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</tbody>
</table>
TRANSPORT

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ANALYSIS OF THE EFFICIENCY OF LOCOMOTIVE TRACTION
ON A HILLY SECTION OF THE RAILWAY

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ABSTRACT

Received the numerical values of the kinematic parameters of the movement of freight trains and the energy indicators of the transportation work of diesel locomotives of the 3TE10M, UzTE16M3 series and electric locomotives 3VL80S in quantitative and monetary terms for the real conditions of the organization of the transportation of goods on a virtual, hilly on difficulty section of the railroad without stops at intermediate separate points are obtained. It has been proven that electric traction and diesel locomotives UzTE16M3 are economically more profitable than diesel traction and diesel locomotives 3TE10M, therefore, the introduction of the first two positions into the practice of the Uzbek railways will undoubtedly increase the efficiency of using both types of traction of the locomotive fleet of JSC “O’zbekiston temir yo’llari”.

These studies are devoted to assessing the energy efficiency and comparing the main indicators of locomotives of electric and diesel traction on a virtual hilly section of the railway, based on the values of the indicators of the transportation work of the investigated three-section electric locomotives 3VL80S and of diesel locomotives 3TE10M, UzTE16M3.

To implement the above, we use the recommendations [1, 2] and research results [3-5, 7]. According to [7], for the generalizing criteria of the above estimates

Keywords: locomotive traction, freight train, diesel locomotive, railroad, electric locomotive, diesel traction, electric traction, section, virtual.

Ключевые слова: локомотивная тяга, грузовой поезд, тепловоз, железная дорога, электровоз, дизельная тяга, электрическая тяга, участок, виртуальный.
and comparisons, we accept the reduced costs of funds per one kilometer of the railway track and the $K_E$ coefficient for evaluating the efficiency of using different types of locomotive traction.

In Table 1 presents data on the technical speed and motion time of freight trains for different driving modes and, accordingly, various conditions for organizing freight traffic (traction calculation options), as well as the amount of natural diesel fuel consumed diesel locomotives and electric energy by electric for a trip for virtual hilly section railroad. An asterisk * denotes values including value added tax (VAT).

### Table 1.

The main indicators of the transportation work of locomotives on a virtual hilly section of the railway track

<table>
<thead>
<tr>
<th>Calculation option</th>
<th>Technical speed $V_t$, km/h</th>
<th>Train running time, min</th>
<th>Consumption and cost of diesel fuel</th>
<th>Consumption and cost of electricity</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>$t$, $t^e$</td>
<td>$E$, kg</td>
<td>full $c_f$ thousand soums</td>
<td>specific cost $c_f$, thousand soums /km</td>
</tr>
<tr>
<td><strong>Diesel locomotives UzTE16M3</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>86.06</td>
<td>32.00</td>
<td>22.20</td>
<td>9.80</td>
</tr>
<tr>
<td>2</td>
<td>84.22</td>
<td>32.70</td>
<td>24.10</td>
<td>8.60</td>
</tr>
<tr>
<td>3</td>
<td>79.36</td>
<td>34.70</td>
<td>25.30</td>
<td>9.40</td>
</tr>
<tr>
<td><strong>Diesel locomotives 3TE10M</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>86.06</td>
<td>32.00</td>
<td>22.20</td>
<td>9.80</td>
</tr>
<tr>
<td>2</td>
<td>84.22</td>
<td>32.70</td>
<td>24.10</td>
<td>8.60</td>
</tr>
<tr>
<td>3</td>
<td>79.36</td>
<td>34.70</td>
<td>25.30</td>
<td>9.40</td>
</tr>
<tr>
<td><strong>Electric locomotives 3VL80</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>91.34</td>
<td>30.15</td>
<td>20.05</td>
<td>10.10</td>
</tr>
<tr>
<td>2</td>
<td>89.12</td>
<td>30.90</td>
<td>20.30</td>
<td>10.60</td>
</tr>
<tr>
<td>3</td>
<td>85.79</td>
<td>32.10</td>
<td>20.60</td>
<td>11.50</td>
</tr>
</tbody>
</table>

The above values characterize the movement of freight trains without stops at intermediate stations in the considered range of train mass fluctuations from $Q_1 = 2500$ t to $Q_2 = 3500$ t with a change interval of $\Delta Q = 500$ t and a constant number of axles in the composition $m = 200$ axles. The load on the axes of the wheel sets of the rolling stock was approximately $q_1 = 12.5$ t/axle, $q_2 = 15.0$ t/axle and $q_3 = 17.5$ t/axle.

Based on the data in Table 1, taking into account [3-5, 7] and the standards of "Temiryuilenigyta/min" for the selling price of one kilowatt - hour of electric energy and one ton of full - scale diesel fuel for linear enterprises of the locomotive complex, were determined the costs of fuel and energy resources for train traction in monetary terms for the studied locomotives.

The specific cost of rail transportation of goods on various types of locomotive traction was determined by the following dependencies [6]:

\[
\begin{align*}
&\text{diesel locomotive traction} \quad c_f = \frac{E \cdot H_f}{10^3 \cdot L} \quad \text{thousand soums} / \text{km} \\
&\text{electric locomotive traction} \quad c_r = \frac{A \cdot H_r}{10^3 \cdot L} \quad \text{thousand soums} / \text{km}
\end{align*}
\]

Where $E$ – diesel fuel consumption per trip, kg; $A$ – electrical energy consumption per trip, kWh; $L$ – plot length for calculation, km; $H_f, H_r$ – selling price for the consumption, respectively, of one ton of diesel fuel and one kilowatt-hour of electrical energy, soums.

The $K_E$ coefficient for evaluating the efficiency of various types of locomotive traction, which is equal to the ratio of the specific costs of diesel fuel $c_f$ and electric energy $c_r$, to each other, that is, $K_E = c_f / c_r$, is taken as a criterion for the energy efficiency of traction (main) rolling stock.

Cash costs for rail transportation of goods for locomotives of electric and diesel traction were calculated according to the tariff [6]. The cost of one kilowatt - hour...
for electric energy was $\text{Ц}_e = 87,04$ soums / kWh (excluding VAT) and $\text{Ц}_e = 104,40$ soums / kWh - including VAT, and for one ton of full-scale diesel fuel - $\text{Ц}_f = 1770,45$ thousand soums / t.

On fig. 1 shows the criteria for evaluating the efficiency of using diesel and electric locomotives when driving freight trains on a virtual hilly section of the railway, where the values of the unit cost of electric energy, including VAT, are increased by 1.5 times. The values of the $K_E$ coefficient for evaluating the efficiency of different types of locomotive traction for diesel locomotives $UzTE16M3$, $3TE10M$ (excluding VAT) are increased by 4 times and reduced by 2 times for diesel locomotives $3TE10M$, including VAT.

![Figure 1. Criteria for the efficiency of using locomotives on a virtual hilly section of the railway](image)

Analysis of the research results showed the following:

- for both types of traction, a decrease for every $\Delta Q = 500$ tons of train mass from 3500 tons to 2500 tons also leads to a decrease in the cost of transporting goods, on average, by approximately 4.66 – 7.66 and 4.83 – 7.52 percent (diesel locomotives $UzTE16M3$ and $3TE10M$), and by 8.95 – 11.21 percent - electric locomotives $3VL80$;

- diesel locomotives $UzTE16M3$, in comparison with diesel locomotives $3TE10M$, provide a reduction in diesel fuel consumption for train traction and the cost of rail transportation of goods, on average, by 10.62 percent;

- electric locomotives $3VL80^4$ are more efficient ("more economical") than diesel locomotives $UzTE16M3$ and $3TE10M$, on average, respectively, by 4.39 (3.65) and 4.91 (4.09) times - $Q_1 = 2500$ tons; 4.21 (3.52) and 4.51 (3.83) times - $Q_2 = 3000$ t; as well as 4.03 (3.43) and 4.51 (3.93) times - $Q_3 = 3500$ tons. In parentheses, the values for the tariff for one kilowatt-hour of consumed electrical energy are given, taking into account value added tax (VAT);

- electric traction, in comparison with diesel traction, will undoubtedly "pollute" the atmosphere with harmful substances much less.

The results of the studies carried out confirm (prove) the advantage of electric traction over diesel traction, and $UzTE16M3$ diesel locomotives over $3TE10M$ diesel locomotives, which is quite logical, correct and agrees quite well with studies [6,7 and others].

Therefore, the electrification of the Uzbek railways, taking into account the transition from diesel to electric traction and the replenishment of the locomotive fleet with mainline diesel locomotives of the $UzTE16M$ series in various sectional designs and modern high-performance freight and passenger electric locomotives "Uzbekistan", will certainly take place not only in the now, but also in the long term.

The introduction of the above into the system of organization of the transportation process, the practice of operation and work of locomotives, will increase the carrying capacity and throughput of railways, the efficiency of using diesel and, especially, electric traction, the operated locomotive fleet as a whole, as well as provide better economic and environmental performance, taking into account reducing the cost of all types of rail transportation.
Reference:


The present studies are a logical continuation of the works [1, 2] and are aimed at substantiating the efficiency of the transportation work of diesel locomotives in real operating conditions.

Freight trains with different train weights and the same number of axles, three-section mainline (train) freight of the 3TE10M, UzTE16M3 diesel locomotives series, and a virtual hilly track profile of the railway section are taken as the object of study.

The subject of the study is the kinematic parameters of the movement of freight trains without stops and with stops at intermediate separate points and the main fuel and energy indicators of the use of the studied diesel locomotives in quantitative and monetary terms on the specified section of the railway.

The purpose of this study is to assess the fuel and energy efficiency of three-section mainline freight diesel locomotives 3TE10M and UzTE16M3 on a virtual hilly section of the railway, which is implemented using the method of averaging the calculated values, into account the differentiations of the compositions mass by value $\Delta Q=500t$ with a constant number of axles in composition equal to $m = 200$ axes.

The basis of the method of averaging the calculated values is the averaged values of the indicators of the movement of freight trains and the use of diesel locomotives UzTE16M3 and 3TE10M, which are defined as arithmetic mean values for both types of movement in the range of changes in masses of trains adopted by us, taking into account the subsequent comparison these.
aforementioned values among themselves. The latter circumstance will allow (pro) to analyze the qualitative component of the implementation of the transportation process by diesel locomotives UзTE16M3 and 3TE10M on a given virtual hilly section of the railway.

Such statements are fair and quite objectively substantiated by numerous studies [1, 3, 4] on the effectiveness of the use of various types of locomotive traction for a wide range of various conditions for organizing freight traffic in operation.

In table 1 show the average values of the indicators of the movement of freight trains and of the use of locomotives of diesel traction for different variants of traction calculations.

Table 1.

<table>
<thead>
<tr>
<th>Indicators of the use of locomotives of diesel traction locomotives on a virtual hilly section of the railway track</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Traction of calculation option</strong></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td>Diesel locomotives UзTE16M3</td>
</tr>
<tr>
<td>1</td>
</tr>
<tr>
<td>2</td>
</tr>
<tr>
<td>3</td>
</tr>
<tr>
<td>Diesel locomotives 3ТЭ10М</td>
</tr>
<tr>
<td>1</td>
</tr>
<tr>
<td>2</td>
</tr>
<tr>
<td>3</td>
</tr>
</tbody>
</table>

Using the standard Microsoft Excel Office program, we obtained analytical expressions (polynomial dependencies) designed to calculate the parameters of some basic indicators of the transportation operation of diesel locomotives UзTE16M3 and 3TE10M on a hilly section of the railway for any $i$ - th mass of the train $Q_i$, where $R^2 = 1.0$ - a sufficient value of the approximation reliability (the necessary reliability condition is $R^2 \geq 0.8$), and $Q_i = 1.2,3$ is a traction calculation option.

Formulas for determining the parameters of some basic indicators of the transportation work of diesel locomotives UзTE16M3 and 3TE10M are given, respectively, in the numerator and denominator, with the exception of the technical speed, which will be the same for both diesel locomotives.

