the processes of decomposition of substances first slow down their activity, and then stop it because of protein denaturation. The lower the drying temperature, the more active are the enzymatic processes of decomposition of biological active substances. The cardiac glycosides, triterpene saponins, glycosides of flavonoids, alkaloids and some other substances undergo the greatest disintegration.

Drying can be considered as the most simple and economical method of preserving medicinal raw materials, ensuring the preservation of biologically active substances.

*Allium motor* R. Kum from Levichov – Onion motor. (Uzbek), the Endem of the Western Tien Shan. As an onion plant, the onion motor has become more or less known in the last 10–15 years [8].

Chemical analysis showed that leaves collected in the budding phase contain fiber – 12,3%, crude protein – 22,6%, dissolved protein 7,7%, water 10,4%, flavonoids 0,7%, phosphorus 0,11%, the amount of soluble sugars is 3,6%, moisture is – 4,5% [8].

Among the country's fauna "Motor" (*Allium motor*) is distinguished by its medicinal properties and rich vitamin composition. The composition contains vitamins C, B, B<sub>2</sub>, PP, E and provitamin A. Sugars, proteins, macro- and microelements.

Therefore, the motor has long been used by the population for cooking Uzbek sams from greens and other culinary products. According to the stories of the elderly people, in the famine years, experienced by our ancestors, the local population used wild-growing motor, plantain, shepherd's ordinary bag, the boyar saved his life.

Currently, these medicinal plants have not lost their importance in people's lives, on the contrary, they are used to heal many diseases.

The main advantage of the motor is an increase in the power of man, enhances sexual activity, raises immunity, positively affects the digestive system of man.

The motor belongs to the family of bulbous plants. It mainly grows on the foothills of the Chatkal mountains of the western Tien Shan. Refers to endemic plants, t. grows only in a limited area. The motor grows on the foothills of mountains, in sandy places, among shrubs, in open wastelands, in shady places. There are 250 species of bulbous plants in the republic, but the motor that belongs to this family differs sharply from other family members, external morphological species of vegetative and



morphological organs (bulb, stem, foliage, flowers) and taste.

The motor is known to people for a long time, but science knows almost nothing, for a long time remained unknown to what kind of motor concerns. The reason for this is the peculiar biological properties of the motor. Usually, to study a plant growing in nature, the herbarium is made from it during flowering, which consist of stems, leaves, flowers. To complete the herbarium, the underground organs of the plant.

The biological properties of the motor are that in addition to a sharp difference from other bulbous plants, they first grow a leaf, then the stem grows and the plant blooms, but at that time the leaf will be already dried. Therefore, they could not study the herbarium motor completely, therefore, for many years scientists could not collect complete information about the motor. The motor belongs to the Molium section of wild relatives of *Allium* onions.

It is known that wild bulbs, like cultural ones, have a sharp odor, but the motor differs from wild bulbous ones such as anzur, Chimian onion, Suvorov onion, etc. with a sweet taste and pleasant taste. This indicates the abundance of sugars and aromat-

ics in the engine. In the 80th years of the last century, in the biosphere reserve Chatkal, by scientist biologists A. Levichev and professor R. Kamelin, on the basis of his own research, the motor was introduced into science as *Allium* motor, thereby imprinting the word motor, emanating from our people.

The motor can multiply from the seed, from the extra bulbs that have appeared. First, the motor should be propagated in places close to growth in natural conditions, then gradually transferred to other places.

Currently, work is underway to cultivate the motor by employees of the scientific and production center «Shifobahsh» under the State Forestry. Only in this way can you achieve the production of this miracle plant, and make available to the people [9].

Currently, drying medicinal plants is carried out in a natural way. It is associated with a significant low quality of the finished product, so it is necessary to develop new drying plants and technologies.

Scientists of Tashkent state technical university have developed helio accumulation drying plant for obtaining high-quality products from medicinal herbs [10–15].

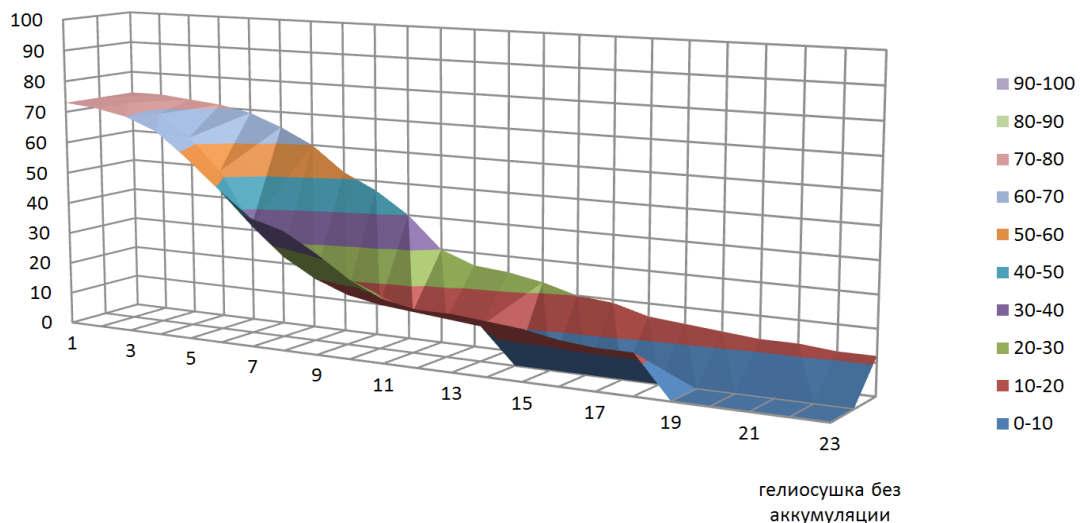


Figure 1. Diagram of change in humidity by time of herbal motor – *Allium* motor

Experiments were carried out on the developed mini solar-drying plant. During the drying process, the temperature was held at 46–54 °C and the drying

time was 13 hours (fig.1). With these parameters, the engine is well dried and it is well preserved vitamins. In appearance you can determine that the

color and taste has not changed. The authors determined the optimal drying time for drying the plants. The dried motor can be ground as needed to produce a powder.

The time of drying of each medicinal plant is determined depending on their properties. According to the results of scientific research, it is recommended to dry medicinal plants in solar energy plants with accumulation of solar energy.

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## DEVELOPMENT AND APPLICATION OF DRYING TECHNOLOGIES FOR MEDICINAL PLANTS FOR USE IN THE FOOD INDUSTRY

**Abstract:** The technique and technology of drying medicinal plants with preservation of biologically active substances are developed. The medicinal property of the plant is described. Data on installation and drying procedures are given.

**Keywords:** ziziphora, plants, drying, technique, technology, composition, installation, convective.

Rational use of wildlife today is one of the most important tasks of the modern food industry. Of great importance in determining the resources of medicinal plants are studies on the influence of environmental factors on crop yields in natural communities. Carrying out of such works allows identifying optimal areas for harvesting high-quality raw materials, outlining measures to increase the yield of medicinal plants, and also to process them for consumption by the population.

In turn, the need for medical and pharmaceutical industry in plant raw materials is continuously increasing, and today the issue of safety of medicines used in medical practice in connection with anthropogenic contamination of plant raw materials is acute.

To date, one of the priority areas of development is the expansion of the assortment of the pharmaceutical industry through the production of phytopreparations based on domestic raw materials. The solution of this problem is possible through the introduction of scientific research on the basis of natural raw materials that have sufficient renewable industrial reserves. Flora of Uzbekistan develops more than 6000 species of higher plants. Of these, over 1,500 species are characterized by medicinal proper-

ties. Medicinal plant zizifora used as a cardiological, hypotensive, analgesic, soothing and wound healing medium.

Ziziphora thin [1], is used in folk medicine for the treatment of fever, dysentery, gynecological infections and as an analgesic. It is also used to stop various gastrointestinal disorders, especially as a carminative or anti-diarrheal remedy. The ability to stop attacks of nausea is caused by the presence of essential oil and its main components: piplegone, thymol, menthone, isomentone and piperitone [2]. Ziziphora thin contains a large amount of essential oil, which means that it is a good feedstock source of Pulegon, which is widely used in the food and pharmaceutical industries [3; 4]. Sezik E. et al. (2004) during the study of medicinal plants in Uzbekistan [3] found that this plant has antihypertensive properties.

The Bengu zizifora herb is used in Uighur medicine as a decoction that relieves respiratory distress, dizziness and other symptoms associated with cardiovascular diseases, such as ischemic heart disease or hypertension [4]. In the literature there are patents [5-13], on the use of ziphyphor species or their individual components for medical purposes. Capsules containing a mixture of extracts of the aerial parts of

Bunge ziphir and wormwood wormwood and burdock extract are used to treat various viral infections of the upper respiratory tract. In patent applications, data on the antipyretic activity of the extract in rabbits, anti-inflammatory activity in rats, and antitussive activity in mice are also noted. The antiviral activity of the drug was also evaluated *in vitro* [5].

The method for producing the flavonoid fraction of the Bunge extract is obtained by combining the extraction of the above-ground portion with an organic solvent with dispersion of the obtained extract into an aqueous phase and subsequent filtration through a macroporous resin and washing with ethanol is described in the patent [6]. The flavonoid fraction showed a positive effect in the treatment of cardiovascular diseases. The drug based on the flavonoid fraction of 3. Bunge for the treatment of cardiovascular diseases is registered in the patent [7]. A number of other patents also describe the use of the flavonoid fraction of Z.Bunge [8].

Selection and special development of drying plants for drying medicinal plants makes it possible to preserve the medicinal properties of the plant and to obtain a high-quality product for further use as a raw material for the food and pharmaceutical industries. The above mentioned medicinal properties of the plant scientists of the Tashkent State Technical University decided to preserve by creating an energy-saving water heating convection plant designed for high-quality drying of medicinal plants such as zizifora, plantain, mint and other forestry plants.

To conduct the research, a water-heating convection drying plant was made, which allows to conduct the process of dehydration and fixing the optimum parameters of dried medicinal plants and to save energy. This installation allows you to conduct research: the dynamics of heat and moisture transfer in the layer of a drying medicinal plant; values of specific moisture capacity and moisture conductivity of grass; aerodynamic resistance of the layer, depending on the moisture content and density of the dehydrated plant [14].

The water-heating dryer operates on natural gas (or coal, wood, briquettes, electricity, oil products) using a boiler [15].

In the drying installation, the heat transfer medium is supplied by a line of heat conducting pipes. Metal tubes withstand the long-term impact of active elements released from the product during the drying process. Heat-transfer pipes are attached to the frame of the drying chamber by means of special fastening elements. Hot water is used as a heat agent. A removable pallets are placed in the water heating dryer.

After loading the raw material into the chamber, the boiler of the dryer is lit. The heating temperature reaches 90-100 °C. With this heating, the temperature inside the drying chamber reaches the required value up to 60-65 °C. This temperature is considered optimal for drying medicinal plants. In order to maximize the preservation of the final product during the drying process, the temperature is maintained automatically by means of a thermostat located in the chamber [14].

The installation takes into account the adsorption properties of substances saturated with drying products, that is, their own rates of adsorption and desorption of substances in the wet state are determined, according to which the drying regime of the product is established. As a result, a product with a layered distribution of the substances contained in the product is obtained, which makes it possible to maximally maintain useful biologically active substances in the composition of the final product.

In the course of experimental studies, the regularities of the variation in the intensity and rate of drying of medicinal plants were studied, allowing one to determine the moisture content of the material at any time and representing a qualitative picture of the drying process in its various periods.

A water-heating drying plant allows to obtain quality final products. In addition, low-temperature dehydration of the products allows maximum preservation of useful biologically active substances in the final products.



The water-heating convection installation offered by us allows us to intensify the technological process of drying vegetable raw materials from herbs, tubers, fruits and flowers; reduce losses of processed raw materials up to 25%, save up to 80-90% of biologically active substances and obtain high-quality products with improved marketability and chemical composition, solve the problem of energy and resource saving bringing to the required level, due to the use of flue gases or solid fuel.

Freshly cut ziziforu sorted from weeds, washed out the dust is cleaned from other contaminants. Cut into a size of 5 cm and previously wilted in the shade in the open air for 1 to 2 hours to reduce the initial moisture. To preserve biologically active substances exclude direct sunlight. Before drying, chopped pieces of ziphypora evenly place mesh pallets in stainless steel, each with a useful area of 0.9 m<sup>2</sup> and a depth of 5 cm. The drying process is carried out by supplying a coolant (bottom-up) at a temperature of 45–55 °C for 120–180 minutes. Hot air is used as the heat carrier, which is supplied from the outside. The fuel used is gas or solid fuel.

With the method of convective drying, the appearance of the medicinal plant was preserved, the drying time was 100 minutes. When IR drying, changes in appearance are insignificant, the drying

time is 80 min. However, in comparison with convective dehydration, the infrared drying ends for 20 minutes. before. The method has a disadvantage: for generating IR rays, the device consumes energy.

Shadow drying lasted 7 days; the appearance of the product has not changed much. Solar drying lasted 4 days; The leaves of the mint turned yellow, which already speaks of the non-quality of the final product obtained by this method.

Drying temperature is selected individually for each type of product, based on the content of BAS in raw materials. Drying is carried out at a temperature that does not denature enzymes, otherwise lysis reactions that occur during the entire drying process can be obtained.

For the ideal removal of bound moisture in the raw materials, the temperature and velocity of the coolant are regulated, proceeding from the morphological and biochemical characteristics of the raw materials.

The results of the conducted experiments show that in terms of speed and quality, the drying in the water-heating convection dryer gives the most productive. The quality of the resulting finished product meets the requirements of the food and pharmaceutical industries.