Technical speed of motion, km/h

$$V_i = -0.865Q_i^2 + 0.295Q_i + 80.77 \quad R^2=1.0 \quad (1)$$

Total of natural diesel fuel consumption per trip, kg

$$E = -9.87Q_i^2 + 75.37Q_i + 462.32 \quad /$$
$$E = -10.66Q_i^2 + 82.53Q_i + 579.69 \quad R^2=1.0 \quad (2)$$

Specific consumption of natural diesel fuel per trip, kg/10 t km gross

$$e = 0.005Q_i^2 - 4.355Q_i + 50.34 \quad /$$
$$e = 0.235Q_i^2 - 5.825Q_i + 57.14 \quad R^2=1.0 \quad (3)$$

Full cash costs of natural diesel fuel $C_f$, thousand soums

$$C_f=-17.47Q_i^2+133.47Q_i+818.57$$
$$C_f=-18.86Q_i^2+146.06Q_i+920.14 \quad R^2=1.0 \quad (4)$$

Present value of natural diesel fuel $c_f$, thousand soums / km

$$C_f = -0.3825Q_i^2 + 2.9145Q_i + 17.827$$
$$c_f = -0.405Q_i^2 + 3.155Q_i + 20.07 \quad R^2=1.0 \quad (5)$$

On fig. 1 shows the dynamics of the averaged parameters of some main indicators of the use of diesel locomotives UзTE16M3 and 3TE10M on a given virtual hilly section of the railway, where the values of specific consumption $e$, kg/104 t km of gross natural diesel fuel per trip for diesel locomotives 3TE10M and UзTE16M3 are increased by 10 and 15, respectively once.
Analysis of the results of the conducted research showed the following:

- the dynamics of the average values of the parameters, some of the main indicators of the use of the studied diesel locomotives, depending on the mass of the freight train, is described by polynomial laws;
- an increase in the mass of the composition and the operating time of power power plants of diesel locomotives UzTE16M3, 3TE10M in traction modes leads to an increase in the amount of diesel fuel consumed by them for train traction;
- for the studied series of diesel locomotives, a consistent increase in the mass of the composition of freight trains for every $\Delta Q = 500$ tons leads, respectively, to an increase in the cost of rail transportation of goods and a decrease in the specific consumption of diesel fuel for train traction;
- diesel locomotives UzTE16M3, in comparison with diesel locomotives 3TE10M, with a differentiation of changes in the mass of the train in $\Delta Q = 500$ tons, save diesel fuel for train traction and money for the transportation of goods, on average, by approximately 11.99 percent.

Thus, the replenishment of the locomotive fleet with new, modernized, mainline freight diesel locomotives of the UzTE16M series in various sectional designs will provide better indicators for the use of diesel traction and reduce the cost of freight rail transportation on a virtual hilly section of railways.


Figure 1. Dynamics of the parameters of some main indicators of the use of locomotives diesel traction of on a virtual hilly section of the railway

The analytical dependencies (regression equations) obtained by us will be useful to drivers - instructors in heat engineering and specialists of the locomotive complex, whose work is directly related to the organization and implementation of the transportation process of traction (main) diesel rolling stock in freight of motion.

Reference:
EFFICIENCY EVALUATION OF 3VL80S ELECTRIC LOCOMOTIVES BY THE METHOD OF AVERAGING CALCULATED OF VALUES

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ABSTRACT

An assessment of the efficiency of the transportation work of three-section main (train) freight electric locomotives 3VL80S on a virtual hilly section of the railway when freight trains move without stops and with stops on intermediate separate points is presented. The foregoing is implemented by substantiating the energy indicators of the use of 3VL80S electric locomotives by averaging the calculated values, taking into account the kinematic parameters of the movement of freight trains. The results of the research are recommended for practical use by driver-instructors whose activities relate to the energy issues of the movement of freight trains on virtual and, identical to them, real hilly sections of railways, including Uzbek ones.

Keywords: freight train, electric locomotive, railroad, parameter, electric traction, calculated value, section, virtual.

At the department "Locomotives and locomotive economy" of the Tashkent State Transport University (TSTU), many years of research are being carried out to substantiate the indicators of fuel and energy efficiency of using the locomotive fleet of the Uzbek railway, some of which are indicated in works [1-3 and others].

The present research is a continuation of the work [4,5], the purpose of which is to substantiate the indicators and evaluate the efficiency of the transportation work of electric locomotives by averaging method the calculated values in various conditions for the organization of railway transportation of goods on a virtual, hilly section of the railway.

The basis of the method of averaging the calculated values is the averaged values of the indicators of the transportation work of three-section main (train) freight electric locomotives 3VL80S on the studied section of the railway. These are the arithmetic mean values obtained as a result of the movement of freight trains without stops and with stops at intermediate stations in the range of changes in masses of compositions accepted by us from \( Q_1 = 2500 \) t to \( Q_5 = 3500 \) t, taking into account their differentiations by \( \Delta Q = 500 \) t value and a constant number of axles in the composition \( n = 200 \) axles.

In Table 1 shows the average values of the indicators of transportation work (use) of the mentioned 3VL80S electric locomotives for different variants of traction calculation [6], where the asterisk index * is the value of the cost of consumed electrical energy, into account of value added tax (VAT).

Table 1.

Indicators of the use of electric locomotives 3VL80S on a virtual hilly section of the railway

<table>
<thead>
<tr>
<th>Traction of calculation option</th>
<th>Conditions of transportation work</th>
<th>Train travel time, min</th>
<th>Electrical consumption energy</th>
<th>Cash costs</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>composition mass ( Q_t )</td>
<td>number of axes ( m ), axes</td>
<td>total, ( t_{\text{tm}} )</td>
<td>in idling and braking mode, ( t_{\text{id,br}} )</td>
</tr>
<tr>
<td>1</td>
<td>2500</td>
<td>200</td>
<td>84,24</td>
<td>32,92</td>
</tr>
<tr>
<td>2</td>
<td>3000</td>
<td>200</td>
<td>81,57</td>
<td>34,05</td>
</tr>
<tr>
<td>3</td>
<td>3500</td>
<td>200</td>
<td>78,47</td>
<td>35,40</td>
</tr>
</tbody>
</table>

Electric locomotives 3VL80S

On fig. 1 shows the nature of the change in the average parameters of some of the main indicators of the transportation work (use) of three-section mainline (train) freight electric locomotives 3VL80S on a given hilly section of the railway. The average values of some parameters of the main indicators of the use of the studied freight electric locomotives 3VL80S in fig. 1 are changed: the value of the total \( A \) consumption of electrical energy is reduced by 10 times, the values of the technical speed \( V_t \) of movement are increased by 2 times. The value of specific of the cost \( Ce \) and \( Ce^* \) (including VAT) of electric energy is of increased, respectively, by 20 and 10 times.

Figure 1. Dynamics of the average parameters of the main indicators of use of electric locomotives 3VL80S on a virtual hilly section of the railway

The analytical expressions obtained by us (polynomial dependencies), designed to organize the calculation of the average parameters of some basic indicators of the transportation operation of 3VL80S electric locomotives on a hilly section of the railway track, are built using the standard Microsoft Excel Office program, in which the value of \( R^2 = 1.0 \) is a sufficient value for the approximation reliability (necessary condition of reliability - \( R^2 \geq 0.8 \)). Here the index asterisk * - is the value of the cost of consumed electrical energy, taking into account value added tax (VAT).
Technical speed of motion, km/h

\[ V_t = -0.215Q^2 - 2.025Q_t + 86.48 \quad R^2 = 1.0 \quad (1) \]

Reduced (specific) cash costs, thousand soums/km

\[ c_s = -0.0695Q^2 + 0.7925Q_s + 4.004 \quad R^2 = 1.0 \quad (9) \]

Total train time, min

\[ t_{tr} = 0.11Q^2 + 0.8Q_t + 32.01 \quad R^2 = 1.0 \quad (2) \]

Reduced (specific) cash costs including VAT, thousand soums/km

\[ c_{s,v} = -0.0465Q^2 + 0.7695Q_s + 4.947 \quad R^2 = 1.0 \quad (10) \]

Train travel time in idling and braking mode, min

\[ t_{id,b} = 0.06Q^2 + 0.45Q_t + 20.56 \quad R^2 = 1.0 \quad (3) \]

Analysis of the results of the conducted research showed the following:

- the nature of the change in the averaged parameters of some basic indicators of the transportation work (use) of 3VL80° electric locomotives on a hilly railway section, depending on the mass of the freight train compound, is described by polynomial laws (dependencies);
- a decrease of the mass compound and the operating time of the power energy systems of 3VL80° electric locomotives in the traction mode leads to a decrease in the amount of electric energy consumed by them for traction of trains;
- an increase for every \( \Delta Q = 500 \) t of mass compound from 2500 t to 3500 t leads to an increase in the cost of rail transportation of goods and a decrease in the specific consumption of electrical energy for train traction.

The regression equations obtained by us will be useful to locomotive instructor drivers and specialists of the locomotive depot operation shop, whose work is directly related to the transportation process of traction (main) electric rolling stock.

Reference:


LIGHTING OF INDUSTRIAL PREMISES IN THE LOCOMOTIVE DEPO

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ОСВЕЩЕНИЕ ПРОИЗВОДСТВЕННЫХ ПОМЕЩЕНИЙ В ЛОКОМОТИВНОМ ДЕПО

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ABSTRACT

The results of the lighting calculation of artificial lighting of the department for on the repair of electrical and electronic equipment in the locomotive depot are presented. The numerical values of the quantitative and qualitative indicators of the specified lighting are obtained in the form of tabular data, graphical and analytical dependencies, which are recommended for use in the design of objects of the locomotive complex.

АБСТРАКТ

Приведены результаты светотехнического расчёта искусственного освещения отделения по ремонту электрической и электронной аппаратуры в локомотивном депо. Численные значения количественных и качественных показателей указанного освещения получены в виде табличных данных, графических и аналитических зависимостей, которые рекомендуются для использования при проектировании объектов локомотивного комплекса.

Keywords: lighting installation, luminous flux, lighting, indicators, calculation, department, qualitative, quantitative.

Ключевые слова: осветительная установка, световой поток, освещение, показатели, расчёт, отделение, качественный, количественный.
For lighting industrial and office buildings, including railway transport enterprises, natural light and light from artificial lighting sources are used. There are the following types of lighting [1]:
- natural lighting created by direct sunlight and diffused by the light of the sky;
- artificial lighting created by light sources;
- combined lighting, in which natural lighting, which is insufficient according to the norms, is supplemented by artificial lighting.

According to the design, artificial lighting can be of two types - general and combined.

General lighting is used in industrial premises, where the same type of work is carried out over the entire area (foundry, welding, galvanizing shops), as well as in administrative, office and warehouse premises.

When performing precise visual work (plumbing, turning) in places where the equipment creates deep sharp shadows or work surfaces are located vertically (stamps, guillotine shears), along with general lighting, local lighting is used.

Combined lighting - there is a combination of local and general lighting. The system of general artificial lighting is performed by ceiling or pendant lamps placed parallel to the light openings.

According to the functional purpose, artificial lighting is divided into working, emergency and special, which can be security, duty, evacuation, erythema, bactericidal, signal and other types.

This work was carried out in parallel with the study [2] and is due to the study of the organization of artificial lighting at the locomotive repair and linear enterprises of JSC "O`zbekiston temir yo`llari".

The purpose of this study is to assess the impact of the layout characteristics of enterprises (objects) on the quantitative and qualitative indicators of artificial lighting on the example of one of the repair departments of the traction rolling stock of the main locomotive depot.

It should be noted that the main task of lighting calculations for artificial lighting is to determine the required power of an electric lighting installation to create a given illumination.

In the future, we will agree on the number of light sources (lamps) \( N \) (pcs) and the power of the lighting installation \( P_{lig,lm} \) (kW) to be attributed to quantitative indicators, and of the calculated luminous flux \( \Phi_{lit} \) (lm), which the lamps in each lamp should emit and their actual illumination \( E_{act} \) (lx), to qualitative indicators. In this case, the location of light sources and the geometric dimensions of the buildings (structures) under study will be referred to the layout characteristics of these buildings.

To achieve this goal, based on the method of calculating the illumination, taking into account the coefficient of use of the luminous flux [3], we determine the quantitative and qualitative indicators of artificial lighting according to the condition of the problem [4], varying the area of the department for the repair of electrical and electronic equipment of locomotives by changing the length department, leaving its width constant.

The luminous flux utilization coefficient \( K_{lit} \) is the ratio of the actual luminous flux \( \Phi_{lit} \) to the value of the calculated luminous flux \( \Phi_{lit} \), necessary to ensure normalized illumination \( E_{lit} \), that is, \( K_{lit} = \Phi_{lit} / \Phi_{lit} \).

In the table 1, using the calculation method and recommendations [4], omitting intermediate arithmetic calculations and reasoning, we present the final results of lighting calculations for incandescent lamps of the G125-135-200 type.

**Table 1.**

<table>
<thead>
<tr>
<th>№ p/h</th>
<th>Geometric dimensions of the department</th>
<th>Indicators</th>
<th>Quantitative</th>
<th>Qualitative</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>( A, \text{m} )  ( B, \text{m} )  ( S = A \cdot B, \text{m}^2 )</td>
<td>( N, \text{pcs} )  ( P_{lig,lm}, \text{kW} )  ( \Phi_{lit}, \text{lm} )  ( E_{act}, \text{lx} )</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>12 12</td>
<td>144</td>
<td>12 2,4</td>
<td>3393 94,3</td>
</tr>
<tr>
<td>2</td>
<td>18 12</td>
<td>216</td>
<td>20 4,0</td>
<td>2948 108,5</td>
</tr>
<tr>
<td>3</td>
<td>24 12</td>
<td>288</td>
<td>28 5,6</td>
<td>2772 115,4</td>
</tr>
<tr>
<td>4</td>
<td>30 12</td>
<td>360</td>
<td>36 7,2</td>
<td>2690 119,0</td>
</tr>
<tr>
<td>5</td>
<td>36 12</td>
<td>432</td>
<td>44 8,8</td>
<td>2626 121,8</td>
</tr>
<tr>
<td>6</td>
<td>42 12</td>
<td>504</td>
<td>52 10,4</td>
<td>2600 123,0</td>
</tr>
<tr>
<td>7</td>
<td>48 12</td>
<td>576</td>
<td>60 12,0</td>
<td>2555 125,2</td>
</tr>
</tbody>
</table>

According to Table 1 we build graphic dependences \( \Phi_{lit} = f_1(S) \), \( N = f_2(S) \), \( P_{lig,lm} = f_3(S) \) and \( E_{act} = f_4(S) \) presented in Fig. 1, which depict the nature of the change in the quantitative and qualitative indicators of artificial lighting, depending on the area of the department for the repair of electrical and electronic equipment of locomotives.

It can be seen that the dynamics of changes in the luminous flux and illumination with an increase in the area of the illuminated room is described by a curvilinear dependence, and the number and power of lighting means are characterized by a linear dependence.

Based on the generalization and analysis of the results performed by the authors of the calculations, analytical dependencies were obtained that describe the nature of the change in artificial lighting indicators depending on the geometric dimensions of the object under study, taking into account the layout of light sources.
1. For the number of light sources - 
\[ N = K_1 S - N_{\text{lig,in}} \], when \( K_1 = 0,111 \) pcs/m\(^2\) and \( N_{\text{lig,in}} = 4 \) pcs.

2. Для мощности осветительной установки 
\[ P_{\text{lig,in}} = K_2 S - P_{\text{lig,in}} \], when \( K_2 = 0,0222 \) kW/m\(^2\) and \( P_{\text{lig,in}} = 0,8 \) kW.

3. For the of calculated luminous flux of the lamp. 
We divide the graphical dependence of the calculated luminous flux on the area of the illuminated room into three zones (zone I - \( S_1 = 114 \ldots 216 \) m\(^2\), zone II - \( S_2 = 216 \ldots 288 \) m\(^2\) and zone III - \( S_3 = 288 \) m\(^2\)) taking into account the assumption of the linear nature of the change in the calculated luminous flux of the lamp. 

Therefore we have: 
\[ \Phi_{\text{est}} = -K_3 S + \Phi_{\text{est}}^{11} \], 
when \( K_3 = 6,18 \) lm/m\(^2\) and \( \Phi_{\text{est}}^{11} = 4283 \) lm;

\[ \Phi_{\text{est}}^2 = -K_3 S + \Phi_{\text{est}}^{11} \], 
when \( K_4 = 2,444 \) lm/m\(^2\) and \( \Phi_{\text{est}}^{11} = 3476 \) lm;

\[ \Phi_{\text{est}}^3 = -K_3 S + \Phi_{\text{est}}^{11} \], 
when \( K_5 = 0,7535 \) lm/m\(^2\) and \( \Phi_{\text{est}}^{11} = 2952 \) lm.

4. The actual illumination of the lamp in the considered range of areas varies according to a curvilinear law and, with an increase in the latter by a factor of four, it also increases, approximately by 32.77 percent.

Thus, the graphical and analytical dependences obtained by the authors can be used to predict the parameters of quantitative and qualitative indicators of artificial lighting at the design stage of railway transport facilities, as well as buildings of industrial enterprises.

Reference:


ЕСТЕСТВЕННОЕ ОСВЕЩЕНИЕ ПРОИЗВОДСТВЕННЫХ ПОМЕЩЕНИЙ В ЛОКОМОТИВНОМ ДЕПО

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ABSTRACT
A methodik for substantiating the parameters of natural lighting in a production facility in a locomotive depot is proposed. Received numerical values of the area of light openings in the extension of the production facility, the projected workshop of a large type of current repair for 3VL80 electric locomotives in the locomotive depot, which ensure full compliance with of sanitary and hygienic standards for natural lighting on the same level with standard norms.

АНОТАЦИЯ
Предложена методика обоснования параметров естественного освещения производственного помещения в локомотивном депо. Получены численные значения площади световых проёмов в пристройке производственного помещения, проектируемого цеха крупного вида текущего ремонта для электровозов 3VL80 в локомотивном депо, которые обеспечивают полное соответствие санитарно - гигиенических норм по естественному освещению стандартным нормативам.

Keywords: light opening, area, luminous flux, natural lighting, side lighting, calculation, coefficient, standard.
Ключевые слова: световой проём, площадь, световой поток, естественное освещение, боковое освещение, расчёт, коэффициент, норматив.
In railway transport and in transport construction, in order to create healthy and highly productive working conditions during the repair, maintenance and operation of rolling stock, as well as in ensuring the safety of train traffic, natural lighting is of particular importance, which is used for general lighting of production and utility rooms. The specified lighting is created by the radiant energy of the sun and has the most favorable effect on the human body.

With this type of lighting, one should take into account meteorological conditions and their changes during the day and periods of the year for a given, specific, area. The foregoing is necessary in order to know how much natural light will enter the room through the arranged light openings of the building: windows - with side lighting; skylights of the upper floors of the building - with overhead lighting. With combined natural lighting, side lighting is added to the top lighting.

The main task of lighting calculations for industrial (residential) buildings and structures for natural lighting, created by direct sunlight and diffused light from the sky, is to determine the required area of their light openings.

To characterize light, certain lighting concepts and quantities are used [1], the main of which are luminous flux, luminous intensity, illumination and brightness.

The purpose of this study is to substantiate the parameters of natural lighting of the extension of the production premises of the projected workshop for the maintenance of TR - 3 electric locomotives 3VL80/ in the locomotive depot.

The algorithm for realizing the goal of the research is as follows.

The calculation of the area of light openings with side lighting of the mentioned extension is carried out according to the formula [2]:

$$S_o = \frac{\ell_N \cdot S_h \cdot K_3 \cdot \eta_0 \cdot K_3}{100 \cdot \tau_0 \cdot \tau_1}, \text{m}^2$$

(1)

where $S_0$ - area of light openings, m$^2$;

$\ell_N$ - is the normalized value of the natural light factor, %.

The coefficient of natural illumination (CNI) is the ratio of illumination at a given point inside the room to the simultaneous value of the external horizontal illumination created by the light of a completely open sky, expressed as a percentage.

The value of the normalized value of the specified CNI for industrial buildings located in different areas according to the resources of the light climate is determined by the following formula:

$$\ell_N = \ell_H \cdot m_N$$

(2)

where $\ell_H$ - is the normal value of the natural light factor, %;

$m_N$ - coefficient taking into account the peculiarities of the light climate of the administrative region;

$N$ - groups number group of the administrative region according to natural light supply;

$S_h$ - room floor area, m$^2$;

$K_3$ - factor determined taking into account the dust content of the room, the location of the glasses (tilted, horizontal or vertical) and the frequency of cleaning;

$\eta_0$ - light characteristic of windows;

$K_{build}$ - coefficient taking into account window shading by buildings opposing;

$\tau_0$ - total coefficient light transmittance;

$\tau_1$ - coefficient taking into account the increase in the coefficient of natural illumination with side lighting due to the light reflected from the surface of the room and the underlying layer adjacent to the building.

The value of the total coefficient light transmittance is determined by the following relationship, that is

$$\tau_0 = \tau_1 \cdot \tau_2 \cdot \tau_3 \cdot \tau_4 \cdot \tau_5$$

(3)

where $\tau_1$ - coefficient light transmittance of the material;

$\tau_2$ - coefficient taking into account the loss of light in the bindings of the light opening;

$\tau_3$ - coefficient taking into account light losses in load-bearing structures;

$\tau_4$ - coefficient that takes into account the loss of light in sun protection devices;

$\tau_5$ - coefficient, which is not taken into account in calculations for side lighting.

The coefficient $\tau_1$ given above depends on the weighted average reflection coefficient of the surfaces of the room $P_{av}$ (%), which is determined by the formula for side and top lighting:

$$P_{av} = \frac{P_{ceil} \cdot S_{ceil} + P_{wall} \cdot S_{wall} + P_{fl} \cdot S_{fl}}{S_{ceil} + S_{wall} + S_{fl}} \%$$

(4)

where $P_{ceil}, P_{wall}, P_{fl}$ - respectively, the reflection coefficient of the ceiling, walls and floor;

$S_{ceil}, S_{wall}, S_{fl}$ - respectively, ceiling, wall and floor areas, m$^2$.

$$S_{ceil} = L \cdot B; \quad S_{wall} = 2 \cdot H \cdot (L+B); \quad S_{fl} = L \cdot B, \text{m}^2$$

(5)

where $B$ - room width, m;

$L$ - room length, m;

$H$ - room height, m.

Further, we provide a rationale for the natural lighting parameters of the extension of the production premises of the projected workshop for the maintenance TR - 3 of electric locomotives 3VL80/ for the following initial data: the locomotive depot is located in the fifth group of administrative districts in terms of natural light supply, and the geometric parameters of the said extension are $L = 132$ m in length, width $H = 12$ m and height $H = 10.8$ m. Adopted lateral one-sided natural lighting.

1. We determine the value of the weighted average reflection coefficient of the room according to formula (4) taking into account formula (5), that is

$$P_{av} = \frac{12 \cdot 132 \cdot (50+10) + 2 \cdot 10.8 \cdot (132+12) \cdot 70}{2 \cdot (132+12 \cdot 10.8 \cdot (132+12))} \approx 49.82\%$$

май, 2022 г.
It’s accepted here: $P_{cel} = 50\%$, $P_{wall} = 10\%$ и $P_{fl} = 70\%$.

According to [3], when the ratio of the length of the room to its depth is one, taking into account the ratio of the depth of the room to its height from the level of the conditional work surface to the top of the window from 1,5 to 2,5 units and the ratio of the distance of the calculated point from the outer wall to the depth of the room in 0,7 units, value $t_1 \approx 2,0$.

2. Determine the value of the total coefficient of light emission

$$\tau_0 = 0,8 \cdot 0,75 \cdot 1,0 \cdot 1,0 = 0,6$$

where $t_1 = 0,8$ – window glass sheet double;

$t_2$ – bindings for windows and lanterns of industrial buildings, wooden, $t_2 = 0,75$;

$t_3$ – loss light at side lighting, $t_3 = 1,0$;

$t_4$ – retractable adjustable blinds and curtains (inter-pane, internal, external, $t_4 = 1,0$;

$t_5$ – side lighting is not taken into account, $t_5 = 0$.

With high accuracy and the third category of visual work, the sub-category of which is “b”, and the contrast of the object with the background and its characteristic is for average - the magnitude of the normal value of the CNI is $\ell_{N} = 1,2\%$.

Therefore, for these light apertures, which are oriented along the horizon to the northeast, the value of the light climate coefficient of the administrative region is $m_N = 0,8$ [4].

Then, we have

$$\ell_N = 1,2 \cdot 0,8 = 0,96 \%.$$  

For industrial premises with an air environment containing less than 1 mg / m3 of dust, smoke and soot in the working area, and an angle of inclination of the light-transmitting material to the horizon of 46 - 75 degrees with two cleanings of the glazing of light openings per year, the safety factor is equal to $K_3 = 1,5$. The value of the light characteristics at a side light at according to [5] is $\eta_0 = 9,25$. We accept the value of the coefficient $K_{build} = 1,4$.

Hence

$$S_0 = \frac{0,96 \cdot 12 \cdot 132 \cdot 1,5 \cdot 9,25 \cdot 1,4}{100 \cdot 0,6 \cdot 2,0} = 246,15 \text{ m}^2$$

Thus, to in order for the sanitary and hygienic standards of natural lighting to comply with the standards, the required area of light openings in the extension of the production premises of the designed workshop for the maintenance $TR - 3$ of electric locomotives 3VL80$^5$ locomotive depot should be more than two hundred and forty - six square meters.

Reference:


TO REPAIR OF TRACTION ELECTRIC MOTORS DT-9N AT ALMLAYK MINING AND METALLURGICAL WORKS

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ABSTRACT

Is shown the production and technological process of organizing the current repair of traction electric motors DT-9N of the traction unit PE-2M on the basis of the rationing flow chart developed by the authors technological standardization map for this type of repair. The norm of time for the current repair of the traction electric motor DT-9N in volume TR-3 is substantiated, taking into account the photo timing of each repair operation, which made it possible to open additional reserves that ensure of efficiency an increase of repair production.

К РЕМОНТУ ТЯГОВЫХ ЭЛЕКТРОДВИГАТЕЛЕЙ ДТ-9Н НА АЛМАЛЫКСКОМ ГОРНО-МЕТАЛЛУРГИЧЕСКОМ КОМБИНАТЕ

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АННОТАЦИЯ

Показан производственно-технологический процесс организации текущего ремонта тяговых электродвигателей DT-9N тягового агрегата ПЭ-2М на основе разработанной авторами технологической карты нормирования на данный вид ремонта. Обоснована норма времени на текущий ремонт тягового электродвигателя DT-9N в объёме TR-3 с учётом фотохронометража каждой ремонтной операции, что позволило открыть дополнительные резервы, обеспечивающие повышение эффективности ремонтного производства.