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## Section 6. Chemistry

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### INVESTIGATION OF THE INFLUENCE OF THE ACTIVATION MODE ON THE TECHNOLOGICAL PROPERTIES OF CLAYS OF KARAKALPAKSTAN

**Abstract:** The influence of process of disintegrator method of activation on viscosity and forming properties of suspensions prepared from bentonite clay of some deposits of Karakalpakstan is considered. It is shown, that at activation there is a change of chemical-mineralogical and granulometric compositions of the investigated objects.

**Keywords:** bentonite, disintegrator, funnel viscosity, static shear stress, filtration properties.

The variety of geological and technical conditions of drilling exploratory wells on oil and gas deposits of Ustyurt Plateau, the development of drilling technology, high requirements for the economy of drilling operations and environmental protection - all this requires improving the quality of mud and cementing slurry. As muds at drilling of wells on oil and gas the most distribution have received clay drilling solutions on water basis, which are multi-component and polydisperse systems [1].

The suitability of the mud for use is judged by several parameters characterizing certain properties of the fluid. The main purpose of drilling fluids is to take out the cuttings breed, to protect the well walls from destruction and to increase the strength of unstable ones [2; 3].

The high dispersion of clay minerals and their specific properties are achieved due to the peculiarities of the crystal-chemical structure, the ability of basal facets and microcrystals to actively interact with the water molecules [1]. In this regard, the most important clay minerals of interest for the preparation of drilling fluids are montmorillonite, kaolinite, hydromica and palygorskite [4].

There is no industrial production of modified clays in Karakalpakstan. Therefore, the products produced by LLC "Bentonite" are used. There are also researches on activation and chemical modification of clays of domestic deposits in order to obtain competitive with imported analogues of mud powders for various purposes. For these purposes clay minerals of Beshtjuben, Krantau and Hodzhakul deposits with

high content of minerals of group smectite and prosperous geographical locations [5; 6] were chosen.

The purpose of this work is to study the influence of mechanic activation methods on the rheological properties of water suspensions of bentonite clays of the aforementioned fields for subsequent production of clay slurries in accordance with the required Technological regulations on their application.

The research uses enriched forms of clay samples. The grinding of the enriched clay was made in disintegrator, constructed in laboratory conditions with variable number of revolutions of rotor up to 12000 rpm. The control measurement of technological parameters of the prepared suspensions by means of devices BCH-3, BM-6, ББР-2, the cylinder of ЛЦ-2 is carried out. The concentration of hydrogen ions was measured by ion meter of type И-160МИ.

The laboratory tests used enriched forms of clay, the humidity of which fluctuated within the limits of 3-18%. The influence of operation mode of disintegrator and degree of humidity of clay on the degree of its grinding and on technological properties of their suspensions is studied. The information on grinding of clay with various humidity is given in tables 1 and 2.

As it can be seen from the table data, the specific surface area of the clay increases when the rotor turns. At the same time with the humidity of clay up to 15% and more, there is a decrease in their specific surface to a large extent. However, in spite of this, increase of humidity of clay improves technological properties of ready mud powders. This is indicated by the higher values of the SSS and the low values of water loss of the drilling fluids on their basis. Such character of Dependence is explained by double increase of amorphous silica in mud powders, which at dissolution forms polysilicon acid, due to which the structural-mechanical and filtration properties of drilling fluids are improved [7].

From the point of view of drilling technology The best thixotropic properties have a solution whose strength increases faster and the ratio of  $SSS_{10}/SSS_1$  decreases.

As shown, the results of the study of the disintegrator activation of clay and its humidity on the SSS-suspensions on their basis, with the rotation of the rotors of the disintegrator 10000 rpm and moisture clay 10% achieved the best structure forming ability for clay of Krantau deposits. To achieve the comparatively better values of this indicator for the Beshtjuben field, the rotor rotation and the humidity of clay are 12000 rpm and 8%, respectively. Probably, differences of optimum modes of mechanical activations are connected, first of all, by difference of mineralogical compositions of clay.

As a result of chemical analysis of clay there was established appreciable decrease of the general content of  $SiO_2$  in comparison with the initial enriched clay. Further reduction was caused with the growth of the specific surface of the clay. Probably, it is connected with aggregative stability of the suspensions prepared on their basis, at the expense of what chemical analysis gets complicated with difficult coagulation of sparingly soluble  $H_2SiO_3 \cdot H_2O$  in the form, which is determined by silica in clay. It is also established that after disintegrator grinding losses of  $SiO_2$  make up to 3%, which leads to inflated content of  $R_2O_3$  oxides, and change of quantitative content of clay minerals, as evidenced by the change of intensity X-ray patterns.

The study of the influence of disintegrator activation of clay on the funnel viscosity of their suspensions showed that the increase in viscosity goes only up to a certain number of rotations, and then there is a slight decrease in the indicator, i.e the increase in the number of rotations above 8000-10000 per minute negatively affected the funnel viscosity of suspensions. This effect is due to the partial hydrophobization of clay particles by adsorption of the air. As the results of the conducted researches have shown, at disintegrator processing it is possible high-temperature flashes which promote hydrophobization in connection with high-temperature loads on the newly formed areas of a surface. Therefore increase of humidity of clay pro-

motes increase of optimum number of rotations as considerable share of heat is spent and the total weight for evaporation of water during processing the con- of clay is cooled.

Table 1. – Effect of clay moisture and disintegrator treatment mode on the granulometric composition of clays

№, rpm	Clay	Humidity, %	Particle size, mm				
			1,0 – 0,063	0,063 – 0,01	0,01 – 0,005	0,005 – 0,001	Less 0,001
5000	Krantau	5%	3,1	17,8	19,8	28,6	30,7
		10%	2,4	12,4	10,2	26,3	48,7
		15%	6,1	29,2	10,2	15,7	38,8
	Beshtjuben	5%	5,6	21,6	10,7	33,4	28,7
		10%	2,1	8,4	18,2	30,2	41,1
		15%	7,1	31,6	13,6	10,9	36,8
	Hodzhakul	5%	0,4	21,8	9,6	15,6	52,6
		10%	0,2	3,5	2,3	25,6	68,4
		15%	3,6	16,5	4,5	46,5	28,9
10000	Krantau	5%	1,2	11,2	18,4	29,5	39,7
		10%	0,9	9,4	8,7	22,4	58,6
		15%	0,4	7,2	15,2	27,4	49,8
	Beshtjuben	5%	5,6	21,6	10,7	33,4	42,4
		10%	2,1	8,4	18,2	30,2	56,7
		15%	7,1	31,6	13,6	10,9	57,8
	Hodzhakul	5%	0,4	21,8	9,6	15,6	58,9
		10%	0,1	2,5	1,6	26,6	69,2
		15%	0,1	2,3	2,3	16,8	78,5

Table 2. – Influence of clay moisture and treatment mode on properties of 10% suspensions

№, rpm	Clay moisture, %	Rigidity, MPa*s	Funnel viscosity,	Water loss, sm <sup>3</sup> /min.	Thickness корки, мм	SSS <sub>1</sub> / SSS <sub>10'</sub> мг/см <sup>2</sup>	Dialy residue, %
<b>Clay of Krantau</b>							
<b>1</b>	<b>2</b>	<b>3</b>	<b>4</b>	<b>5</b>	<b>6</b>	<b>7</b>	<b>8</b>
4000	5	16,8	31	16	1	34/38	1
	10	18,7	32	14	0,5	37/41	0
	15	17,8	32	14	0,5	37/44	0
8000	5	19,1	34	13	0,5	39/47	0
	10	25,5	43	10	0,5	54/87	0
	15	22,1	38	12	0,5	48/61	0
12000	5	22,3	39	11	0,5	41/49	0
	10	27,2	45	10	0,3	56/84	0
	15	27,5	49	9	0,3	59/74	0

1	2	3	4	5	6	7	8
Clay of Hodzhakul							
4000	5	13,1	24	17	1,5	24/28	1
	10	16,2	27	15	1,5	27/34	0
	15	15,3	26	16	1,5	28/35	0
8000	5	15,6	27	16	1	29/37	0
	10	19,1	35	14	1	44/57	0
	15	18,2	34	15	0,5	46/61	0
12000	5	20,8	31	12	0,5	38/49	0
	10	25,9	39	11	0,5	48/74	0
	15	29,2	42	10	0,5	49/76	0

The results of the completed research of structural changes occurring in the process of disintegrator activation led to the development of the technology of creation of high quality mud powders for drilling from alkaline-earth bentonites. Powders with high technological characteristics were obtained on the basis of bentonite clay of Krantau deposit without the consumption of chemical reagents modifiers and with the output of the fluid solution 18-20 м<sup>3</sup>

with the minimum values of filtration indicators. Use in the process of disintegrator grinding of clay of Beshtjuben deposit, soda ash in the amount of 3-4% of the mass of dry clay contributes to the obtaining mud powder with comparatively high technological parameters and output drilling mud not less than 15 м<sup>3</sup>. Such results are also obtained for clay of Hodzhakul deposits with the addition of soda ash in the amount of 1.5% of the mass of enriched clay.

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## ACTIVATION OF MOLECULAR OXYGEN WITH TRANSITION METALS COMPLEXES

**Abstract:** The influence of complex formation on reactivity of a bound ligand has been elucidated. Significant activation of molecular oxygen and butene as a result of their coordinating with transition metals has been established. The combined catalyst has been proposed to conduct the reaction of butene oxidation to methylethylketone under mild conditions (low temperature, atmospheric pressure) with high selectivity and yield of main product.

**Keywords:** molecular oxygen, methylethylketone, metal complex, absorption, dimethylformamide.

All chemical processes from 80 to 90% of are effected by of catalysts, the problem of their activity significantly increases.

At present there are two approaches to the creation of highly efficient catalytic systems. The first of them is based on biological catalysts – enzymes. Due to their selectivity and activity enzymes are an inaccessible ideal for synthetic catalysts.

They, however, conduct only the processes proceeding in animate nature. Unfortunately, the majority of important catalytic processes don't relate to such ones.

The other approach consists of catalytically active complexes of transition metals for the purposes of industrial catalysis.

The development of chemistry of transition metals organic compounds led to the creation of a great number of catalytically active transition metals complexes capable to catalyze reactions important for industry.

Transition metals complexes with organic ligands are most important for catalysis. Using them one can change energetic and structural of the catalysts the catalysts. As the majority of reactants are organic compounds, it is necessary to attain the true homogeneity of a catalytic system, i. e. solubility of complexes in organic solvents. The complexes

with inorganic ligands don't have enough solubility in organic solvents. In this case the reaction rate is limited with catalyst concentration or diffusive hindrances connected with the reaction localization at the interface of aqueous and organic phases.

Recently the interest to transition metals complexes with organic ligands has significantly increased because of their great importance in chemical synthesis and significant role in catalytic conversions of organic compounds. Besides, they found wide use in analytical chemistry, instrument making, medicine and etc.

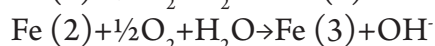
Study of the properties and reactivity of such complexes can help to find new types of theoretically interesting and practically important reactions. It is traditionally accepted that the main problem of the coordination chemistry is to establish the influence of complexing on the property of metal atom, far less the research has been devoted to study of the complexing influence on ligands reactivity.

In the modern applied chemistry the specific activation of simple molecules is rather significant. Many of them may be used as ligands. Such molecules in complexing can be so activated that become capable to conduct the processes of practical importance [1].

One of the extremely important, properties of complex compounds of transition metals with or-

ganic ligands is their binding with molecular oxygen. This type of complex compounds has the perspectives for possibility for their use as oxidizing agents in oxidative reactions of organic substances.

In animate nature enzymes play a role of oxygen complexes having transition metal ions. Ferro gem proteins in mammals and mollusks are the examples to it. In proteins oxidation degrees ferrum and copper are at low-valent state. Contact with oxygen metal ions usually transfer to high-valent-states:



However, in hemoglobin and hemocyanine, even when Fe (II) and Cu (I) contact with oxygen metal ions is not oxidized and oxygen coordinates with metal ions are in the form of molecular oxygen, in consequence with it stable existing oxygen complexes are formed. Such combined oxygen molecule becomes active and it is capable to oxidize the organic compounds both at low temperatures and at the temperature of creatures. The given reaction heat is the constituent part of energy source of living organisms. However, when isolated from living organisms such complexes become so unstable that metal ions are quickly oxidized with oxygen whereby they lose their catalytic activity.

From this point of view the search of new catalytic systems being the models of enzymes, capable under mild conditions to conduct reaction of substrates oxidation, to form stable oxygen complexes with transition metals, is rather urgent.

At present the extensive researches on a large number of complexes capable for modeling functions and in some cases for creating the structure of active center of O<sub>2</sub> natural carriers are carried out. The study of these models by means of modern physical methods allowed in a number of cases to establish the nature of metal active center interaction with oxygen molecule [2]. The complexes of metals of the first transition series at low oxidation degree Mn (II), Fe (II), Ni (II), Cu (I) proved to be close to O<sub>2</sub> natural carriers. They are able to be oxygenat-

ed in aqueous solutions and have inner coordination sphere composition similar to natural active centers.

The information on reactivity of coordinated oxygen in transition metals

complexes is rather little. But the available data allow to consider [3; 4] that coordinated molecular oxygen in many compounds is in the activated state.

The interest to the activation of coordinated molecular oxygen has been raised also by the possibility for formation of short-lived intermediates in homogeneous – catalytic reactions of autooxidation. The study of O<sub>2</sub> reactivity in oxygenated complex has a special importance for elucidation of reaction mechanisms.

The study of intermediate reaction allows to present the complex mechanism of homogeneous — catalytic reaction in the form of separate stages. Hence, the transition metal complexes with O<sub>2</sub> play an important role for modeling biological processes as well as for clearing up mechanism and search of catalysts for oxidation-reduction processes.