Ключевые слова: норма времени, текущий ремонт, тяговый агрегат, электродвигатель, кантователь, расчёт, параметры, оперативное время, депо.

Almalyk Mining and Metallurgical Combine (AMMC) belongs to the enterprises of the mining industry of Uzbekistan, for the successful operation of which, in terms of organizing the extraction and processing of copper ore, an electric rolling stock of industrial railway transport is used - a traction unit PE - 2M, the main technical data and characteristics of which are given in [1].

One of the main components of the undercarriage of the traction unit PE - 2M is a wheel - motor block, the design of which includes a wheel pair with axle boxes, as well as a unified DC traction electric motors DT - 9N of protected execution and with of support - axial of the suspensions.

The design feature of the traction electric motor DT - 9N is a double-sided jaggeds gearing with a traction gearbox and the presence of a compensation winding on the additional poles of the skeleton.

This allows, with a smaller mass of the mentioned engine, to obtain such a torque and armature speed that will be necessary to provide the tangent power of the electric rolling stock required when operating it in mountainous conditions.

The main parameters of the traction electric motor DT - 9N are given below:

- Collector voltage, V = 1500
- Power, kW = 467
- Shaft efficiency, % = 93
- Highest rotation frequency, rp/min = 1530
- Insulation class:
  - for coils of skeleton: B
  - for armature windings: F
- Cooling air quantity, m³/min = 95
- Mass (weight), kg = 4600

To date, the traction unit PE - 2M is operated on electrified sections of the AGMK railway tracks in the open pit of the Kalmakyr mine, as well as outside it, and therefore the technical condition of the traction motor DT - 9N plays a significant role in ensuring traffic safety and increasing the efficiency of transportation work on transportation copper ore and its constituents.

Repair of traction electric motors DT - 9N is organized in the electric machine shop of the AGMK locomotive depot and begins with the diagnostic section, where they arrive with dismantled gears and removed motor - axial bearing caps, previously cleaned and washed.

Here they measure the insulation resistance of the traction electric motor circuits, check the operation of the brush apparatus, collector and anchor bearings, and also measure the radial clearances and the axial takeoff run of the armature in them.

Next, the traction electric motor is moved to the disassembly department position, where he is installed on a tilter of the EK-20-61 type and dismantled by assemblies is carried out with the subsequent repair of these assemblies. After the node-by-nodal assembly, the final assembly of the traction motor is carried out and its control tests are carried out, followed by painting and transfer to a representative of the technical control department (QCD). Then, the traction motor enters the workshop for the repair of traction rolling stock to the assembly position of wheel - motor blocks (units).

Similarly [2], norm the time for the repair of one traction motor DT - 9N is determined by the formula:

$$ T_r = T_{op} + T_{pe, fa} + T_{w, m} + T_{r, br} \tag{1} $$

where

- $T_{op}$ - operating time for the accounted amount of work, norm - min or normo - h;
- $T_{pe, fa}$ - preparatory - final actions, norm - min;
- $T_{w, m}$ - workplace maintenance, norm - min;
- $T_{r, br}$ - regulation breaks for locksmith work, norm - min.

The total time that falls on preparatory and final actions, taking into account the time for servicing the workplace and routine breaks for locksmith work, according to the recommendation [3], is 9.3 percent of the operational time for the accounted amount of work.

The last time is calculated on the basis of the technological and normalization map developed by the authors for the traction motor DT - 9N of the traction unit PE - 2M, which indicates the name of the work and the type of repair, as well as their content, taking into account recommendations for the use of tools, fixtures and equipment, based on the volume taken into account repair work per unit of measure.

In order to determine the costs of operational time for those individual elements of the normalized operation that were performed using technical equipment that differed from that adopted in the typical norm, one of the well-known methods of technical normalization was used - photo timing to perform repair work for each operation, that is, the duration of each normalized operation was recorded in minutes.

Then, the operational time for the entire volume of the current repair of TR-3 of one traction electric motor DT - 9N is $T_{op} = 3450,7$ standard - minutes. Based on the foregoing, the norm of time for the mentioned repair will be equal to $T_r = 1,093 \cdot T_{op} = 62,86$ standard - hours.

It should be noted that in the process of carrying out the specified photo timing, additional reserves were discovered that ensure an increase in the efficiency of repair production, primarily associated with a reduction in operational time by eliminating non-production repair operations and through of increase of the specific gravity parallel works and improving the level of qualifications of production workers.

The results of the study obtained by the authors are the starting point for the subsequent development of a production process on organizing the current repair of the TR-3 traction electric motor DT-9N of the repair depot of the Almalyk Mining and Metallurgical Combine.
Reference:


TO THE ENERGY OF NON-ELECTRIFIED SECTIONS OF RAILWAYS

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Abstract
An algorithm is proposed for the grapho-analytical method for calculating diesel fuel consumption for train traction. Curves of train speed and travel time for diesel locomotives on a virtual railway section are represented. A method for calculating diesel fuel consumption by diesel locomotives in the traction and idling modes of the train is represented. The research results can be implemented in the analysis and evaluation of the traction and energy efficiency of the transportation work of diesel locomotives under operating conditions.

Keywords: study, freight train, diesel locomotive, railroad, parameter, way, station, time, speed, section, virtual.

Introduction. Efficient and rational use of fuel and energy resources, taking into account the widespread reduction in diesel fuel consumption for train traction for mainline diesel locomotives in operating conditions, now continues to be a very urgent problem.

This problem can be solved by further improving the energy resources management system and ensuring the throughput and carrying capacity of railways at the lowest material costs.

For many years, the Department of «Locomotives and Locomotive Economy» of TSTU has been conducting theoretical studies to improve the energy efficiency of using diesel locomotives, which are based on the “classical” traction calculation for different types of traction railway rolling stock.

Statement of the research problem. Recently, despite the intensive and widespread electrification of the Uzbek railways, about thirty percent of these roads fall on non-electrified sections, where railway transportation of goods and passengers of different structure, view, type and content is carried out by diesel traction locomotives.

Moreover, about fifty percent of the entire operating locomotive fleet of JSC "O'zbekiston temir yo'llari" are mainline (train) diesel locomotives of the TE10M and UzTE16M series in various sectional designs.

The purpose of this study is to substantiate the algorithm and methodology for calculating the consumption of diesel fuel by mainline diesel locomotives (locomotives diesel traction) for train traction in relation to a virtual section of the railway.

The formulated goal of the research is realized through the methods [1,2] of the theory of locomotive traction, the object and subject of research.

The subject of the study is the kinematic parameters of the movement of a freight train of a unified mass of goods and passengers on non-electrified sections of the mainline railway.
the composition and the parameters of the energy efficiency indicators of the studied diesel locomotives 3TE10M and UzTE16M3 on a given section of the railway.

The given (accepted) virtual section of the railway with a length of \( L = 8.6 \) kilometers, consisting of four elements of the track profile, is shown in Fig. 1, three of which are ascents with a steepness of +1.5 % and +2.0 %, and one element is a descent with a slope equal to \( i_{dp} = -2.73 \) %.

Freight trains of a unified mass of composition \( Q = 3000 \) tons and the number of axles \( m = 200 \) axles consist of fifty-four-axle cars on rolling bearings (roller). There are no permanent or temporary warnings or speed limits. Brake pads are cast iron – \( \nu_{est} = 0.33 \) kN/kN, and the length of the receiving and dispatch tracks is \( L_{rd-w} = 1050 \) m.

**Research results and their analysis.** The implementation of the purpose of this research is based on the following main provisions of the proposed generalized algorithm for performing traction calculation:

- chooses the parameters of the state of the material and technical base and the conditions for organizing the railway transportation of goods by locomotives on a given (accepted) section of the account;
- develops models for driving a freight train of various masses, organized by locomotives without stops and with stops at intermediate stations, sidings and separate points;
- solve the differential equations of motion of a freight train, using a graphical method to determine the speed and travel time of the train on a given (accepted) section of the railway;
- perform traction calculations on a given section of the railway (Fig. 1) and the results obtained are processed by known methods of mathematical statistics with their subsequent analysis;
- determine the values of diesel fuel consumption by locomotives for train traction in quantitative and monetary terms.

![Figure 1. Fragment of the tractioned calculation option for locomotives of diesel traction on a virtual section of the railway](image)

The movement of the train is described by a differential equation [2]:

\[
\frac{dv}{dt} = \zeta u
\]

where \( v \) - is the speed of movement, m/s;

\( t \) - train travel time, s;

\( u \) - specific resultant force of the train, N/kN;

\( \zeta \) - is the actual acceleration of the train, kNm/Ns².

The methodology for substantiating the kinematic parameters of the movement of freight trains and the parameters of the main energy indicators of the transportation work of the investigated diesel locomotives 3TE10M and UzTE16M3 initially provides for the compilation of a table and the construction of a diagram of the specific of resultant forces of the train.

Further, based on the recommendations of [1,2] and similarly to [5], a curve is constructed for the speed and time of the train on a given virtual section of the railway.
On fig. 1 shows the constructed curves for the speed $V = f(S)$ and travel time $t = f(S)$ of a freight train with a unified mass of the train $G = 3000$ tons and the number of axles $m = 200$ axles for the studied diesel locomotives 3TE10M and UzTE16M3 on a virtual section of the railway, where marked: Art. P - freight train departure station; $t$ and $txx$, $t_{id}$ are, respectively, the travel time of a freight train in the modes of traction and idling, braking (in Fig. 1, this mode of driving a freight train is not used); $off$ and $k$. incl. - respectively, the driver controller is turned off and on, that is, the idle mode of the freight train.

The basis for constructing (calculating) the trajectory of a freight train is the principle of maximizing the use of power and traction and operational qualities (properties) of a locomotive [6], taking into account the kinetic energy of the train on each element of the track profile track, which for diesel locomotives 3TE10M and UzTE16M3 is the 15th nominal position of the driver's controller at full field (FF), as well as the first (FW1) and second (FW2) stages of field weakening of traction motors.

The consumption $E$ of diesel fuel by a diesel locomotive spent on moving the train along the section is calculated by the formula:

$$E = G_f \cdot t_t + g_{id} \cdot t_{id}, \text{kg} \hspace{1cm} (2)$$

where $G_f$ is the consumption of diesel fuel by diesel locomotives at the nominal position of the driver controller, kg/min;

$t_t$ is the total operating time of the diesel locomotive in the traction mode, min;

$g_{id}$ is the consumption of diesel fuel by a diesel locomotive in idling and braking modes, kg/min;

$t_{id}, t$ is the total time of locomotive movement in the idling and braking mode, min.

The consumption of diesel fuel by a diesel locomotive in the traction mode at the 15th position of the controller of the driver and idling of the train is, respectively, $G_f = 25.4$ kg/min and $g_{id} = 1.14$ kg/min (3TE10M diesel locomotives), $G_f = 22.65$ kg/min and $g_{id} = 0.69$ kg/min (diesel locomotives UzTE16M3).

The specific consumption of diesel fuel is determined by the formula:

$$e = \frac{E \cdot 10^4}{q \cdot L}, \text{kg}/10^4 \text{t km gross} \hspace{1cm} (3)$$

The unit cost of rail transportation of various cargoes for diesel traction locomotives was determined by the formula:

$$c_f = \frac{E \cdot \Pi_f}{10^3 \cdot L}, \text{ (thousand soum)/km} \hspace{1cm} (4)$$

where $E$ is the consumption of diesel fuel per trip, kg;

$L$ is the length of the virtual section of the railway, km ($L = 8.6$ km);

$\Pi_f$ – sale price of one ton of diesel fuel, thousand soum/t ($\Pi_f = 1770.45$ thousand soum/t).

In table. 1 shows the results of traction calculation - the parameters of kinematic and energy indicators of the efficiency of using three - section mainline (train) freight diesel locomotives 3TE10M and UzTE16M3 on a virtual section of the railway in quantitative and monetary terms.

Analysis of the research results showed that UzTE16M3 diesel locomotives, in comparison with 3TE10M diesel locomotives, provide a reduction in the consumption of full-scale diesel fuel for train traction and the cost of rail transportation of various views, types, content and structure of cargo, on average, by approximately 11.04 - 11.05 percent.

**Table 1.**

<table>
<thead>
<tr>
<th>train motion speed $V$, km/h</th>
<th>Kinematic</th>
<th>Energy</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Train travel time on the section</strong></td>
<td><strong>Diesel fuel consumption</strong></td>
<td><strong>Diesel fuel cost</strong></td>
</tr>
<tr>
<td></td>
<td></td>
<td>full $E$, kg</td>
</tr>
<tr>
<td>1</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>Diesel locomotives 3TE10M</td>
<td></td>
<td></td>
</tr>
<tr>
<td>72,68</td>
<td>6,1</td>
<td>1,0</td>
</tr>
<tr>
<td>Diesel locomotives UzTE16M3</td>
<td></td>
<td></td>
</tr>
<tr>
<td>72,68</td>
<td>6,1</td>
<td>1,0</td>
</tr>
</tbody>
</table>
Conclusion. The research methodology proposed by the author and the kinematic parameters of the movement of a freight train, the kinematic and energy indicators of the transportation operation of three-section mainline (train) freight diesel locomotives of the 3TE10M and UzTE16M3 series, of course, can be implemented in the analysis and evaluation of the traction and energy efficiency of the transportation operation of diesel locomotives on virtual and identical real sections of the Uzbek railways.

The results of the research are also recommended for use in the practice of the locomotive complex of JSC "O'zbekiston temir yo'llari" in substantiating the effectiveness of different types of locomotive traction in real operating conditions.

Reference:
OPTIMIZATION OF TRANSPORT AND LOGISTICS SERVICES IN SERVICING THE EXPORT POTENTIAL OF THE REPUBLIC OF UZBEKISTAN

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ABSTRACT
The article deals with the problems of carrying out export operations. The role of transport foreign economic activity is revealed. The main methods of optimizing transport costs are presented. The main actions of logistics business processes are the advantages of specialized software. “Green Corridor” – simplification of customs inspection procedures. The article indicates the expansion of the possibilities of using this mechanism.

KEYWORDS: Problems of export operations, logistics approach, optimization of transport costs, "Green" corridor.

UDK: 656.078

In the modern conditions of globalization, when the international market of goods and services is striking in scale, the foreign economic activity of enterprises plays an increasingly important role, since more prospects open up for companies in the international market.

Most often, the mutual exchange of the results of economic activity on the international market and related export operations are carried out in the form of a foreign trade contract.

One of the most important and at the same time complex forms of foreign economic activity (FEA) is
export operations that arise when concluding a foreign trade transaction and represent a special type of economic relations.

Logistics of foreign economic activity has its own specifics in export-import operations related to it, for example, in the passage of customs formalities, regulation of the terms of delivery of goods under purchase and sale agreements based on Incoterms and international rules of carriage, in the registration of transport, shipping documents, insurance, in the transportation of goods on several types transport, etc.

To maintain their positions in the world markets, enterprises need to make certain efforts in the direction of increasing the level of manufacturability and efficiency of business processes.

<table>
<thead>
<tr>
<th>Minimization of transportation costs</th>
</tr>
</thead>
<tbody>
<tr>
<td>Maximum utilization of the vehicle’s load capacity in logistics</td>
</tr>
<tr>
<td>The principle of multiplicity of the consignment transported to the units of order, dispatch and warehousing</td>
</tr>
<tr>
<td>The principle of standardization of containers</td>
</tr>
<tr>
<td>Economy of scale and distance of transportation</td>
</tr>
<tr>
<td>Concentrations of cargo flows on individual channels</td>
</tr>
<tr>
<td>Delivery of goods on time</td>
</tr>
</tbody>
</table>

*Figure 1. Basic principles of transport logistics, ensuring its efficiency*

There is an urgent need to find additional opportunities to further reduce the level of costs for export-import operations, and improve the quality of customer service, improve the processes of regulation and coordination of flow management, which requires a logistical approach.

Despite the difficulties that arise in international transport logistics, it is gaining momentum. This is due to the rapid growth in the volume of international trade, the transfer of some logistics operations to specialized firms, the creation of international, regional unions, which leads to a reduction or cancellation of export and import duties and a reduction in customs formalities and the use of real-time information resources (Internet), which in turn accelerates the process of logistics operations.
Figure 2. Fundamentals of the logistics approach in foreign economic activity

The economic efficiency of a foreign trade operation largely depends on the correctly selected basic and transport conditions of the cargo rate. The effectiveness of the formation of the transport logistics system of foreign economic activity of the enterprise is achieved when the organization wins and retains the trust of consumers of logistics services.

Optimization of logistics costs, especially in the field of export-import transportation, does not mean that the cargo transportation organizer will spend less money on process maintenance, driver salaries, and vehicle service. The essence of optimization is to get a more effective result with a constant amount of expenses. In the language of physics, optimization leads to an increase in the efficiency of the cargo transportation system. At the same time, the main goal of the optimization processes is to provide a more competitive and profitable offer to maintain and increase the number of loyal customers. Dumping in the conditions of the modern market does not lead to profit growth. On the contrary, understating the price harms the carrier and the customer equally. Far-sighted market participants should use optimization tools for the benefit of customers and their reputation.

Today, companies specializing in cargo transportation use the following methods to optimize transportation costs:

1. Optimization of routes using application software.
2. Monitoring of the movement of vehicles involved in transportation.
3. Accounting for real resources of motor transport adjusted for depreciation and amortization.
4. Determination of ways to solve work tasks in case of force majeure situations.

Optimization of logistics business processes begins with data analysis and is implemented through specific actions:

- adjustment of machine sizes and packaging container sizes to maximize the use of the vehicle's load capacity.
- place of containers inside the body in such a way as to use the entire useful volume of the cargo part of the vehicle.
- minimization of the number of product overloads, taking into account route optimization.
- combining several loads in one container to speed up loading and unloading operations.
- development of a cargo packaging system taking into account their nature and dimensions to preserve the integrity and ensure maximum completeness of the cargo body.
- working out factors that increase downtime during unloading and loading operations.
- distribution of cargo deliveries taking into account seasonality and weather conditions.
- optimization of the trip taking into account the location of toll roads and emergency sections of the way.
- timely receipt of information about the condition of transport routes.

Logisticians use various mathematical methods to carry out calculations: heuristic algorithms, linear mathematical programming, the minimum price methodology, the Svir algorithm, and the salesman's method. However, not every company can pay for the work of one specialist or an entire logistics department, who manually determine the optimal way to reduce the costs of transport processes. The best solution for managing
logistics optimization is the use of software created specifically to improve the quality of cargo transportation. This is especially true in the field of export transportation, where the carrier's liability increases several times and requires compliance with a wide range of formalities.

Modern international companies with a developed logistics structure use professional applications in logistics and route optimization. Specialized software greatly simplifies the life of professionals:

- the speed of processing requests for cargo delivery is increasing, due to the notification system, the carrier can promptly respond to an incoming order, and apply for a tender on time.
- the program chooses which vehicles from the carrier's fleet are suitable for the delivery of specific cargo. this is very convenient: you can immediately determine whether the required transport will be available at the right time.
- automatic filling of contracts, waybills, powers of attorney, and other necessary documentation.
- the cost of cargo transportation for the client is calculated by the program. the customer immediately knows what expenses are waiting for him.
- a specialized logistics optimization program simplifies communication with customers, makes life easier for the company's employees, and allows you to increase the efficiency of the entire team to the maximum.

Monitoring vehicles is a good help in the process of optimizing logistics and transportation processes. Tracking cars and analyzing the data obtained allows you to solve a whole range of tasks:
- reduction of vehicle maintenance costs.
- identification of inappropriate trips, fuel drains, and other cases of violation of labor discipline by drivers.
- monitoring how the driver observes the working day and rest during the trip.
- savings on the purchase of gasoline and other fuels due to accurate calculation of total fuel costs for the entire fleet.
- monitoring of deviations of the car from a predetermined route.
- reducing the likelihood of accidents.

An important role in optimizing such transport and logistics services as customs services for export cargo is played by the presence of "green corridors" on the route of cargo traffic.

The simplified customs corridor — the “green” corridor — is a series of simplified border crossings for individual groups of goods, based on the information exchange of information about the supply of goods based on export declarations.

Currently, 14 such agreements have been concluded, of which 5 are being implemented in practice - with Uzbekistan, Italy, China, the Netherlands, and Turkey. This mechanism is designed to reduce the time for customs operations without losing the quality of customs administration through the use of a risk management system and preliminary information on mutual trade and means of transport available to the customs service.

The idea of such a corridor is especially relevant for Uzbekistan given the existing potential of the country-exporter of fruit and vegetable and agro-industrial products.

A striking example of the implementation of this idea is the test transportation between Russia and Uzbekistan within the framework of the Agroexpress project.

The train, which included containers with fruit and vegetable products — grapes, persimmons, tomatoes, and lemons — arrived from Tashkent to Selyatino station of the Moscow Railway in December 2021.

Within the framework of the Agroexpress project, with the support of the Ministry of Investments and Foreign Trade of Uzbekistan and the Ministry of Economic Development of Russia, Uzbekistan Temir Yullari, Uzagrologistics centers, Russian Railways Logistics, in partnership with the Russian Export Center (REC), organized in mid-November the first test shipment of frozen poultry meat from Tambov to Tashkent.

The cargo shipment in autonomous refrigerated containers in the composition of a container train proceeded along the route of Tsna (South-Eastern Railway) — Sergeli (Uzbekistan).

This is a pilot export transportation of goods of the agro-industrial complex, implemented within the framework of a trilateral agreement on cooperation in the development of the logistics corridor "Russia — Uzbekistan". The project is implemented with the participation of REI, railways of Russia, Uzbekistan and Kazakhstan, partner logistics companies, as well as customs and phytosanitary services of the countries participating in the corridor.

During the test shipments, the specialists worked out all the technological and control issues. A special tariff rate has been agreed for the route, and in the future deliveries will be carried out by regular full-service trains according to the schedule.

Delivery of products by rail along the corridor "Russia — Uzbekistan" will take no more than 5-7 days, which is comparable to the speed of transportation by road. At the same time, the organization of a direct railway route will allow exporters to reduce logistical losses, preserve the marketable type of products, and also ensure the rhythm of deliveries with a high speed of goods clearance.

Expanding the capabilities of this promising corridor will attract additional cargo flows from Central Asian markets to Agroexpress routes and additionally stimulate the growth of Uzbek exports of agro-industrial products.

Thus, we can say that the optimization of any transport and logistics service consists of the effective operation of each component of the service accompanying the main transportation.
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STATE OF THE ART OF FUEL CELL TECHNOLOGY IN AUTOMOTIVE INDUSTRY

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ABSTRACT

Vehicles with electric propulsion system are becoming increasingly popular due to a number of advantages they possess. However, there are some drawbacks, like long charging time and low energy density of battery packs that create inconveniences for the customers. Hydrogen fuel cells are implemented in addition to battery packs that can tackle these issues of pure electric drives and generate clean energy. This article illustrates the general concept of fuel cell technology, explains the working principle and describes in details different technologies, auxiliary systems as well as on-vehicle applications. In addition, differentiation is made between fuel cell electric vehicles (FCEV) and fuel cell hybrid electric vehicles (FCHEV). Furthermore, different control strategies for energy management system of FCHEV are described. Finally, the list of mass-produced FCHEVs are listed and future development questions and open research topics are defined.

KEYWORDS: Fuel cell stack, Fuel cell system, Polarization curve, fuel cell electric vehicles (FCEV), Fuel cell hybrid electric vehicles (FCHEV), Toyota Mirai.

COВРЕМЕННЫЕ ТЕХНОЛОГИИ ТОПЛИВНЫХ ЭЛЕМЕНТОВ В АВТОМОБИЛЬНОЙ ПРОМЫШЛЕННОСТИ

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АННОТАЦИЯ

Автомобили с электрической силовой установкой становятся все более популярными благодаря ряду преимуществ, которыми они обладают. Однако есть и недостатки, такие как длительное время зарядки и низкая плотность энергии аккумуляторных батарей, которые создают неудобства для покупателей. Водородные топливные элементы внедряются в дополнение к аккумуляторным батареям, которые могут решить проблемы электрических приводов и генерировать чистую энергию. Эта статья иллюстрирует общую концепцию технологии топливных элементов, объясняет принцип работы и подробно описывает различные технологии, вспомогательные системы, а также применение на транспортных средствах. Кроме того, проводится различие между электромобилями на топливных элементах (FCEV) и гибридными электромобилями на топливных элементах (FCHEV). Кроме того, описаны различные стратегии управления для системы управления энергопотреблением FCEV. Наконец, приводится список серийно выпускаемых FCEV, а также определяются вопросы будущего развития и открытые темы исследований.

Ключевые слова: Блок топливных элементов, система топливных элементов, кривая поляризации, электромобили на топливных элементах (FCEV), гибридные электромобили на топливных элементах (FCHEV), Toyota Mirai.

1. Introduction

The modern world’s transportation sector is primarily reliant on fossil fuels, and its large usage is one of the main reasons of global warming, air pollution, and ozone layer depletion. In addition, the excessive usage of fossil fuel in vehicles contributes to the depletion of petroleum resources [1]. Therefore, global efforts are focused on producing clean and renewable energy sources and reduce the amount of pollutant and greenhouse gases. Different low polluting drive units have been proposed to improve the environmental situation. Some of them include advanced spark-ignition (SI) or compression ignition (CI) internal combustion engines (ICE), series or parallel hybrid electric vehicles, equipped with ICEs (HEV), battery electric vehicles (BEV) and fuel cell vehicles (FCV) [2].