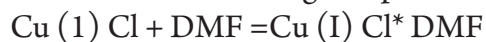
The role of O<sub>2</sub> complexes of transition metals, however, is not limited with purely chemical, biological and medical aspects. The coordination compounds capable to add and activate oxygen may serve as the catalysts of reaction for producing industrially important products [5–9].

The industrially important reactions of this type include a liquid-phase oxidation of paraffins and alkylarenes olefins and carbonyl compounds and complex vinyl and allyl esters as well as numerous processes of alkenes epoxidation. Thus, the oxidation of olefins in the presence of palladium salts became the first example in metal complex catalysis through which it was succeeded to characterize properly all stages and establish a role of catalyst components in this complex multi-stage reaction. In spite of the fact that some details remain as a subject for discussion this process is one of the most studied today.

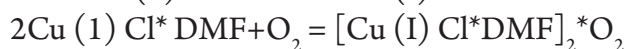
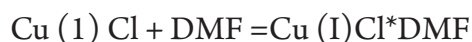
In well studied Walker process using oxidative-reductive system of Pd-Cu aqueous solution the propylene oxidation to acetone proceeds relatively eas-

ily, but in the case of butene and higher olefins with carbon atoms number from 5 and more the reaction slows down because these olefins are poorly soluble in water, hence the production of methylethylketone by means of this catalyst is not practically effected.

With the aim of search of efficient catalyst for the reaction of butene-1 oxidation to methylethylketone we have carried out the extensive studies of catalytic properties of chlorides of 3d transition metals in oxidation of butene-1 with molecular oxygen. It has been established that they are the efficient catalysts of this reaction and in the intermediate stage form stable complexes with molecular oxygen. Dissolution of Cu (I) Cl in liquid dimethylformamide led to the formation of the following complex:

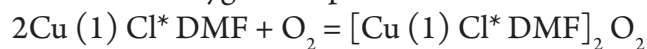


This complex may be represented by general formula  $M_m X_n L_e$ . The case  $m=1, n=1, L=1$  corresponds to  $\text{Cu (I)Cl}^* \text{DMF}$ , further, for instance, if complexing agent  $\text{Ti (3)Cl}^* \text{DMF}$  or  $\text{V (3)C}^* \text{DMF}$ , where  $m=1, n=3, L=1$ . When the solution of added Cu (1) absorbs oxygen, one-valent copper is oxidized with oxygen to two-valent copper. We think that the similar oxidation reaction occurs in this case too. However, the solution of a complex of two-valent copper compound  $\text{Cu (2)Cl}_2$  and DMF is of red-brown color. But in our case when Cu (1)  $\text{Cl}^* \text{DMF}$  solution absorbs oxygen the complex has dark-green color:

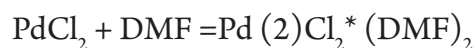


The spectra of complex Cu (1) solution and of complex of  $\text{O}_2$  absorption quite differ from spectra complex Cu (2) solution and complex with  $\text{O}_2$  absorption of green color has maximum absorption at 265 nm that evidences the formation of so-called oxygen complex, where oxygen molecule is coordinated. The amount of absorbed oxygen by complex Cu (1)  $\text{Cl}^* \text{DMF}$  solution with certain concentration has been measured. As a result, it was found that mole ratio of  $\text{O}_2$  to Cu (1) was 1:2 and the compound having maximum absorption at 265 nm and green color was

oxygen complex formed due to the following equation and such oxygen complex was unknown:

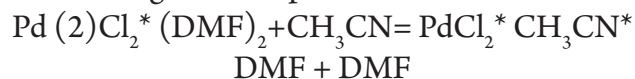


Just in the case of Cu (1)  $\text{Cl}^* \text{DMF}$  solution even when it absorbs oxygen, this oxygen is not consumed for Cu (1) oxidation in solution to Cu (2) and it is available in the form of so-called oxygen complex, where oxygen molecule is coordinated with Cu (1). The specific feature of this oxygen complex is that the coordinated oxygen is not cleaved, not removed from complex even at heating, i. e. absorption is irreversible. When a small molecule, such as (X is coordinated with metal ion a substrate is polarized and activated as a result of electron transfer and in the case of oxygen complex, it has been found that in this case, the coordinated O is activated. As it is described above, methylethylketone is obtained by butene-1 oxidation by means of bound oxygen activated as a result of oxygen complex formation and if butene-1 may be also activated as a result of butene-1 complex formation, then the oxidation reaction will proceed at low temperature and pressure. Therefore the researches have been carried out with different complexes of transition metals of palladium group. It has been found that  $\text{Pd (2) Cl}_2$  chloride formed complex with DMF on-the scheme:



It is well soluble in different solvents.

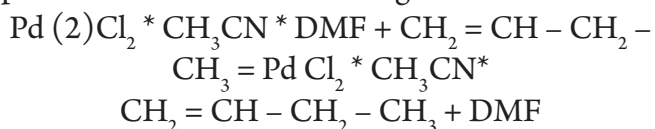
Different researches have been carried out with the purpose to establish the conditions for the formation of more stable butene complexes. Nitrile, such as  $\text{CH}_3\text{CN}$ . has been added as a modifying ligand (an additional complexing agent). In this case the following new complex is formed:



The investigations have been performed due to the gas absorption method to elucidate the reactions of the obtained palladium complex interaction with butene.

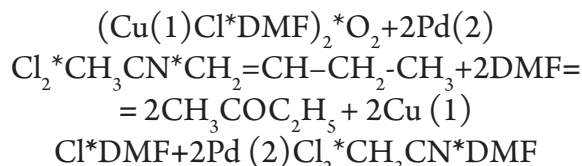
When separate solvent comprising DMF and acetonitrile ( $\text{CH}_3\text{CN}$ ) in case A was compared

with Pd (2) complex in case B, then the amount of absorbed butene was 1,6 times more than in case A. Though the amount of the absorbed butene-1 was great even in the case of pure solvent. This reaction proceeds due to the reaction of a new butene complex formation on the following scheme:



Thus, the formed complex of butene-1 contains marked activated butene-1.

Further the coordinated butene-1 is oxidized with bound in complex oxygen to obtain methylethylketone on the scheme:



The realization of the process for obtaining methylethylketone by the proposed method via interaction of coordinated with transition metals and thereby activated butene and oxygen differs from the existing methods for methylethylketone preparation and a number of advantages: the process is effected under mild conditions, at atmospheric pressure and low temperature 80 degrees with high yield and selectivity of main product. In this case the valency of transition metal ions does not change and water doesn't take part in the formation of methylethylketone.

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## SYNTHESIS AND SPECTRAL RESEARCH OF POTASSIUM SALT OF FERROCENCARBONIC ACID

**Abstract:** The method of synthesis of potassium salt of ferrocenic acid is shown in the article, which shows a high biological activity for living organisms. Based on the analysis of the data, the IR and MASS spectra of the starting and derivative reactions were determined that a monosubstitution product was obtained in the reactions.

**Keywords:** monoacetylferrocene, potassium salt of ferrocenic acid, biostimulant, reactions, spectral studies, biological activity.

Although more than 60 years ago, dicyclopentadienyl iron-ferrocene (Fc) has been discovered, many of its derivatives are well known, and intensive scientific research is now being carried out to obtain new, practically significant derivatives.

Among the synthesized derivatives of ferrocene are many biologically active representatives. The biological activity of such ferrocene compounds has been proved by many experimental studies and some of them have been introduced into practice.

As is known, one of the main requirements for biologically active substances is their solubility in water. Most ferrocene derivatives are poorly soluble in water. To eliminate this deficiency they are transferred to the corresponding sodium or potassium salts. For example, ferrocene-containing substance introduced into medical practice as an anti-anemia agent – “Ferroceron” is the sodium salt of o-carboxybenzoylferrocene [1]. Sodium and potassium salts of p-ferrocenylphenol are proposed as effective biostimulators of agricultural plants [2].



Figure 1. (Ferrocenecarbonyl) sodium benzoate



The literature contains extensive material on the synthesis and various transformations of ferrocene and its derivatives. One of the important derivatives

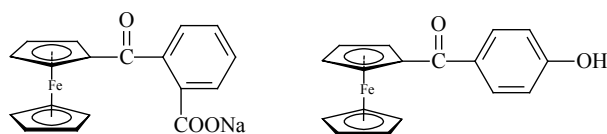


Figure 2. Ferrocenyl (4-hydroxyphenyl) –methanone

A large number of carboxylic acids containing a ferrocene group have been synthesized. In these compounds, the ferrocene is directly bonded to the carboxyl group or linked via a carbon chain.

Ferrocenecarboxylic acids are obtained in several ways, differing in the method of formation of the carboxyl group: carboxylation of ferrocene, hydrolysis

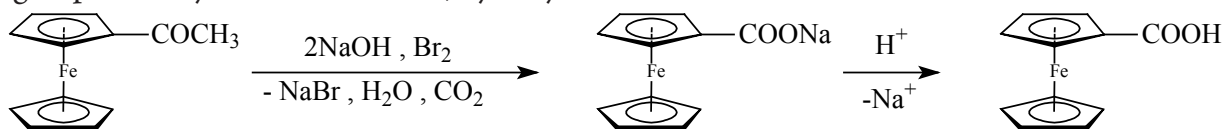


Figure 3. Scheme for the preparation of ferrocenecarboxylic acid from acetylferrocene

The potassium salt of ferrocene-carboxylic acid was prepared by dissolving an acid sample in a 0.5 M solution of potassium hydrogen carbonate. This method is widely used for the preparation of salts of organic acids [5]. The structure

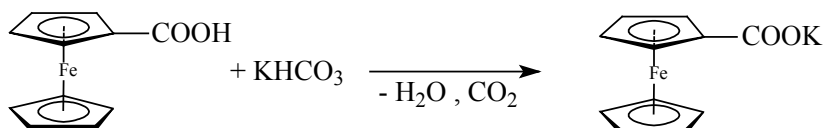


Figure 4. Scheme for the preparation of potassium salt of ferrocenic acid

In this spectrum, two intense absorption bands can be observed in the 1356 and 1388  $\text{cm}^{-1}$  regions, also characteristic of the carboxylate ion ( $\nu_{\text{symme}}$ ). The presence of a ferrocenyl group can be established by characteristic absorption bands in the region of 3096, 1005, 1021, and 1105  $\text{cm}^{-1}$  [1].

The data are consistent with mass spectroscopy data. Thus, the mass spectrum of the salt contains an intense peak with  $m/z$  229.0478 corresponding to the carboxylate ion and a less intense peak with  $m/z$  186.0267 corresponding to the ferrocenyl cation [7].

of ferrocene are oxygen-containing compounds, including carboxylic acids [3; 4].

of nitriles, oxidation of substituted ferrocenes [1]. Oxidation methods can be considered more convenient, since they do not require special conditions and equipment. Therefore, in this paper, we used the oxidation of monoacetylferrocene to produce ferrocenic acid. As an oxidizer, sodium hypobromite was used.

of the obtained salt was studied by IR and mass spectroscopy. Thus, the intense bands at 1661  $\text{cm}^{-1}$  and 1653  $\text{cm}^{-1}$  correspond to the asymmetric valence vibration of C=O in the carboxylate ion [6].

#### Experimental part

**Reagents and equipment.** The melting points were determined on a SMP10 (Germany) instrument, the IR spectra were recorded on a PerkinElmer Spectrum spectrometer (Version 10.4.2), the mass spectra were recorded with a liquid chromatography mass spectrometer PerkinElmer AxION 2 TOF MS.

**Technique of the experiment.** Ferrocenic acid. In a three-necked flask with a volume of 0.5 l, equipped with a thermometer, a dropping funnel and a mechanical stirrer, 4 g (0.1 mole) of sodium hydroxide and 20 ml of water were placed. 4.8 g (0.03 mole)

of bromine were added dropwise to the alkali solution at a temperature of no more than 10 °C. The temperature was then lowered to 0 °C, and 2.28 g (0.01 mole)

of monoacetylferrocene in 10 ml of dioxane was added dropwise to the reaction mixture.