The promotion of electric propulsion, which requires overcoming constraints such as limited driving autonomy and the long time required to recharge the batteries, is one of the most effective strategies to accelerate the transport sector’s decarbonization process [3]. The gradual shift to fuel cell hybrid electric vehicles is critical for addressing the issues caused by fossil fuel dependency and battery electric vehicle constraints. Fuel cell vehicles, powered by pure hydrogen have zero emissions, with the water vapor as the only local emission. However, by considering not only tank-to-wheel, but also well-to-wheels emissions, the environmental effect of fuel cell vehicles significantly depends on the primary source of hydrogen production, its logistics and delivery [2]. Hydrogen produced from renewable energy, that is used in fuel cells can dramatically reduce overall (well-to-wheels) emissions. For the vehicles, powered by fuel cells, Energy Storage Systems (ESS) are prevalent. Hybridization has a number of advantages, including improved transient power demand, the ability to absorb energy via regenerative braking, and the ability to optimize vehicle efficiency [4]. The coordination of the numerous power sources necessitates a high level of vehicle control.

2. Fuel cell stack

2.1 General description

Fuel cells are devices, that are able to directly convert chemical energy into electricity, without neither combustion, nor moving parts through the electrochemical process of combination between hydrogen and oxygen, producing water, electricity and heat [6]. Fuel cells use reactants coming from outside, they continue to run as far as they are supplied with hydrogen and oxygen [5]. Two electrodes ad electrolyte are present in single unit of fuel cell. Negative electrode is called anode and the positive electrode is called cathode. Hydrogen is oxidized as soon as it contacts with anode. The chemical reaction that take place in anode is

$$H_2 \rightarrow 2H^+ + 2e^-$$  (1)

Electrolyte allows the passage of ions ($H^+$ ions), while at the same time blocks the passage of electrons. Electrons produces as a result of oxidation, can travel only through an external circuit, thus transferring electric energy to a generic load connected to the circuit. Finally, oxygen at the cathode combines with hydrogen ions and electrons to produce water. This reduction chemical reaction is

$$\frac{1}{2}O_2 + 2H^+ + 2e^- \rightarrow H_2O$$

The scheme of generic fuel cell unit is represented in Figure 1.

Fuel cell stack consist of a number of individual cell unit series connected. Scheme of a fuel cell stack is illustrated in Figure 2. The intrinsic characteristics of fuel cells are

- Relatively high electrical efficiency, which ranges from 40% to 60% and more
- The ability to use different reactants (hydrogen, methane, methanol, ethanol)
- Small environmental impact and high modularity

![Figure 1. Fuel cell stack unit](image1)

![Figure 2. Fuel cell stack](image2)
2.2 Polarization curve

Equivalent circuit of fuel cell stack consist of an ideal voltage source and a resister series connected. The value of open circuit voltage is always lower than the theoretical maximum potential due to intrinsic losses and conditions (reactant concentration, temperature, pressure). When a load is connected, terminal voltage drops even more and strongly depends on current density [6]. The graphical representation of this dependence is called Polarization curve and is illustrated in Figure 3.

The energy conversion efficiency of a fuel cell can be calculated through the ratio of actual voltage in a given working condition and an open circuit voltage.

$$\eta_{\text{conv}} = \frac{V_{\text{act}}}{V_{\text{OCV}}}$$  \hspace{1cm} (3)

There are different sources for the losses in a fuel cell stack: activation losses, ohmic losses, concentration losses, fuel cross-over losses [5].

Activation losses: reduced reaction kinetics on the surface of electrodes. Part of the voltage is spent in driving the chemical reaction that transfers the electrons. Cell temperature, efficiency of the catalyst, concentration of the reactants and electrode roughness strongly depend on the amount of activation losses.

Ohmic losses: resistance to the flow of electrons through the material of the electrodes. This resistance linearly varies with current density.

Concentration losses: due to the concentration change of the reactant at the surface of the electrodes. It depends mainly on the conductivity of the electrodes.

Fuel crossover losses: due to a portion of a fuel which can flow through an electrolyte and a small number of electrons which can also pass through an electrolyte. These losses become more relevant in lower temperature cells.

Share of different losses and the dependence of current density are illustrated in Figure 4.

2.3 Fuel cell auxiliaries

Additional devices are required to keep the continuous working of fuel cell stack, which are powered by the energy of the stack. We define a fuel cell system, that includes all the auxiliary components and the stack itself. As a result, the effective power of fuel cell system is lower than that of fuel cell stack (Figure 5). The scheme of fuel cell system is illustrated if Figure 6.

Main auxiliary systems are

- Hydrogen supply system: A recirculating pump is used to run an excess of hydrogen.
- Oxidant supply system: Compressor is used to drive air from the environment.
- Humidification system: Hydrogen and electrodes should be humidified to avoid the membrane from drying out.
- Cooling system: Cooling circuit is required to remove the heat generated as a result of intrinsic losses of a fuel cell stack [8].

Figure 3. FC polarization curve [7]

Figure 4. Share of losses in fuel cell stack [7]
On-board hydrogen is mainly stored in either liquid or gaseous form. Hydrogen gas itself is in gaseous form at ambient conditions, thus has very low density at atmospheric pressure. Therefore, it should be stored in compressed form [Figure 7]. On the other side, the mass per unit volume of liquid hydrogen is much higher than the gaseous one, but the temperature should be kept far below the external temperature (around $-270 \, ^\circ C$) to maintain its liquid phase. This process requires an additional refrigeration system, which is powered by fuel cell system, thus reducing the effective output power. In addition, hydrogen tank must be strongly insulated in order to reduce the heat transfer from the ambient to the hydrogen and so prevent hydrogen from boiling.

Figure 5. FC stack and system efficiency [9]

Figure 7. Hydrogen storage tank [10]

2.4 Fuel cell technologies

Alkaline fuel cell (AFC)

This technology is the most efficient among the others, having the potential to reach 70% due to fast kinetics due to low activation losses. At the anode, hydrogen is oxidized, according the following reaction

$$H_2 + 2OH^- \rightarrow 2H_2O + 2e^-$$

At the cathode, oxygen is reduced, at the same time, electrons flow through an external circuit

$$O_2 + 2H_2O + 4e^- \rightarrow 4OH^-$$

These cells use an electrolyte consisting of an alkaline aqueous solution of potassium hydroxide.
Phosphoric acid fuel cell (PAFC)
This technology uses liquid phosphoric acid ($H_3PO_4$) in a silicon carbide (SiC) matrix as an electrolyte. The reaction at the anode is

$$2H_2 (g) \rightarrow 4H^+ + 4e^-$$

The reaction is the cathode is

$$O_2(g) + 4H^+ + 4e^- \rightarrow 2H_2O$$

PAFCs generate electricity (>40% efficiency) and nearly 85% of the steam this fuel cell produces is used for cogeneration and have the advantage of having a big choice of fuels usable.

Molten carbonate fuel cells (MCFC)
Usually operates at high temperatures (600-700°C) and contains an electrolyte composed of a molten carbonate salt mixture suspended in a porous, chemically inert matrix of beta alumina solid electrolyte (BASE). The reaction at the anode is

$$H_2 + CO_3^{2-} \rightarrow H_2O + CO_2 + 2e^-$$

The reaction at the cathode is

$$\frac{1}{2}O_2 + CO_2 + 2e^- \rightarrow CO_3^{2-}$$

The main disadvantages of this technology are high operating temperature and high electrolyte corrosion.

Solid oxide fuel cells
It contains ceramic electrolyte and the has high power conversion efficiency, long-term stability, fuel flexibility. However, these fuel cells operate at extremely high temperatures (around 1000-1200°C). The reaction at the anode is

$$H_2 + O^{2-} \rightarrow H_2O + 2e^-$$

The reaction at the cathode is

$$\frac{1}{2}O_2 + 2e^- \rightarrow O^{2-}$$

Due to high operating temperature, activation losses are strongly reduced and the prevalent one becomes ohmic losses. The disadvantage is the brittleness of electrolyte which can be damaged due to thermal stresses, assembling and costs.

Direct methanol fuel cells (DMFC)
Methanol is used as a fuel and polymer is used as a membrane. The ease of methanol transport and high energy density is one of the advantages of this technology. However, efficiency range between 30 and 40 percent. The reaction at the anode is

$$CH_3OH + H_2O \rightarrow 6H^+ + 6e^- + CO_2$$

The reaction at the cathode is

$$\frac{1}{2}O_2 + 6H^+ + 6e^- \rightarrow 3H_2O$$

Proton exchange cell (PEMFC)
PEMFCs are fueled by hydrogen and an oxidant, usually air or oxygen. This technology is mainly used in transport application. Solid polymer membrane made of perfluoro sulfonic acid which conducts hydrogen protons. Operating temperature is comparably low (50-100°C) and operates on the opposite principle to electrolysis, which consumes electricity [7]. The chemical reaction at the anode is

$$H_2 \rightarrow 2H^+ + 2e^-$$

The reaction at the cathode is

$$\frac{1}{2}O_2 + 2H^+ + 2e^- \rightarrow H_2O$$

PEMFC technology is used in automotive industry due to the following advantages [11]:
- Low-cost technology
- Relatively low temperature operating range
- Air can be directly used as an oxidant
- Durability (3000-5000 h as functional life)
- Fast response

3 Hydrogen fuel cell traction systems
In general, hydrogen fuel cell vehicles can be sub-divided into two categories: pure fuel cell vehicle and simple series hybrid. Simple series hybrid fuel cell vehicles can be classified as full power, load follower and range extender (Figure 8). For the full power configuration of FCHEVs, the fuel cell system is designed in a way to be able to provide maximum transient power demand. In case of load follower configuration, fuel cell system is sized to supply maximum continuous power demand. Finally, fuel cell system is designed to provide average power demand for the case of range extender [12]. One of the main drawbacks of pure hydrogen fuel cell vehicles is the absence of an additional reversible energy source, which is present in hybrid vehicles in the form of battery packs or supercapacitors, that enables the energy recovery during braking phases and assist main driving unit during hard acceleration phases. In general, hydrogen fuel cell system is series coupled (electrically in parallel) with a second energy and/or power source.

![Figure 8. Hydrogen fuel cell vehicle classification](image-url)
3.1 Pure fuel cell propulsion system.

Only fuel cell stack (FCS) is responsible to produce tractive power, no any additional power sources are available (Figure 9). It is a simple solution in which the FCS is sized to supply maximum transient power. Due to irreversibility of FCS, the direction of the power flow cannot be reversed, so regenerative braking is not possible. FCS must fully manage the instantaneous power demand of the vehicle and may face with warm-up issues during cold start.

![Figure 9. FCEV propulsion system](image)

3.2 Series hybrid fuel cell propulsion system.

An additional power/energy source is implemented in this solution (Figure 10). FCS is electrically in parallel (series) coupled with either battery or power buffer (supercapacitor) or both. Usually, batteries are applied as a second source. Proper control strategy is required to distribute the power demand between FCS and an additional power source, to optimize the hydrogen consumption of FCS. This done by forcing FCS to work at optimum operating line, i.e. at high efficiency working points, and the rest is supplied by the batteries. At the same time, when the power demand is low, FCS can operate with higher load, yet with high efficiency, charging

![Figure 10. FCHEV propulsion system](image)
batteries. Since battery packs and supercapacitors admit bidirectional power flow, some energy could be regenerated during braking or deceleration phases. Moreover, batteries can supply power during start-up, thus simplifying the transient loading of FCS.

4 On-vehicle applications

Fuel cell technology is realized in several passenger vehicles. Hyundai ix35 FCEV is the first commercially produced hydrogen fuel cell vehicle. Toyota Mirai (1st and 2nd generations), Hyundai Nexo, Honda Clarity are the other examples of mass-produced fuel cell hybrid electric vehicles. Toyota Mirai is for sure the most popular and wide-spread FCHEV in the world (Figure 11). This vehicle can travel 500 km on a full tank, according to EPA UDDS driving cycle with an average consumption of 3.6 liters of hydrogen per 100 km of travel distance. FCS accelerates the vehicle from 0 to 100 km/h in 9.2 seconds. Hydrogen refueling takes from 3 to 5 minutes. The first generation of Toyota FC stack achieved a maximum output power of 114 kW [13]. Electricity generation efficiency was enhanced through the use of 3D fine mesh flow channels. Each stack consists of 370 single-line stacking cells. In addition, it is also equipped converter, developed to boost the generated voltage up to 650 volts. Toyota Mirai contains two hydrogen tanks with a three-layer structure made of carbon fiber-reinforced plastic, which is able to withstand 700 bars of pressure. Mirai has 245 V (1.6 kWh) nickel metal hydride traction rechargeable battery pack.

Figure 11. Toyota Mirai (1st generation) [14]

Table 1. Mass-produced fuel cell vehicles technical specifications

<table>
<thead>
<tr>
<th>Vehicle</th>
<th>Travel range [km]</th>
<th>Curb weight [kg]</th>
<th>Motor Power [kW]</th>
<th>Max speed [km/h]</th>
<th>Acceleration time (0-100 km/h) [s]</th>
</tr>
</thead>
<tbody>
<tr>
<td>Toyota Mirai (2nd gen)</td>
<td>647 (UDDS)</td>
<td>1920</td>
<td>136</td>
<td>175</td>
<td>9</td>
</tr>
<tr>
<td>Honda Clarity Fuel cell</td>
<td>589 (UDDS)</td>
<td>1875</td>
<td>120</td>
<td>165</td>
<td>8.7</td>
</tr>
<tr>
<td>Hyndai Nexo (2018)</td>
<td>805 (NEDC)</td>
<td>1850</td>
<td>113</td>
<td>177</td>
<td>8.4</td>
</tr>
</tbody>
</table>

By considering Kia Optima Lx 2019, equipped with conventional internal combustion engine, having 137 kW maximum power and 1465 kg of curb weight, it is clear that specific power density for the ICE vehicle is much lower than those, equipped fuel cell technology, being equal 0.0935 kW/kg for Kia Optima Lx 2019 and 0.07 kW/kg for Toyota Mirai. The reason for this phenomenon is the complexity of fuel cell system, power converters and electric motors. Therefore, the total weight becomes larger than the weight of ICE vehicle’s powertrain and drivetrain.

5 Future development and perspectives

As it is mentioned earlier, FCHEV overall (well-to-wheels) emissions significantly depend on hydrogen production methods. The main sources for hydrogen are fossil fuels (coal, oil, natural gas), biomasses and water. The primary energy, needed to be supplied for hydrogen production can be taken from fossil fuels, nuclear energy and renewable energy. Electrolysis of water is the cleanest way to produce hydrogen, yet the most expensive. The cost for the electrolysis might be up to 10-12 times more than the conventional steam reforming process. Therefore, a number of current researches are concentrated around the simplification and price reduction of electrolysis process for hydrogen production [15]. Moreover, the capacity and safety of hydrogen on-board storage system is another issue. One of the main reasons, of why FCHEV are not widely spread in the world is the lack of infrastructure (hydrogen refueling stations), which requires high capital investments.
6 Conclusion

This article demonstrates the capabilities and functionality of hydrogen fuel cell technology, applied in automotive industry. These vehicles promise zero tank-to-wheel emissions, and is an evident solution concerning the environmental concerns of pollutant and greenhouse gases emissions from transportations sector. Pure water ($H_2O$) is the only emission, which is produced as a result of the reaction of hydrogen ($H_2$) and oxygen ($O_2$). Vehicles, equipped with fuel cell technology promise a working efficiency range, that is higher of gasoline and diesel internal combustion engines, but lower than of battery electric vehicles. Fuel cell hybrid electric vehicles can take an advantage of regenerative braking and flexibility in operating conditions of FC system. There are, however, some challenges, such as aiding regenerative braking, maximizing efficiency, increasing the transient performance of FC in the system, and decreasing FC fuel consumption, have still to be resolved. Nonetheless, researchers expect that in the near future, FCHEV will be a strong rival to traditional ICEV, as the cost of FC and related technology continues to fall.

References:
ASSESSMENT OF THE DECISION-MAKING IN JUSTIFICATION OF STRENGTHENING THE CAPACITY OF RAILWAYS IN UZBEKISTAN UNDER CONDITIONS OF UNCERTAINTY AND RISKS

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ABSTRACT
As a result of the evaluation of the work, types of uncertainty and risk factors were identified when justifying the increase in the capacity of the railways of Uzbekistan, which affect the choice of the design decision being made. After the types of uncertainty and risk classification are identified, it is necessary to determine the decision-making methods when justifying the increase in the capacity of railways, consider their advantages and disadvantages.

Risk factors and uncertainties in justifying the increase in the capacity of the operated railways of Uzbekistan are currently not taken into account as indicators that require special attention.

Let us turn to the schedule of transportation mastering (Fig. 1) [2-3]
Finding the best way to increase the capacity of the railways of Uzbekistan in order to switch transit cargo flows between China, Central and South Asia is a difficult task, which is due, on the one hand, to the uncertainty of the time for switching transit cargo flows, and on the other hand, the reliability of the initial information on the size of transit cargo flows between China, Central and South Asia.

As can be seen from the graph, when choosing the variant of the scheme for mastering the transportation of the Angren-Pap railway line, a rather long period (15 years) of operation of the line is considered, while, obviously, deviations in traffic volumes are possible, both in time intervals and in general over the horizon calculation (this depends on many factors independent of each other).

The prospect of developing the existing Angren-Pap line as a link between China, Central and South Asia may not provide large transit cargo flows between China, Central and South Asia, since there are bottlenecks on this railway line that significantly reduce throughput and carrying capacity, which need to be subjected to an increase in the capacity of the line when switching transit cargo flows between China, Central and South Asia. The same can be said about the schemes of options for strengthening the operated railway line Angren - Pap, i.e. there are conditions of uncertainty. Obviously, the longer the calculation horizon, the higher the level of uncertainty and risk when adopting a particular scheme based on the results of an economic assessment of the effectiveness of investments [1].

Before proceeding to consider the issue of making a decision when justifying the strengthening of the capacity of the Angren-Pap railway projects under conditions of uncertainty and risks, we will formulate the concepts of "uncertainty" and "risk" themselves, and establish the differences between them.

Uncertainty implies the presence in the information block of factors for which it is impossible to give deterministic (single-valued) values, i.e. information is incomplete or inaccurate. In our case, such factors include, for example, information about the volume of traffic or the size of traffic in the future, which depend on the formation of a corridor between China and Central and South Asia.

Uncertainty factors can be divided according to their genetics into external and internal. External factors include information, for example, on the size and structure of transportation, which depend on the country’s macroeconomic development programs, the legal framework, the actions of competitors in the transport services market, etc.

Internal - this is, first of all, the competence of the apparatus of managers of the railway company when choosing a strategy for its functioning, and here, in our opinion, it is important to involve science and educational institutions in solving this problem.

There are various methods for determining the volume of traffic and the size of traffic for the estimated time and perspective, showing that uncertainty cannot be interpreted as a complete lack of information, but only about its incompleteness and inaccuracy. Hence the

Figure 1. Graph of transportation mastering in each calculation case

\[
\begin{align*}
\text{I-design case} & \quad t_{i1} = 4.5, \\ \text{II-design case} & \quad t_{i1} = 4.5, \\ & \quad t_{i2} = 4.3, \\ & \quad t_{i3} = 5.6, \\ & \quad t_{i4} = 4.6 \\
\end{align*}
\]
conclusion: - the available information must be used as “conditionally accurate” when assessing the options for the program to increase the capacity of the operated railway Angren - Pap. If new information is received in the process of project implementation, then, obviously, it is necessary to correct the course (process, technology, scheme) of implementation.

The risk should be understood as the probability of occurrence of such conditions that lead to negative consequences in the course of implementing decisions to increase the capacity of the operated Angren-Pap railways or its individual elements.

In the process of strengthening the capacity of the operated railways in order to switch transit cargo between China and Central and South Asia, the Uzbek railways are faced with a combination of various types of risk that differ in place and time of occurrence, a combination of external and internal factors affecting their level and, consequently, according to the method of their analysis and methods of description.

Risk classification consists in systematizing a large number of risks according to certain characteristics and criteria, which will make it possible to combine a subset of risks into more general concepts. The classification of risks, which is recommended for evaluating investment projects, is shown in fig. 2. In addition, a brief description of each type of risk is given, taking into account the particular justification for increasing the capacity of Uzbekistan's railways in order to switch transit cargo between China and Central and South Asia.

The systematic risks include, first of all, the risks of force majeure (Fig. 3), where the first place is the risk of impact on the progress of the project and its (object) functioning during the life cycle of natural disasters (earthquakes, avalanches, mudflows), landslides, etc.) [4-5].

It should be noted that the territory of Central Asia is located in a seismically dangerous zone. The project of an international corridor between China and Central and South Asia is envisaged in a complex mountainous area, which is a seismic hazard zone. In winter, there will be periodic threats of avalanches, mudflows and landslides in the area of the international corridor between China and Central and South Asia.

If we talk about country risk (Figure 3), then here we are talking, first of all, about the political and economic stability of the country, the size of its participation in foreign economic relations. Country risk can be divided into political (Figure 4) and economic (Figure 5). Political risks of direct losses and losses or shortfalls in profits arise due to adverse changes in the political situation in the state or the actions of local authorities. Vivid examples of the manifestation of country risk are the events that occurred in some countries in 2010-11. (eg Libya, Syria, Sudan, etc.) and current events (Syria, Yemen, Ukraine, etc.).
The successful development of the project to strengthen the capacity of Uzbekistan's railways in order to switch transit cargo between China and Central and South Asia largely depends on a stable political and economic situation in the region. The instability of the situation in Central Asia will have a negative impact on the effectiveness of decisions made. As previously noted, the construction of a new railway line through Afghanistan has continued, which will provide Central Asia with access to the seaports of Iran and Pakistan on the coast of the Indian Ocean. However, today it comes up against the unresolved situation in Afghanistan.

Economic risks are caused by unfavorable changes in the economies of countries. When choosing design parameters for increasing the capacity of the operated railways of Uzbekistan in order to switch transit cargo between China and Central and South Asia, the following types of uncertainty and economic risks seem to be the most significant:

- lack of the state budget and own funds of the Uzbek railways to increase the capacity of the railways;
- a decrease in the volume of cargo traffic due to the fall of the state economy and the economic crisis in the region;
- the need for additional investments in the infrastructure and rolling stock of railways due to their quality service;
- lack of capacity and low technical level of development of the locomotive and car fleet;
- lack of infrastructure development (warehouses, terminals, etc.);
- reduction of transit cargo flows due to the development of alternative railway routes bypassing the territory of Uzbekistan;
- high level of inflation;
- lack of conversion for foreign investors.
At the same time, there are “bottlenecks” on the railway network of the Republic of Uzbekistan that significantly reduce the throughput and carrying capacity and require significant modernization. The most important work in this direction is to reduce the depreciation of fixed assets, and for rolling stock (diesel locomotives - 76%; freight electric locomotives - 30.8%; freight cars - 70%; passenger cars - 49.1%) and track facilities (railway tracks – 33%), this figure is much higher.

It is important to note that the absence of an intergovernmental agreement on the permanent operation of Uzbekistan's railways will become a serious obstacle to the implementation of plans to increase the capacity of Uzbekistan's railways in order to switch transit cargo between China and Central and South Asia. The intergovernmental agreement on the permanent operation of Uzbekistan's railways should become a supporting legal document, creating the basis for the implementation of draft plans to strengthen the capacity of Uzbekistan's railways in order to switch transit cargo between China and Central and South Asia, as well as the second stage of development of the country's railway network.

References:
FOOD TECHNOLOGY

INFLUENCE OF SPRINKLING ON THE GROWTH AND DEVELOPMENT OF PROMISING VARIETIES OF WINTER WHEAT

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ВЛИЯНИЕ ДОЖДЕВАНИЯ НА РОСТ И РАЗВИТИЕ ПЕРСПЕКТИВНЫХ СОРТОВ ОЗИМОЙ ПШЕНИЦЫ

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ABSTRACT
This article describes how the irrigation method affects the growth and development of promising varieties of winter wheat "Grom" and "Nodira" on light gray soils of the Andijan region.

АННОТАЦИЯ
В данной статье описано, как способ орошения влияет на рост и развитие перспективных сортов озимой пшеницы «Гром» и «Нодира» на светло-серых почвах Андижанской области.

Keywords: groundwater, chdns, slope length, moisture thickness, irrigation methods.

Ключевые слова: подземные воды, предельная полевая влагоёмкость (ППВ), длина склона, мощность увлажнения, способы орошения.

Today, winter wheat is grown on 220.4 million hectares in more than 132 countries. Of this, 12.3% is irrigated land, the average grain yield is 31.1 quintals per hectare, and the bulk of food is grown on these lands1. In recent years, the sharp change in climate has caused a number of inconveniences in the cultivation of grain crops. A number of countries around the world, including the United States, Australia, Russia, China, India, Pakistan, Bangladesh, North Africa, Central Asia, South Kazakhstan, Transcaucasia, are finding solutions through the introduction of modern agricultural technologies and reclamation measures. Therefore, the norm of seasonal irrigation, the timing of irrigation is based on the water consumption of each crop, depending on the natural and climatic conditions.

Adherence to scientifically based irrigation procedures in the context of water shortages in world agriculture today has a positive impact on increasing crop yields and its quality. In this regard, it is important to conduct research to improve modern science-based irrigation procedures that save water and resources, as well as to improve the reclamation of lands.