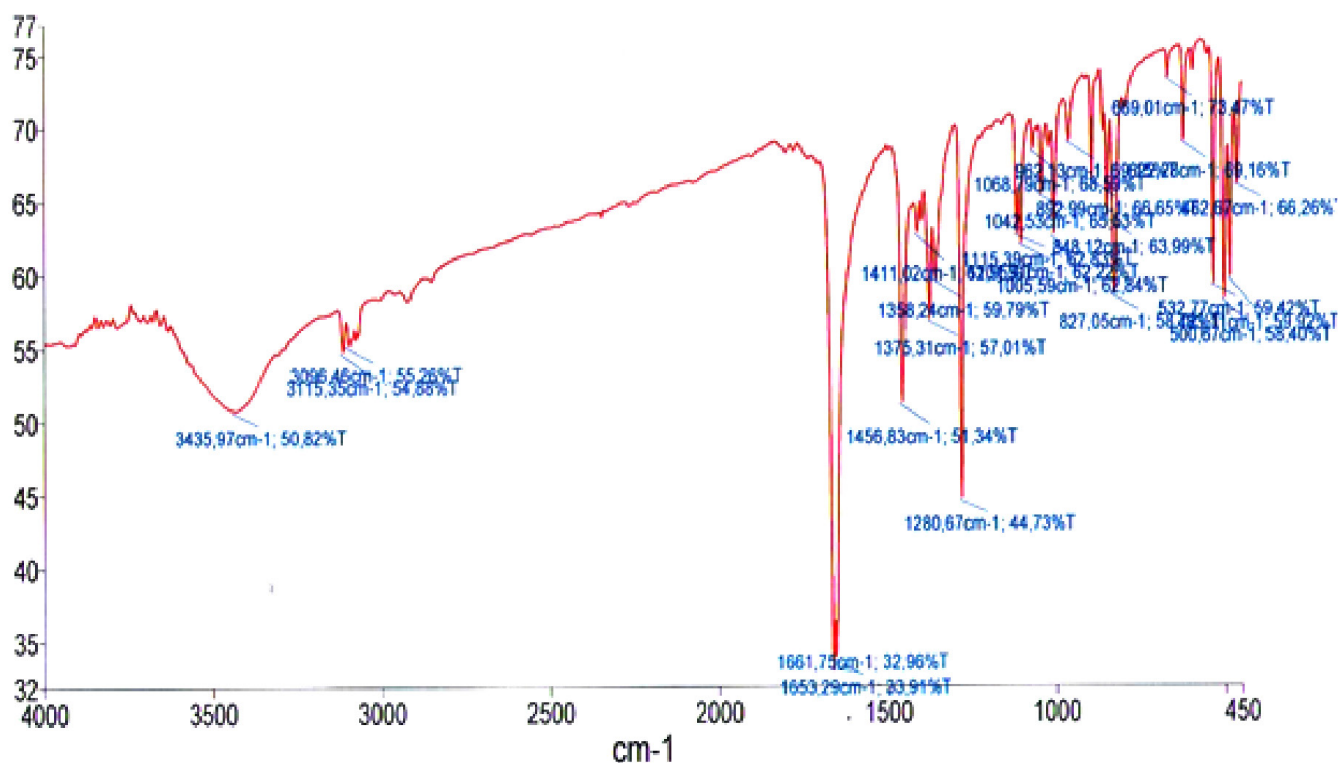


Figure 5. IR spectrum of the potassium salt of ferrocenecarboxylic acid

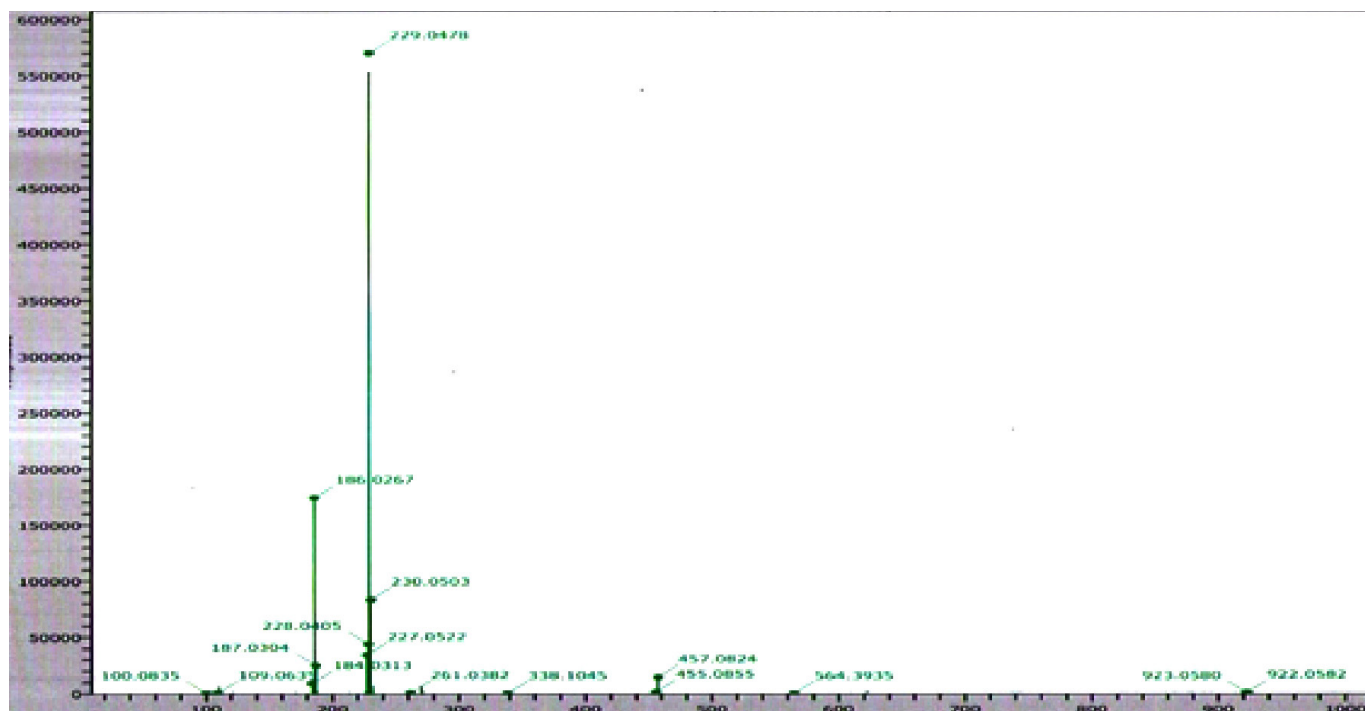


Figure 6. Chromatomass spectrum of potassium salt of ferrocenic acid

**Technique of the experiment.** Ferrocenic acid. In a three-necked flask with a volume of 0.5 l, equipped with a thermometer, a dropping funnel and a mechanical stirrer, 4 g (0.1 mole) of sodium hydroxide and 20 ml of water were placed. 4.8 g (0.03 mole) of bromine were added dropwise to the alkali solution at a temperature of no more than 10 °C. The temperature was then lowered to 0 °C, and 2.28 g (0.01 mole) of monoacetylferrocene in 10 ml of dioxane was added dropwise to the reaction mixture.

Potassium salt of ferrocene-carboxylic acid. 0.23 g (0.01 mol) of ferrocenecarboxylic acid was placed in a porcelain cup. To the acid, 2 ml of a 0.5 M solution of potassium hydrogencarbonate

was added dropwise. The cup was placed in a water bath and heated gently with stirring until the water evaporated completely. After that, the dish was cooled, a dark yellow precipitate was isolated. The yield is 0.2 g (87%), T. m. = 284–285 °C. The gross formula is  $C_{11}FeH_9O_2K$ .

Thus, we synthesized the potassium salt of ferrocenic acid and established the structures using IR and chromatographic mass spectroscopy. We have for the first time synthesized the oxidation reaction product – ferrocenecarboxylic acid and its salts according to the technique that we have improved. Based on the analysis of the obtained spectral data, the structure of the products of the reactions was confirmed.

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## THE RATIONALE OF THE PROCESS OF RECEIVING NEW CLASS DEFOLIANTS

**Abstract:** The study of a mutual influence of components in two aqueous systems consisting diurea of chlorate of sodium, monoethanolamine acetate, ethanol and cypermethrin found that in these studied systems, there is no formation of new compounds. That is the system components retain their individuality with the co-presence. The results of the studied systems show the possibility of obtaining a liquid defoliant with insecticidal activity.

**Keywords:** mutual system, diagram of solubility, the crystallization temperature, chart solubility polythermal system, defoliant, diurea of chlorate of sodium, acetic acid, monoethanolamine acetate.

### Introduction

For the pre-harvest removal of cotton leaves, seed crops of legumes, potatoes, sunflowers and rice, special substances are used – defoliants, causing the leaves to fall off [1–2]. Timely application of defoliants ensures high-quality harvesting of raw cotton, accelerates the opening of boxes, raises the grade of products.

For the period of cotton ripening, a period of development of a number of sucking pests occurs: aphids, whiteflies, and clusters [3], often causing broadening of the fiber of the opened bolls. This adversely affects the grade and technological properties of cotton fiber [4–5]. To protect plants from sucking pests and prevent “broadening” of cotton fiber, the following insecticides are most widely used: mospilan (acetamiprid), acephate and cypermethrin [6].

Cypermethrin ( $C_{22}H_{19}Cl_2NO_3$ ) is an active substance  $\alpha$ -cyano-3-phenoxybenzyl-cis, trans – 2,2-dimethyl-3-2,2 (dichlorovinyl) cyclopropane carboxylate. The empirical formula is  $C_{22}H_{19}Cl_2NO_3$ .

It is viscous yellowish liquid with a faint odor. The technical product contains  $\approx 90\%$  of the main substance. Precautions should be used – as with medium-toxic pesticides. It is used in the fight against pests of cotton against sucking pests at rates of 15–25 g/ha.

The destruction of sucking pests also contributes to holding the defoliation of cotton. After defoliation of cotton is significantly reduced the number of sucking pests, but it is impossible to achieve 100% kill insects. For qualitative defoliation of cotton and to achieve 100% destruction sucking pests, such defoliants must be used which exhibits both physiological and insecticidal activity.

The foregoing makes it necessary to create a low-toxic, effective defoliants, having physiological and insecticidal activity. When using this preparation excluded two-fold cotton processing and reduced rate of pesticide consumption.

To study the physico-chemical process of obtaining a new class defoliants having both physiological

and insecticidal activity was studied solubility in the systems;  $\text{NaClO}_3 \cdot 2\text{CO}(\text{NH}_2)_2 - [95,0\% \text{C}_2\text{H}_5\text{OH} + 5,0\% \text{C}_{22}\text{H}_{19}\text{Cl}_2\text{NO}_3] - \text{H}_2\text{O}$ ;  $[99,65\% \text{NaClO}_3 \cdot 2\text{CO}(\text{NH}_2)_2 + 0,35\% \text{NH}_2\text{C}_2\text{H}_4\text{OH} \cdot \text{CH}_3\text{COOH}] - [95,0\% \text{C}_2\text{H}_5\text{OH} + 5,0\% \text{C}_{22}\text{H}_{19}\text{Cl}_2\text{NO}_3] - \text{H}_2\text{O}$  visually polythermal method in a wide temperature range.

The solubility of the components in the complex system  $\text{NaClO}_3 \cdot 2\text{CO}(\text{NH}_2)_2 - [95,0\% \text{C}_2\text{H}_5\text{OH} + 5,0\% \text{C}_{22}\text{H}_{19}\text{Cl}_2\text{NO}_3] - \text{H}_2\text{O}$  (Fig.1) was studied in a wide temperature range to determine the mutual influence of the components at their joint presence in obtaining new types of defoliant.

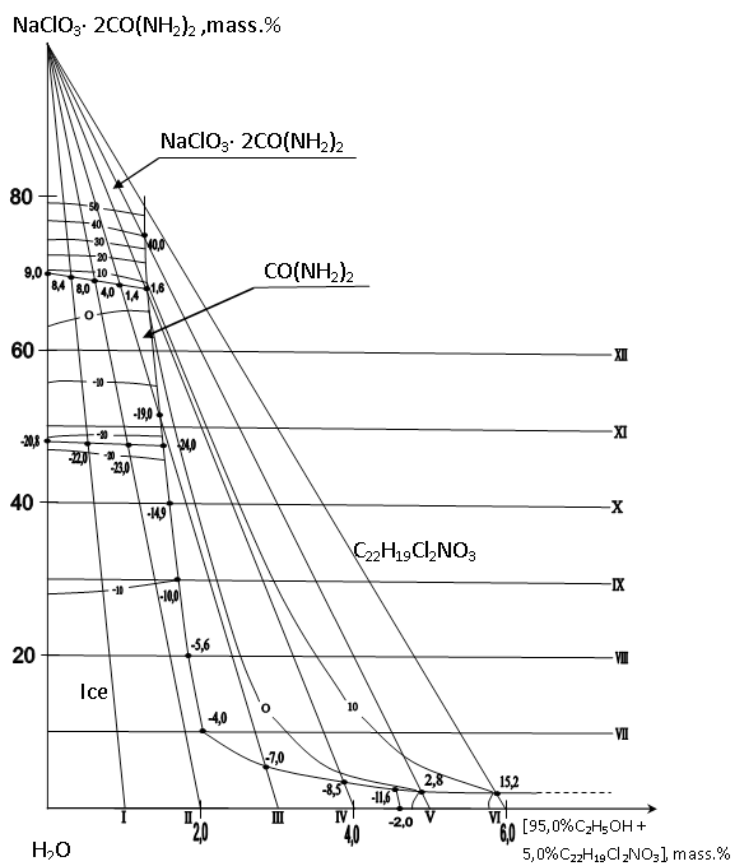


Figure 1. The polythermic solubility diagram of the system  $\text{NaClO}_3 \cdot 2\text{CO}(\text{NH}_2)_2 - [95,0\% \text{C}_2\text{H}_5\text{OH} + 5,0\% \text{C}_{22}\text{H}_{19}\text{Cl}_2\text{NO}_3] - \text{H}_2\text{O}$

The mutual influence of the components in the system  $\text{NaClO}_3 \cdot 2\text{CO}(\text{NH}_2)_2 - [95,0\% \text{C}_2\text{H}_5\text{OH} + 5,0\% \text{C}_{22}\text{H}_{19}\text{Cl}_2\text{NO}_3] - \text{H}_2\text{O}$  studied using twelve internal incisions. Based the polythermal solubility of binary systems and the system of internal incisions  $\text{NaClO}_3 \cdot 2\text{CO}(\text{NH}_2)_2 - [95,0\% \text{C}_2\text{H}_5\text{OH} + 5,0\% \text{C}_{22}\text{H}_{19}\text{Cl}_2\text{NO}_3] - \text{H}_2\text{O}$  constructed polythermic solubility diagram of the eutectic freezing point  $-24,0^\circ\text{C}$  to  $40^\circ\text{C}$ , which is characterized by the presence of regions of crystallization of ice, urea, diurea of chlorate of sodium, cypermethrin and ethanol.

The indicated crystallization fields converge at three points of nonvariant ternary systems for which set the equilibrium compositions of the solutions and the corresponding crystallization temperature (Table. 1).

The eutectic point system corresponds to 47,6%  $\text{NaClO}_3 \cdot 2\text{CO}(\text{NH}_2)_2$ , 1,72%  $[95,0\% \text{C}_2\text{H}_5\text{OH} + 5,0\% \text{C}_{22}\text{H}_{19}\text{Cl}_2\text{NO}_3]$  and 52,97%  $\text{H}_2\text{O}$  at  $-24,0^\circ\text{C}$ .

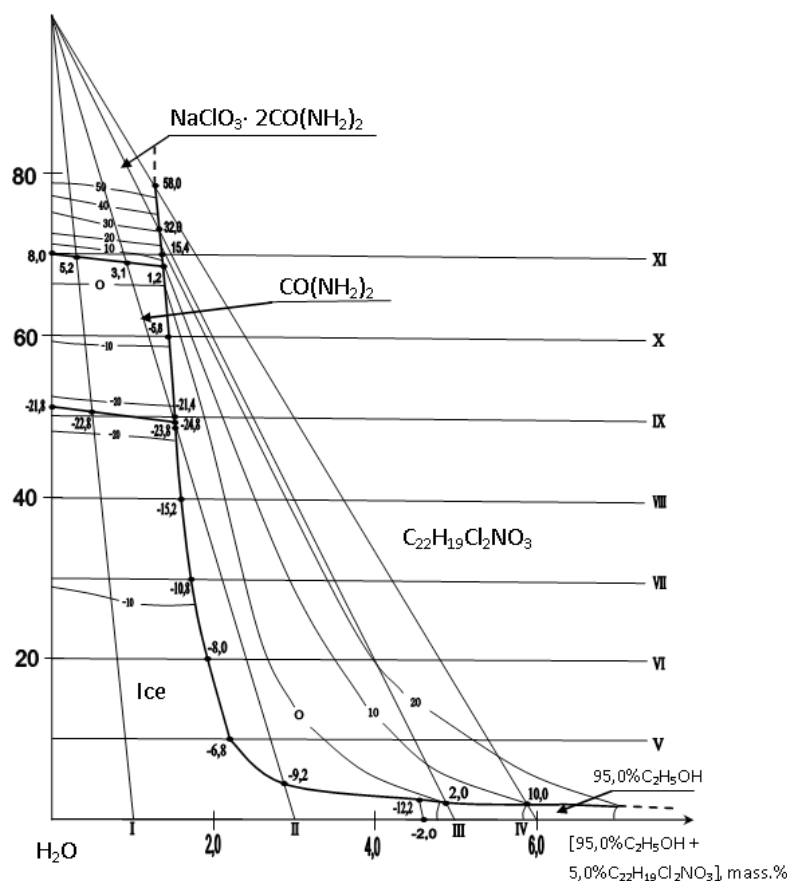
The mutual influence of components in the system  $[99,65\% \text{NaClO}_3 \cdot 2\text{CO}(\text{NH}_2)_2 + 0,35\% \text{NH}_2\text{C}_2\text{H}_4\text{OH} \cdot \text{CH}_3\text{COOH}] - [95,0\% \text{C}_2\text{H}_5\text{OH} + 5,0\% \text{C}_{22}\text{H}_{19}\text{Cl}_2\text{NO}_3] - \text{H}_2\text{O}$  studied us with eleven internal cuts (Figure 2).



Table 1. – Triple and double points of the system  $\text{NaClO}_3 \cdot 2\text{CO}(\text{NH}_2)_2$  –  $[95,0\% \text{C}_2\text{H}_5\text{OH} + 5,0\% \text{C}_{22}\text{H}_{19}\text{Cl}_2\text{NO}_3] - \text{H}_2\text{O}$ 

Composition of liquid phase, %			$T_{\text{cr}} \text{ } ^\circ\text{C}$	Solid phase
$\text{NaClO}_3 \cdot 2\text{CO}(\text{NH}_2)_2$	$[95,0\% \text{C}_2\text{H}_5\text{OH} + 5,0\% \text{C}_{22}\text{H}_{19}\text{Cl}_2\text{NO}_3]$	$\text{H}_2\text{O}$		
70,0	–	30,0	9,0	$\text{CO}(\text{NH}_2)_2 + \text{NaClO}_3 \cdot 2\text{CO}(\text{NH}_2)_2$
68,0	1,3	30,7	1,6	$\text{CO}(\text{NH}_2)_2 + \text{NaClO}_3 \cdot 2\text{CO}(\text{NH}_2)_2 + \text{C}_{22}\text{H}_{19}\text{Cl}_2\text{NO}_3$
48,0	–	52,0	-20,8	Ice + $\text{CO}(\text{NH}_2)_2$
47,6	1,72	50,68	-24,0	Ice + $\text{CO}(\text{NH}_2)_2 + \text{C}_{22}\text{H}_{19}\text{Cl}_2\text{NO}_3$
2,8	4,56	92,64	-11,6	Ice + $\text{C}_2\text{H}_5\text{OH} + \text{C}_{22}\text{H}_{19}\text{Cl}_2\text{NO}_3$
–	4,6	95,4	-2,0	Ice + $\text{C}_2\text{H}_5\text{OH}$

99,65%  $\text{NaClO}_3 \cdot 2\text{CO}(\text{NH}_2)_2 +$   
 0,35%  $\text{NH}_2\text{C}_2\text{H}_4\text{OH} \cdot \text{CH}_3\text{COOH}$ , mass. %


 Figure 2. The polythermic solubility diagram of the system  $[99,65\% \text{NaClO}_3 \cdot 2\text{CO}(\text{NH}_2)_2 + 0,35\% \text{NH}_2\text{C}_2\text{H}_4\text{OH} \cdot \text{CH}_3\text{COOH}] - [95,0\% \text{C}_2\text{H}_5\text{OH} + 5,0\% \text{C}_{22}\text{H}_{19}\text{Cl}_2\text{NO}_3] - \text{H}_2\text{O}$ 

Based the polythermal solubility of binary systems and internal sections constructed solubility of the system  $[99,65\% \text{NaClO}_3 \cdot 2\text{CO}(\text{NH}_2)_2 + 0,35\% \text{NH}_2\text{C}_2\text{H}_4\text{OH} \cdot \text{CH}_3\text{COOH}] - [95,0\% \text{C}_2\text{H}_5\text{OH} + 5,0\% \text{C}_{22}\text{H}_{19}\text{Cl}_2\text{NO}_3] - \text{H}_2\text{O}$  from

an eutectic freezing point ( $-24.8 \text{ } ^\circ\text{C}$ ) to  $50 \text{ } ^\circ\text{C}$ , which is characterized by the presence of regions of crystallization of ice, urea, diurea of chlorate of sodium, cypermethrin and ethanol.

The indicated crystallization fields converge at three triple points nonvariant ternary systems for which set the equilibrium solution compositions

and the corresponding crystallization temperature (Table 2).

Table 2. – Triple and double points of the system [99,65%  $\text{NaClO}_3 \cdot 2\text{CO}(\text{NH}_2)_2 + 0,35\% \text{NH}_2\text{C}_2\text{H}_4\text{OH} \cdot \text{CH}_3\text{COOH}$ ] – [95,0%  $\text{C}_2\text{H}_5\text{OH} + 5,0\% \text{C}_{22}\text{H}_{19}\text{Cl}_2\text{NO}_3$ ] –  $\text{H}_2\text{O}$

Composition of a liquid phase,%			$T_{\text{cr}}$ , °C	Solid phase
[99,65% $\text{NaClO}_3 \cdot 2\text{CO}(\text{NH}_2)_2 + 0,35\% \text{NH}_2\text{C}_2\text{H}_4\text{OH} \cdot \text{CH}_3\text{COOH}$ ]	[95,0% $\text{C}_2\text{H}_5\text{OH} \cdot 5,0\% \text{C}_{22}\text{H}_{19}\text{Cl}_2\text{NO}_3$ ]	$\text{H}_2\text{O}$		
70,0	–	30,0	8,0	$\text{NaClO}_3 \cdot 2\text{CO}(\text{NH}_2)_2 + \text{CO}(\text{NH}_2)_2$
68,1	1,4		1,2	$\text{NaClO}_3 \cdot 2\text{CO}(\text{NH}_2)_2 + \text{CO}(\text{NH}_2)_2 + \text{C}_{22}\text{H}_{19}\text{Cl}_2\text{NO}_3$
49,4	1,56		–24,8	Ice+ $\text{CO}(\text{NH}_2)_2 + \text{C}_{22}\text{H}_{19}\text{Cl}_2\text{NO}_3$
51,0	–		–21,8	–//–
2,8	4,56		–12,2	Ice+ $\text{C}_{22}\text{H}_{19}\text{Cl}_2\text{NO}_3 + \text{C}_2\text{H}_5\text{OH}$
–	4,6		–2,0	Ice+ $\text{C}_2\text{H}_5\text{OH}$

Thus, the results showed that in the studied systems do not form any solid solution or new chemical compounds on the basis of the starting components, that is, the components retain their individuality, and consequently, their physiological activity. The studied system is a simple eutonic type.

From the results of the studied system [99.65%  $\text{NaClO}_3 \cdot 2\text{CO}(\text{NH}_2)_2 + 0.35\% \text{NH}_2\text{C}_2\text{H}_4\text{OH} \cdot \text{CH}_3\text{COOH}$ ] – [95.0%  $\text{C}_2\text{H}_5\text{OH} + 5.0\% \text{C}_{22}\text{H}_{19}\text{Cl}_2\text{NO}_3$ ] –  $\text{H}_2\text{O}$  implies the possibility of pro-

ducing a liquid defoliant with physiological and insecticidal activity by dissolving 5.0% alcohol solution of cypermethrin in aqueous solution diurea of chlorate of sodium and monoethanolamine acetate composition [99.65%  $\text{NaClO}_3 \cdot 2\text{CO}(\text{NH}_2)_2 + 0.35\% \text{NH}_2\text{C}_2\text{H}_4\text{OH} \cdot \text{CH}_3\text{COOH}$ ].

According to the results of the studied system is obtained defoliant formulation based on diurea of chlorate of sodium, monoethanolamine acetate, ethanol and cypermethrin.

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## **SYSTEMATIC ANALYSIS OF PRIMARY PREPARATION PROCESSES OF OIL FOR INDUSTRIAL REFINING**

**Abstract:** In this article the process of initially preparation of oil refining in industry condition was analyzed system. Furthermore, systematic analysis of distillation oil devise (DOD) shows existing process line is insufficient, that is it contents the process of low parameter stability. It is confirmed by indicator of technological system integrity. Hence, development of the basic processes for separation of water and salts off oil in DOD allows increasing considerably technical and economic of operating benefits, as well as quality oil preparation for refining.

**Keywords:** demulsifier, emulsion, hydrophob, globule, gas condensate, oil, destruction, dehydration, desalination.

### **Introduction**

It is known, in Uzbekistan oil mining main-

ly is carried out as a water-oil emulsions (WOE), which subjected to initially preparation into DOD

with various output [1]. Equipments on oil preparation are as typical complex chemical technological systems to develop and optimize necessary application of modern ways of systematic analysis that solved by two stages: first, there are analysed

DOD quality properties, second, there are quantitative ones [2].

The systematic analysis of DOD assumes high rate of summary of studied processes scheme is presented in (Figure 1).

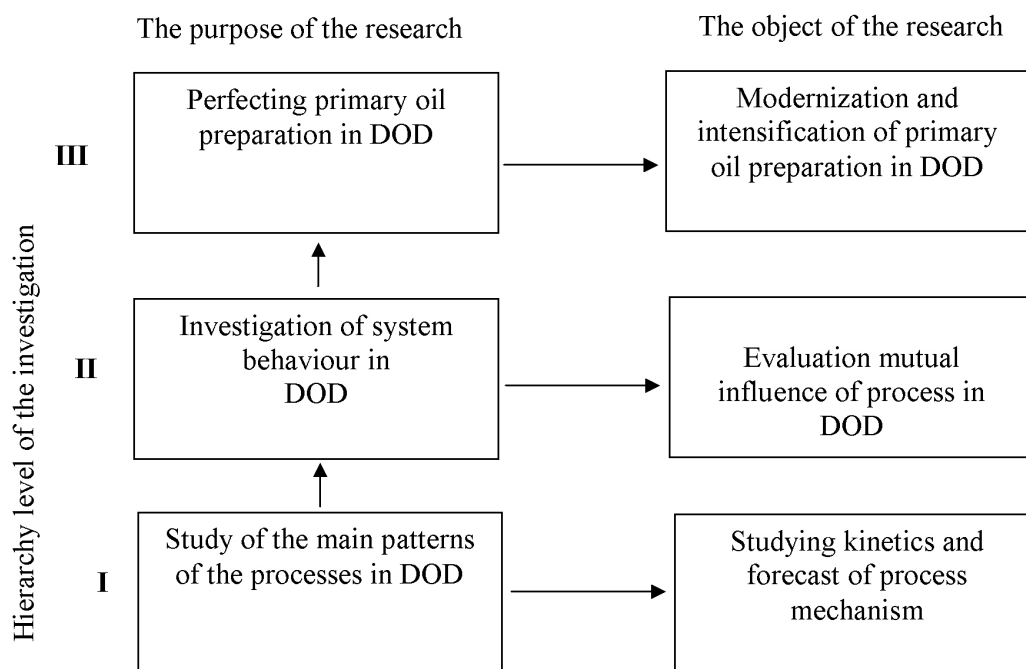


Figure 1. Structural diagram of the processes in DOD

As it is seen from Fig.1 on each level of systematic analysis there are increased the specification rate. At the same time, correction and refinement of solution accepted previous levels. Flow chart of DOD can be divided into four functional subsys-

tems namely A, B, C and D presenting in (Fig. 2). Furthermore, the subsystems can be embodied into different flowsheets differing each other on number of elements and their compounds.

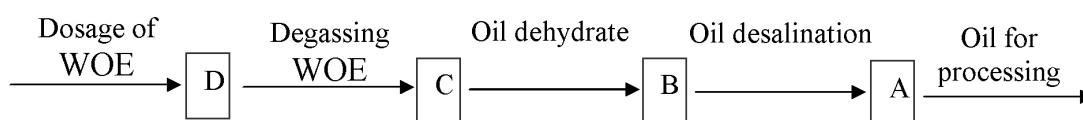


Figure 2. Coherence of goal attainment of subsystems in DOD

It is from (Fig. 2). A is oil refining in industrial condition, B is oil desalination, C is oil dehydration, Δ is degassing water-oil emulsion (WOE).

Thereby, the analysis of technological operation in DOD has shown that some processes can be implemented in two and more.

(Figure 3) illustrates flowsheet of installation for preparation of oil, which functioned as fol-

low [3]: crude oil from well feeds into oil-gas tank C-1 whence it directed to settler O-1. In that case, gas of high and medium pressure from the latter directed into booster compressor station (BCS). From the settler O-1 oil enters the reheating furnace (RF) whence it directed into second settler O-2. Before entering oil on RF it is mixed with demulsifier by block-doser D-1. However, the gas released from O-2 with

medium pressure feeds into BCS. Stratal and bottom water from settlers O-1 and O-2 directed into water-purification (WP) and subsequence into device to keep stratal pressure (SP) then the water flows in the strata. Form settler O-2 oil feeds into second oil and gas tank C-2 and it can be fed into processing vessel reservoir water-oil suspension (RWOS № 1). As a con-

sequence, water separated from the latter flows into drain capacity and then by pump it is directed in WP. After that, oil from reservoir RWOS № 1 enters the second one RWOS № 2, whence the oil via pump station as marketable oil enters in oil refinery (OR). Thus, low-grade oil (LGO) as a recycle returns in the manufacturing locating between O-1 and RF.

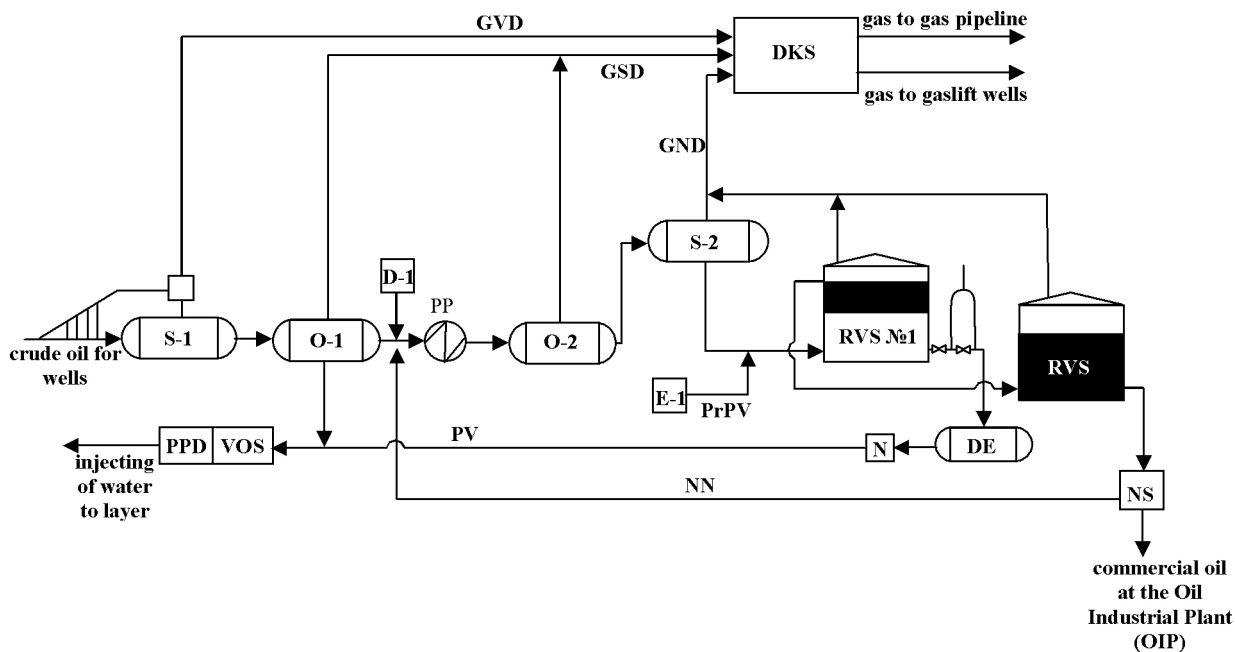


Figure 3. flowsheet of installation for preparation of oil

As it is seen from Fig. 3 flowsheet of the equipment in order to prepare oil is compound chemical engineering object is being recirculation lines.

Absolutely, functioning efficiency of present set depends on the oscillation of oil composition, especially oil attendant that stabilize water-oil emulsion formation (pyrobitumen, paraffin, resin, mechanical impurities and etc.).

Yet, in industrial condition there is not possibility for maintenance of all oil attendants that explained continuous ingress of oil from multitude of wells. In addition, changing contents maintained above oil attendants, stratal water and mineral salts significantly impact on efficiency of marketable oil process. If development of DOD supposes some directions

on improvement assessment of property wholeness (O) of the flowsheet will be important task.

Scientific basis of calculation of wholeness property of the flowsheet was stated in [4].

Evaluation of DOD wholeness consists of figures process stability belonging to the system. In that case, stable and “narrow” processes are revealed insufficiently that can be developed, intensified and optimized.

Furthermore, we have been studied unity of DOD based on account of stability of its compound processes. For that, there were assorted the normal technological conditions indicated but it approved time limit on present set. Data collection was realized in 24 days through per two hours and they were treated according to [5].



### Materials and Methods

Hence, residual moisture content in oil (wt.%) was used as a variable output parameter of RWOS № 1 while for RWOS № 2 it was residual salt, mg/l.

Based on processing data observations it was received the following equations of wholeness DOD:

$$N_{DSVA} = \eta_D + \eta_{S/D} + \eta_{V/S} + \eta_{A/V} - 3 = 0.81 + 0.73 + 0.76 + 0.87 - 3 = 0.17 \quad (1)$$

It is noticeable from present equation stability of the processes in DOD is low that linked mainly by considerable fluctuations of preparing oil composition.

### Results and discussion

It is known that in oils, along with dissolved salts, there are various highly dispersed salts in the form of crystals, which are difficult to remove during traditional dehydration of NOE.

To extract them from dehydrated oil, a multiple washing with fresh water is used, which is expensive in commercial conditions.

Flushing with fresh water (without recirculation) can reduce the content of salts and clusters in it. At the same time, the fresh water consumption for oil flushing is calculated according to the formula.

$$Q^{H_2O} = \frac{Q^{FW}}{0.8} \cdot \frac{BK_L - X}{X - BK_2} \cdot Q^0$$

Table 1. – Indicators of preparation of local oils after the first and second washing using fresh water, ultrasonic treatment and without it

Name of local oils	After the first wash		After the second wash	
	Mass fraction of water, %	Mass concentration of chloride salts, mg/dm <sup>3</sup>	Mass fraction of water, %	Mass concentration of chloride salts, mg/dm <sup>3</sup>
Mingbulak (control) <sup>(x)</sup>	0,48	289	0,41	183
Mirshadi (control) <sup>(x)</sup>	0,67	364	0,57	215
Mingbulak	0,35	157	0,33	102
Mearshadi	0,38	230	0,35	184

Note: (x) without ultrasound (control)

From Table 1 it can be seen that double washing of oil with fresh water helps to reduce the content of chloride salts in it by about 1.6–2.0 times. In this case, the use of ultrasound also significantly reduces the residual content of chloride salts in oil.

where  $Q_2^{H_2O}$  is the flow rate of the washing water, m<sup>3</sup>;

$Q^{FW}$  – the amount of formation water in the oil before the step esalination, m<sup>3</sup>/m<sup>3</sup>;  $Q^{FW} = W1/(1-W_1)$ ;

$B$  – the amount of water in the oil at the outlet of the desalting stage, m<sup>3</sup>/m<sup>3</sup>;

$$B = W_2/(1 - W_2);$$

$X$  – salt content in desalted oil, mg/l;

$K_L$  – salt content in formation water, mg/l;

$K_2$  – salt content in washing water, mg/l;

$Q^0$  – the amount of oil to be prepared, m<sup>3</sup>;

0.8 – coefficient of mixing efficiency.

As can be seen from this equation (2), the consumption of fresh water during desalting of oil is significantly affected by the intensity of phase mixing, which can be increased through the use of ultrasonic action. This allows not only to reduce the frequency of oil flushing, but also the amount of fresh water consumed during oil flushing.

With a view to deeper removal of chloride salts from oil, we performed a two-fold flushing with the regimes noted in the previous experiment. Analyzes of the residual water content and the concentration of chloride salts were carried out according to the procedures.

The results are shown in Table 1

Moreover, the use of the last bole effectively works during the first washing of oil with fresh water, in the second relatively less efficiently, which confirms the presence of hard-to-remove salts in oil.

Therefore, it is necessary to design approaches their increase including conventional ways of impact on water-oil system.

Low wholeness of DOD is consequence of unstable functioning of multiple processes in DOD.

### **Conclusion**

To sum up, systematic analysis of DOD shows that present technological line is completed insuf-

ficiently, that is it contents processes of low stability of output parameters. It is confirmed also indicator of wholeness of the flowsheet. Therefore, working the main processes of water separation and mineral salts from oil in DOD allows to rise considerably technical and economic efficiency for its functioning, as well as quality of oil preparation to industrial processing.

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## QUANTUM–CHEMICAL CALCULATIONS AND MATHEMATICAL MODELATION OF SYNTHESIS OF ACETYLENICAL DIOLS

**Abstract:** structural-dinamical and elektronical properties of new synthesised acetylenic diols: butin-2-diol-1,4; it's mono- end divinyl ethers by using of calculated computer program HyperChem by semi- emperical quantum – chemical method RMZ have been investigated. Geometrical structures, distribution of charges and electronical density of molecules of synthesised compounds were determined. By quantum- chemical method calculation of such parameters of synthesised compounds as: energy of band, full energy, electronical energy and charge on oxygen atoms have been calculated. Also mathematical treatment of experimental data obtained at carrying out of chemical reactions was carried out because at present time the mathematical modelation and mathematical treatment of experimental data are used wide in modern investigation (particularly also method of the least squares).

**Keywords:** acetylenic alcohols, homogeneous synthesis, catalysis, mathematical modeling, quantum chemical calculations of a molecule.

### Introduction

At present time calculated methods of quantum chemistry are developed in great degree owing to which possibility of calculation of geometry of molecules of different reagents and products and value of stability of intermediate products and transitional states in chemical reaction has appeared. The experimental obtain of such data for different reactions is bounded by difficulties caused by many – staging of processes, synchronous carrying out of elemental stages and very small time of living of intermediate products. Development of calculated methods of quantum chemistry and appearance of powerful computer means has allowed to calculate some important characteristics of complex organic compounds. Precision and trustworthiness of such calculations are very satisfactory. By this reason quantum-chemical and molecular dynamical calculations at present time are used as one of physico-chemical methods of investigations for obtain data necessary for deter-

mination some regularities of mechanisms of formation of different organic compounds. Quantum chemistry has allowed to explain experimental data about reactional ability of organic compounds and to predict possible ways of carrying out of different reactions. The base of quantum chemistry is equation of Schrödinger which is decided in adiabatic process for stationary states.

**Objects and methods of investigation.** Synthesised acetylenic alcohols and their derivatives were object of this scientific investigation. In this work calculated computer program HyperChem and semi-empirical quantum-chemical method RMZ were used.

**Results and their discussion.** At present time methods of quantum chemistry are more accessible, inexpensive and universal methods of investigation of electronical structure of molecules of different compounds [1; 2]. But also it is necessary to understand that it is impossible to refuse from some experimental methods of investigation of compounds.

Investigation of geometrical structure of monovinyl ether of butin-2-diol-1,4 (Fig. 4) has shown that vinyl group has plane structure and hybridization of carbon atom in it is  $sp^2$ . Distribution of electronical density and charge in molecule of this compound (Fig. 5) has shown a changing of charge of hydrogen atom of hydroxylic group (+0,186) at formation of above mentioned monovinyl ether. Obviously an hydrogen atom of hydroxylic group of diol is more active that is vinylation of one hydroxylic group has carried out to passivation of second hydroxylic group. Synthesis of divinyl ether was carried out through formation of monovinyl ether. Limitation stage of all process is a vinylation of second hydroxylic group.

In this work an geometrical structures, distribution of charges and electronical density in molecules of following compounds: acetylene; methanale; butin-2-diol-2,4; it's mono- and divinyl ethers; benzene-1,3-diol; 3,6-dimethyloctin-4-diol-3,6 and it's mono- and divinyl ethers with using of program "Hyper Chem" by quantum-chemical method RMZ [5; 6]

As example low results of investigation of geometry and electronical structure of molecules butin-2-diol-1,4; butin-diol-1,4; benzene-1,3-diol and it's mono- and divinyl ethers are presented.

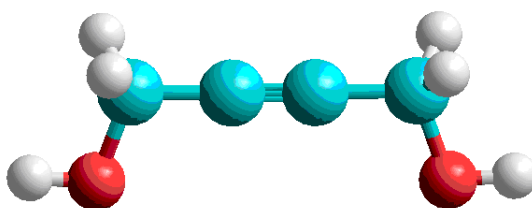


Figure 1. Geometrical structure of molecule butin-2-diol-1,4

On (Fig. 1) geometrical structure of butin-2-diol-1,4 is presented. It is shown that in it carbon atoms  $C_1$  and  $C_4$  have  $sp^3$ -hybridization in tetrahedral

state; carbon atoms  $C_2$  and  $C_3$  have an linear structure with  $sp$  - hybridization. Owing to this carbon chair of molecule has formed an linear structure:

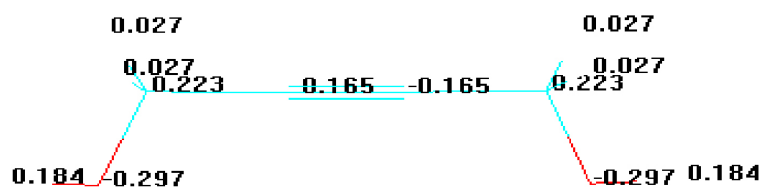


Figure 2. Distribution of charges in molecule butin-2-diol-1,4.

On (Fig. 2) distribution of charges in molecule butin-2-diol-1,4 is presented. It is shown that both hydroxylic groups have the same position and also that atoms of hydrogen of these groups possessed by the same charge (+0,184). This also was shown at calculation of distribution of electronical density in molecule of this compound.

Comparasium of values of electronical charges in this molecule has shown that the great quantity of negative charge was concentrated on the oxygen atom. Obviously by this reason namely atom of oxygen is an

reaction center by which catalytical vinylation by acetylene has carried out in the presence of high-basical system KOH-DMSO (dimethyl sulfoxide).

By this reason the selectivity of catalytical systems wasn't high and in all cases mixture of mono- and divinyl ethers of investigated diol has been obtained. Molecular-dinamical characteristics of divinyl ether of butin-2-diol-1,4 were investigated (Fig. 6). It was observed that with formation of divinyl ether charges on carbon atoms in molecule butin-2-diol-4 have been decreased; there carbon at-

atoms  $C_1$ ;  $C_2$ ;  $C_3$  and  $C_4$  have charges 0,023; -0,165; -0,165 and 0,223 correspondently. With formation of divinyl ether these values have changed and were equal correspondently: 0,206; -0,163; -0,163 and

0,206. It is possible to suppose that character of triple bond in molecules of butin-2-diol-1,4 and its divinyl ether is the same (without accounting of stretch factor)

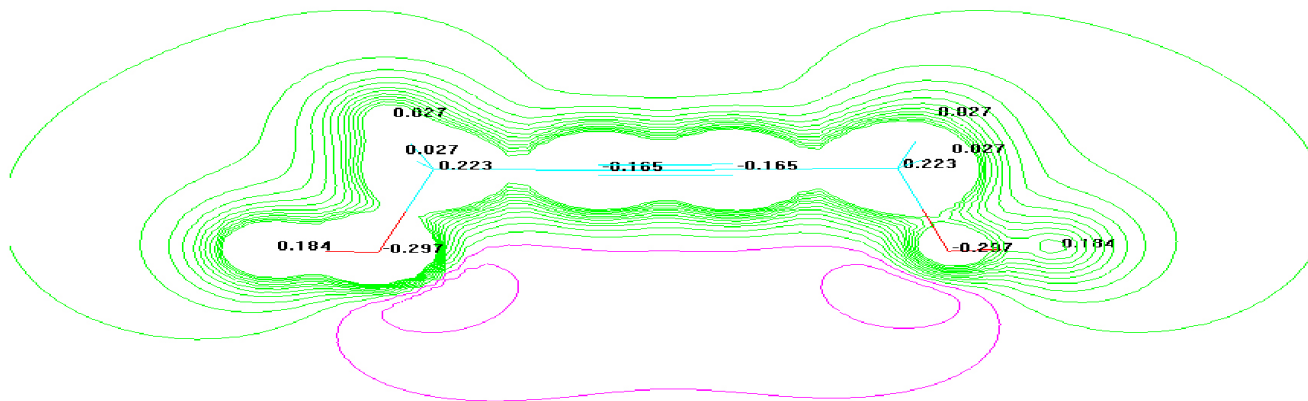


Figure 3. Distribution of electronic density by atoms in molecule of butin-2-diol-1,4

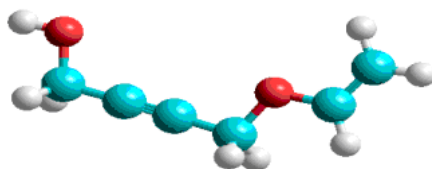


Figure 4. Geometrical structure of monovinyl ether of butin-2-diol-1,4 (vinyl-oxy-butin-2-ol-1)

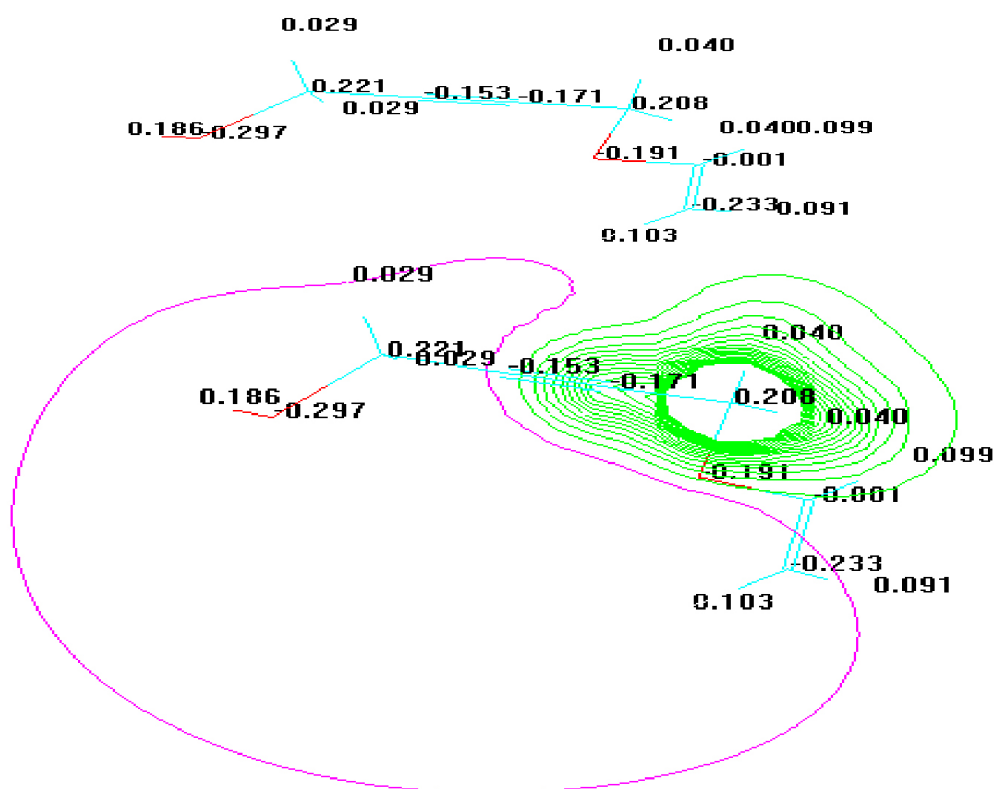


Figure 5. Distribution of electronic density by atoms in molecule of monovinyl ether of butin-2-diol-1,4



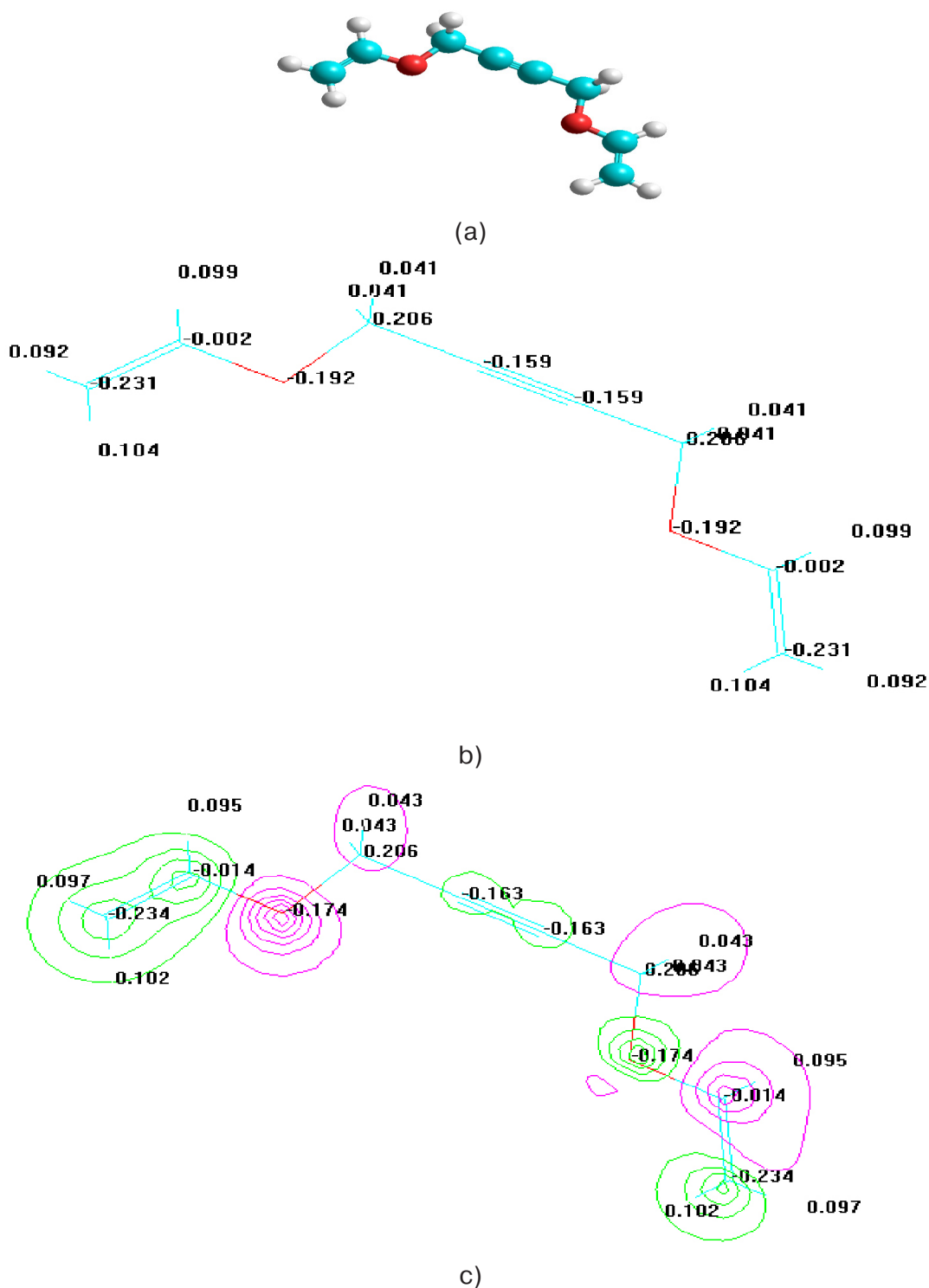


Figure 6. Geometrical structure (a); distribution of charges (b) and electronical density (c) in molecule of divinyl ether of butin-2-diol-1,4

Investigation of geometrical structure; distribution of charges and electronical density by atoms in molecule 3,6-dimethyloctin-4-diol-3,6 (Fig. 7) has shown that this molecule has symmetry, the quan-

tity of negative charge and at this electronical density have concentrated on atoms of oxygen and at this they have possessed by the same activity in reaction of basical vinylation by acetylene.

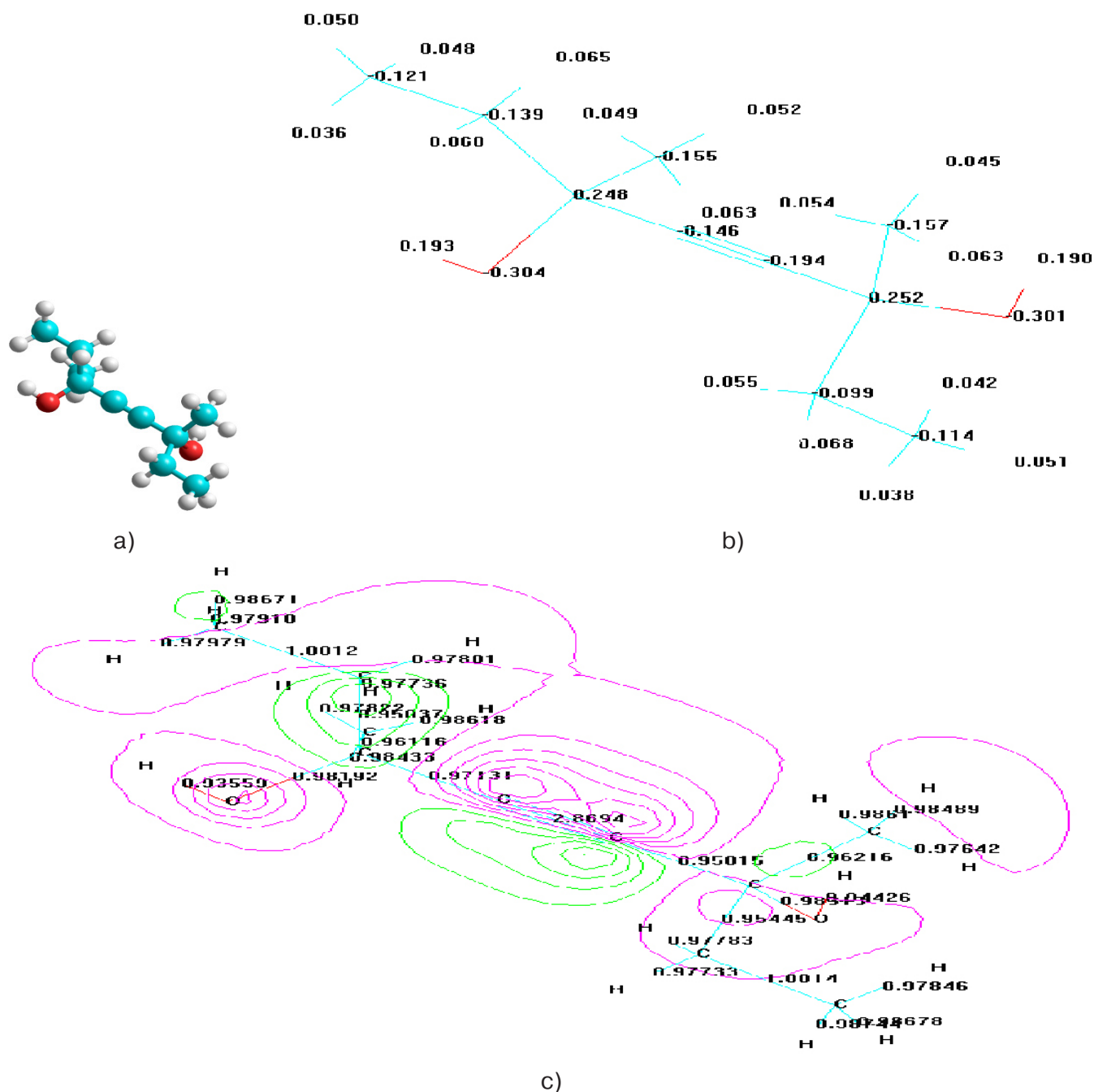


Figure 7. Geometrical structure (a); distribution of charges (b) and electronical density (c) in molecule 3,6-dimethyloctin-4-diol-3,6

Also were obtained results by investigation of structure, distribution of charges and electronical density for some others compounds such as: methanale (Fig. 2); monovinyl ether of 3,6-dimethyloctin-4-diol-3,6 (Fig. 3); divinyl ether of 3,6-dimethyloctin-4-diol-3,6 (Fig. 4); resorzin (Fig. 5); it's mono – (Fig. 6) and divinyl (Fig. 7) ethers.

Also quantum-chemical calculations of some other parameters (general anergy; energy of formation; heat of formation; energy of electron; energy of curn; dipole moment, charge on the oxygen atoms) have been carried out for following molecules: butin-2-diol-1,4; resorzin; 3,6-di-ethyloctin-4-diol-3,6; methanale; monovinyl ether of butin-2-diol-2,4;

Table 1. – Quantum-chemical calculations of investigated compounds

Nature of compound	Energy of bond (ccal/mole)	The full energy (ccal/mole)	The full energy (ccal/mole)	The full energy (ccal/mole)	Isolation of atomic energy (ccal/mole)	Electronical energy (ccal/mole)	Interaction (ccal/mole)	Heat of formation (ccal/mole)	Gradient (ccal/mole)	Charge of oxygen atom
<b>Synthesized compounds</b>										
Resorzin	-1524.5266444	-32068.8672664	-51.103972614	-30544.3406220	-129757.5445498	97688.6772834	-67.4566444	0.0100481	-0.227 -0.229	
Butin-2-diol-1,4	-1156.7236304	-26570.9141924	-42.342601625	-25414.1905620	-88070.0518435	61499.1376512	-41.4336304	0.0068146	-0.297 -0.297	
3,6-Dimethyloctin-4-diol-3,6	-2835.4623029	-50227.1087189	-80.040394540	-47391.6464160	-271772.8764646	221545.7677457	-69.6083029	0.0095789	-0.301 -0.304	
Monovinyl ether of butin-2-diol-1,4	-1991.4560396	-38871.8525336	-61.945003260	-36880.3964940	-170830.3919642	131958.5394305	15.8019604	0.0097181	-0.191 -0.297	
Divinyl ether of butin-2-diol-1,4	-2843.1886834	-47265.5468614	-75.320939537	-44422.3581780	-269876.0436325	222610.4967712	-77.3346834	0.0184108	-0.192 -0.192	
Monovinyl ether of resorzin	-1938.9570685	-38216.4006565	-60.900495061	-36277.4435880	-175513.4723243	137297.0716677	-35.9030685	0.0093965	-0.130 -0.226	
Divinyl ether of resorzin	-2353.4005691	-44363.9471231	-70.697038346	-42010.5465540	-225838.6149920	181474.6678688	-4.3625691	0.0091260	-0.127 -0.129	
Monovinyl ether of 3,6-dimethyloctin-4-diol-3,6	-3249.0876783	-56747.6097483	-53498.5220700	-334722.6583164	-334722.6583164	277975.0485681	-37.2496783	0.0093937		
Divinyl ether of 3,6-dimethyloctin-4-diol-3,6	-3664.1100366	-63269.5077606	-100.824365421	-59605.3977240	-402851.2880456	339581.7802850	-6.2880366	0.0099521		
1-ethyloxy-4-vinyloxybutin-2	-1850.0436328	-38708.5552378	-61.684777650	-36858.5116050	-156940.0477383	118231.4925005	-13.6756328	0.0015691	-0.121 -0.343	
1-ethyloxy-4-vinyloxy-4-methylhexyn-2	-3106.2189350	-50696.6050490	-80.788569629	-47590.3861140	-305485.6005429	254788.9954939	-65.2709350	0.0098751	-0.192 -0.268	
1-Ethyloxy-3-vinyloxybenzol	-2486.5999300	-45100.0993900	-71.870148234	-42613.499460	-236892.2477376	191792.1483476	-33.3579300	0.0092637	-0.128 -0.193	
1-Methacryloil-4-vinyloxybutin-2	-2556.6639195	-55631.3017485	-88.652352371	-53074.6378290	-263177.4924690	207546.1907205	-43.8629195	0.0097901	-0.190 -0.226 -0.337	
1-Acryloil-3-vinyloxy-3-methylhexyn-2	-3105.2192196	-58727.2904136	-93.586025851	-55622.0711940	-338612.3170070	279885.0265934	-42.2302196	0.0196108	-0.194 -0.235 -0.329	
1-Vinyloxy-3-methacryloilbenzol	-2904.0822408	-61536.4671918	-98.062644621	-58632.3849510	-326224.5301165	264688.0629247	-49.5012408	0.0099009	-0.241 -0.128 -0.325	

3,6-dimethyloctin-4-diol-3,6; divinyl ether of butin-2-diol-1,4 (table 1).

Such on the base of results of investigation of structure, distribution of charges, electronical density and energetical characteristics of investigated molecules by semi-empirical quantum-chemical method their reactional centers were determined and also some experimental data have been confirmed.

It is known that chemical processes have carried out on the base of different laws and regularities. Mathematical treatment of experimental data obtained at carrying out chemical reactions has allowed to test and to value of their rightness.

At present time for mathematical modeling and mathematical treatment of experimental data the method of the least quadrants has used. This method in comparison with some other methods is characterized by fact that obtained results are more precise. We have used this method to reaction of vinylation of investigated compounds. As example the mathematical treatment of experimental data of vinylation reaction of butin-2-diol-1,4 is presented:

$q$	$Y$
$q_1$	$Y_1$
$q_2$	$Y_2$
...	...
$q_n$	$Y_n$

where:  $Y_i$  – yield of vinyl ether; to each  $q_i$  ( $i = 1, \bar{n}$ )  $Y_i$  ( $i = 1, \bar{n}$ ) is corresponded which is determined by experimentally. Such it is possible to proposed that  $q$  – factor influencing on the yield of vinyl ether of butin-2-diol-1,4.

For determination of precision of experimental data of vinylation it was proposed that dependence of value of yield of the mathematical treatment has appearance of secondary.

$$YMM = aq^2 + bq + c \quad (1);$$

where  $a$ ,  $b$  and  $c$  are unknown coefficients.

According to method of the least quadrants the best values of parameters  $a$ ,  $b$  and  $c$  are values for which the sum of quadrants of deviations is minimal:

$$F = \sum_{i=1}^n \varepsilon_i^2 = \sum_{i=1}^n [Y_i - YMM(q_i)]^2 = \sum_{i=1}^n [Y_i - (aq_i^2 + bq_i + c)] = \min \quad (2)$$

For obtain of minimal value of function  $F$  values of private derivatives by coefficient  $a$ ,  $b$  and  $c$  must to equal to nought:

$$\frac{\partial F}{\partial a} = 0, \quad \frac{\partial F}{\partial b} = 0, \quad \frac{\partial F}{\partial c} = 0. \quad (3)$$

Then private derivatives  $F$  ( $a$ ,  $b$ ,  $c$ ) of changing parameters  $a$ ,  $b$ ,  $c$  have been determined. At this the best value of these parameters are these at which private derivatives of this function by changing parameters converted in nought:

$$\frac{\partial F}{\partial a} = 2 \sum_{i=1}^n [Y_i - (aq_i^2 + bq_i + c)] \cdot (-q_i^2) = 0,$$

$$\frac{\partial F}{\partial b} = 2 \sum_{i=1}^n [Y_i - (aq_i^2 + bq_i + c)] \cdot (-q_i) = 0,$$

$$\frac{\partial F}{\partial c} = 2 \sum_{i=1}^n [Y_i - (aq_i^2 + bq_i + c)] \cdot (-1) = 0.$$

From these equations for determination of values didn't determined coefficients  $a$ ,  $b$  and  $c$  the system of algebraic equations was formed:

$$\sum_{i=1}^n q_i^4 \cdot a + \sum_{i=1}^n q_i^3 \cdot b + \sum_{i=1}^n q_i^2 \cdot c = \sum_{i=1}^n q_i^2 \cdot Y_i,$$

$$\sum_{i=1}^n q_i^3 \cdot a + \sum_{i=1}^n q_i^2 \cdot b + \sum_{i=1}^n q_i \cdot c = \sum_{i=1}^n q_i \cdot Y_i, \quad (4)$$

$$\sum_{i=1}^n q_i^2 \cdot a + \sum_{i=1}^n q_i \cdot b + n \cdot c = \sum_{i=1}^n Y_i$$

Low as example experimental data obtained at vinylation of butin-2-diol-1,4 are presented:

$T_i$	$Y_i$
100	35.7
120	46
130	48.1
150	47

where:  $Y$  – yield of product-vinyl ether of butin-2-diol-1,4 forming in reaction of butin-2-diol-1,4 with

acetylene at temperature  $T_i$  (one from influencing factor). This dependence is presented as multimember  $YMM = aT^2 + bT + c$ . For this in system of equations (4) sum of participated factors and values of coefficients  $a$ ,  $b$  and  $c$  are determined with using lined system of equations:

$$\begin{aligned} 1099220000a + 8300000b + 63800c &= 2889790, \\ 8300000a + 63800b + 500c &= 22393, \\ 63800a + 500b + 4c &= 176,8. \end{aligned} \quad (5)$$

$$a = -0.0095, \quad b = 2.6 \quad \text{and} \quad c = -129.323$$

Obviously that dependence of yield vinyl of ether butin-2-diol-1,4 ( $Y$ , %) from temperature of process ( $T$ , °C) at duration ( $t$ ) 8 hours is presented by equation  $YMM = -0,0095T^2 + 2.6T - 129.323$ . Values of yield of vinyl ether of butin-2-diol-1,4 obtained by mathematical treatment ( $YMM_i$ ) and also their experimental values are presented in (table 2).

Table 2. – Values of experimental data and obtained by mathematical treatment of vinylation of butin-2-diol-1,4

$T_i$	$Y_i$	$YMM$	$T_i^2$	$T_i \cdot Y_i$	$T_i^3$	$T_i^4$	$T_i^2 \cdot Y_i$
100	35,7	35,677	10000	3570	1000000	100000000	357000
120	46	45,877	14400	5520	1728000	207360000	662400
130	48,1	48,127	16900	6253	2197000	285610000	812890
150	47	46,927	22500	7050	3375000	506250000	1057500
$\sum_{i=1}^n T_i =$ = 500	$\sum_{i=1}^n Y_i =$ = 176.8		$\sum_{i=1}^n T_i^2 =$ = 63800	$\sum_{i=1}^n T_i \cdot Y_i =$ = 22393	$\sum_{i=1}^n T_i^3 =$ = 8300000	$\sum_{i=1}^n T_i^4 =$ = 1099220000	$\sum_{i=1}^n T_i^2 \cdot Y_i =$ = 2889790

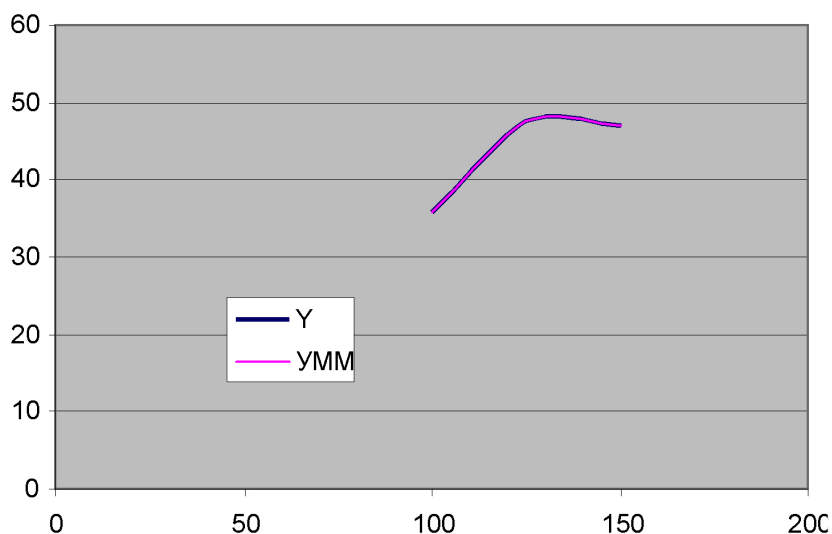


Figure 8. Comparasional data of values of yield of vinyl ether of butin-2-diol-1,4: Y-experimental; YMM-calculated

From it's it is shown that values of experimental yield of vinyl ether of butin-2-diol-1,4 and obtained by mathematical treatment are coincided.

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