The study was conducted in the Andijan region in light gray, medium-heavy sands with mechanical composition, groundwater level at a depth of 1.5-2.0 meters. The experimental system is presented (Table 1).
The experiments were performed in 4 repetitions. The area of the fold 4 times is 0.6 x 8 = 4.8 m², the length of the edge is L=50 m, the distance between the edges is v=0.9 m, the area of the option is 4.8 x 50 = 240 m², the area of the fold is 240 x 5 = 1200 m², total area 1200 x4 = 4800 m² or 0.46 ha.

**Table 1.**

<table>
<thead>
<tr>
<th>Options</th>
<th>Irrigation method and soil moisture before irrigation (wilting point) %</th>
<th>Calculated moisture thickness, cm</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>during planting and harvesting</td>
</tr>
<tr>
<td>Varieties of autumn wheat</td>
<td></td>
<td>0-50</td>
</tr>
<tr>
<td>1</td>
<td>Irrigation (control) 70-70-60</td>
<td>0-50</td>
</tr>
<tr>
<td>2</td>
<td>Irrigation with a flexible hose 70-70-60</td>
<td>0-50</td>
</tr>
<tr>
<td>3</td>
<td>Irrigation with a flexible hose 65-65-60</td>
<td>0-50</td>
</tr>
<tr>
<td>4</td>
<td>Sprinkler Irrigation 70-70-60</td>
<td>0-50</td>
</tr>
<tr>
<td>5</td>
<td>Sprinkler Irrigation 65-65-60</td>
<td>0-50</td>
</tr>
</tbody>
</table>

Data on growth and development of winter wheat depending on irrigation regimes are given in Table 2.

According to the data, in 2022, the optimal irrigation regime for winter wheat in the "Grom" variety is 70-70-60%, the wilting point in the irrigated control variant and 856 cm, the number of stems was 884 in the collection and 3.9 in the tubing.

In 5 variants of rain-fed irrigation with soil moisture 65-65-60% relative to wilting point, these values are: 8.8; 17.9 and 84.6 cm; the number of stems was 860, and 4.8 and 4.6 per plant, respectively, which is 2.2, -3.5; and 856 and 1.3 compared to variant 1. ; 1.0 is the excess. It should be noted that the high soil moisture content of 70-70-60% had an optimal effect on the growth of winter wheat. However, the height of stalks and the number of stalks of winter wheat do not determine the yield, but only increase its dry mass. It was observed that the soil moisture content was higher than the 5 variant values set at 65-65-60% compared to wilting point before irrigation.

Similar data were obtained for winter wheat variety"Nodir".

In conclusion, for optimal growth and high yield of winter wheat, it should be 65-65-60% of the wilting point relative to the limited field capacity in terms of pre-irrigation soil moisture phases, and it is advisable to irrigate by rain.

**Table 2.**

<table>
<thead>
<tr>
<th>Numbers</th>
<th>Soil moisture, in % of ChDNS</th>
<th>Stem height, cm</th>
<th>Number of stems, pcs</th>
<th>Yields</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Tufts</td>
<td>In the tube</td>
<td>Tufts</td>
</tr>
<tr>
<td></td>
<td>variety &quot;Grom&quot;</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>70-70-60</td>
<td>7.6</td>
<td>14.4</td>
<td>83.0</td>
</tr>
<tr>
<td>2</td>
<td>70-70-60</td>
<td>7.5</td>
<td>15.6</td>
<td>84.2</td>
</tr>
<tr>
<td>3</td>
<td>65-65-60</td>
<td>7.8</td>
<td>15.9</td>
<td>84.4</td>
</tr>
<tr>
<td>4</td>
<td>70-70-60</td>
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<td>16.3</td>
<td>84.2</td>
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<td></td>
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<td>1</td>
<td>70-70-60</td>
<td>7.4</td>
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<td>82.0</td>
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References:
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DRYING PRODUCTS WITH INFRARED RAYS

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ABSTRACT

By maximizing the nutritional value and taste of products, the use of infrared rays during drying increases the heat density on the product surface, and the intensity of the process can be increased to a certain extent due to the fact that shortwave IR rays penetrate deeper into the material.

Keywords: IR-rays, range, intensity, vibration, electromagnetic, thermoradiation, combination, absorption.

ANNOTATION

Максимально повышая пищевую ценность и вкусовые качества продуктов, использование ИК-лучей при сушке увеличивает плотность тепла на поверхности продукта, а интенсивность процесса можно в определенной степени увеличить за счет того, что коротковолновые ИК-лучи проникают глубже в материал.

Ключевые слова: ИК-лучи, диапазон, интенсивность, вибрация, электромагнитное, терморадиационное, сочетание, поглощение.

Research in recent years has focused on improving drying methods that maximize the nutritional value and taste of products, as well as ensuring high process efficiency.

Infrared drying, its types and possibilities of application by combining heat carriers. By using infrared rays in the drying of products, the heat density reaching the surface of the product increases and the intensity of the process can be increased to a certain extent due to the fact that short-wave IR rays penetrate deeper into the material.

Infrared rays include rays with wavelengths ranging from 0.77 to 340 μm. In practice, rays with a wavelength of 0.77 to 5-6 microns are used for drying. IR-irradiation of thick material results in a certain temperature change (compared to normal convective drying). Also, the flow of moisture into the material brings with it a certain amount of heat, which accelerates the internal heat exchange. To increase the intensity of thermoradiation drying, IR rays are required to penetrate the material as deeply as possible. It depends on the conductivity of the material and the wavelength of the IR rays. The lower it is, the greater the penetration capacity of infrared rays. As the layer thickness decreases and the moisture content in the material decreases, the permeability of the products increases.

Processing of agricultural products in the electromagnetic field in the IR-RAN range is a combination of heat transfer, in which infrared rays are converted into thermal energy without direct interaction between the energy source and the product, with energy transfer as electromagnetic oscillations entering the product. Infrared rays have the ability to penetrate the product to a certain depth and affect the molecular structure of the material, which ensures a rapid rise in temperature inside the product. Infrared drying is based on the absorption of infrared rays of a certain wavelength by the moisture in the product.

The boiling point of water depends on the total pressure, the lower the pressure, the lower the boiling point. Loss of moisture at low temperatures allows complete preservation of almost all proteins and amino acids, carbohydrates, biologically active substances, vitamins, minerals, dyes and odors. Vacuum drying is the most optimal method.

Despite the intensive (rapid) heating of the surface layer during the initial period of the infrared method of energy transfer, no significant moisture loss from the product is observed. In this case, the moisture is redistributed along the thickness of the layer. In the case of thermal moisture permeability, the transition of the bulk of the moisture to the vapor phase and the transfer of a small amount of moisture into the layer leads to dehydration of the surface layer. These studies have shown that the duration of IR-drying is 1.5-2 times shorter than other methods.

In order to intensify the drying process and maintain the high quality of the finished product, it is necessary to determine the physicochemical, structural-mechanical, thermoradiation and heat-physical properties of the product, as well as the basic laws of heat treatment.

Processing in the electromagnetic field in the IR range corresponds to a wavelength of 0.76-750 μm, which is conventionally divided into three smaller ranges: long-wave - 750-25 μm, medium-wave - 25-2.5, short-wave - 2.5-0.76 μm. The range of IR radiation is represented by three directions: wavelength - short infrared range (NIR) to 0.75-1.4 μm; average - up to 1.4-3 microns (MIR) and long infrared range - up to 3-1000 microns (FIR).

Water and organic components, especially protein and starch, absorb energy over a long range (wavelength 2.5μkm), while many foods have low absorption properties of wavelengths smaller than 2.5μkm. In IR heating, short waves are absorbed by water, while long waves are absorbed by the surface of the product. This means that it is more efficient to dry products of minimum thickness on long-range waves (25-100μkm), while it is more efficient to dry thick pieces on short-range waves (0.75-3.0).

In studying the mechanism of action of IR rays on food, they are described as a matrix of various biological polymers, salts, water. Each element in the food system absorbs IR rays of a certain wavelength. Proteins range from 6 to 9 microns; cha absorbs waves in the range of 0.25 to 10 μm, but absorption peaks occur in the range of 3-4 μm; average - up to 1.4-3 microns (MIR) and long infrared range - up to 3-1000 microns (FIR).

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The use of IR-heating in the drying of thin layers is very effective, as the drying intensity increases by 1.5-2 times, energy consumption is reduced by 1.5 times.

List of references:
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SYSTEMATIC ANALYSIS AND MATHEMATICAL MODELING
OF ULTRASONIC EXTRACTION PROCESS

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СИСТЕМАТИЧЕСКИЙ АНАЛИЗ И МАТЕМАТИЧЕСКОЕ МОДЕЛИРОВАНИЕ ПРОЦЕССА УЛЬТРАЗВУКОВОЙ ЭКСТРАКЦИИ

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ABSTRACT

Systematic analysis of extraction allows a complete study of the object as a system, to determine the input and output parameters of the process and their interaction, and as a result to find the right solution. Initially, the object of research was to classify medicinal plants as a single system (single hierarchical level). Taking the following assumptions, we
construct a mathematical model of mass transfer in the inner and middle quasi layers of a particle, as well as in quasi layers in direct contact with the solvent. It is known that in the quasi layers of the leaves of the mint plant, the substance passes through molecular diffusion to the surface in contact with the solvent.

Аннотация
Системный анализ добычи позволяет всесторонне изучить объект как систему, определить входные и выходные параметры процесса и их взаимодействие и в результате найти правильное решение. Изначально объектом исследования была классификация лекарственных растений как единой системы (единого иерархического уровня). Принимая следующие допущения, построим математическую модель массопереноса во внутреннем и среднем квазислоях частицы, а также в квазислоях, непосредственно контактирующих с растворителем. Известно, что в квазислоях листьев растения мяты вещество переходит путем молекулярной диффузии на поверхность, контактирующую с растворителем.

Ключевые слова: моделирование, систематический анализ, ультразвук, извлечение, иерархическая схема

The proposed method of systematic thinking of the object of obtaining medicinal plants, which we offer, allows you to easily analyze the system of isolation of medicinal plants in the installation of existing methods [1]. According to the proposed method, first of all, the indicators - the object of separation of medicinal plants - the extraction system and the input and output parameters of the process that takes place at the object of separation of medicinal plants are determined. The system under consideration in the device (element) for the production of medicinal plants is then divided into components, the parameters for each selected element and the process in the element are indicated. And similarly, the division of an element (a plant extraction system in an extraction plant) into subsequent systems is not limited. Optimal extraction of medicinal plants in the device was performed depending on the level of need for decision-making and research capabilities [2].

The process of obtaining medicinal plants can be divided into 3 stages [1,2,3]:
1) "internal diffusion", which includes all the phenomena of transfer of substances within the raw material particles (penetration of the solvent into the pores of particles of plant materials; melting of the component);
2) direct distribution of the substance within the boundary layer;
3) The passage of the extracted substance through the shell of the moving extractant and its distribution throughout the entire extractor mass (convective diffusion).

For mathematical modeling of the process, we determined the input and output parameters of the plant extraction process. Fig. 1 shows a level 1 diagram of the hierarchy of medicinal plants.

![Figure 1. Level 1 hierarchical scheme of plant separation](image)

The main input parameters at this level are: M - mass of raw material; \(a_m\) - valuable components of raw materials; \(M_{erit}\) - the mass of the solvent; \(a_{erit}\) - the concentration of the solvent; \(T_{erit}\) - solution temperature. Output parameters are as follows: \(m_x\) - the mass of the remaining medicinal plants; \(a_x\) - valuable components of medicinal plant residues; \(a(t)\) - change in concentration (valuable components) in the apparatus over time; \(M_{erit2}\) - solvent output consumption.

The block diagram of the laboratory experimental equipment and the computer model of the process of obtaining a valuable component from the leaf of the mint plant are as follows:
The structure of the holes in many ways affects the extraction mechanism and the speed of its flow. The particle size of a mint leaf is much larger than the diameter of the pores, so they can be obtained as isotropic porous bodies. Let us assume another: the extracts obtained are a group of components with different diffusion and physicochemical properties.

In a one-dimensional system with a concentration gradient x dc/dx, the rate of change in the concentration of a substance at a given point depends on the diffusion and is determined by Fick’s [3] second law. The result of Fick’s second law is a second-order diffusion equation:

$$\frac{\partial c}{\partial t} = D \frac{\partial^2 c}{\partial x^2}, \quad (1)$$

where $t$ is the time and $x$ is the thickness coordinate of the mint leaf.

Or the time distribution of the concentration of extractives in the particle size of a mint leaf is written by the equation:

$$\frac{\partial c}{\partial t} = D \left( \frac{\partial^2 c}{\partial x^2} + \frac{\partial^2 c}{\partial y^2} + \frac{\partial^2 c}{\partial z^2} \right), \quad (2)$$

Such an equation has been solved by scientists to linearly describe the initial conditions. In the actual process, the initial conditions, in particular the distribution of the concentration of the crushed mint leaf in the body, are related to taking into account the concentration of the valuable component in the external environment, which changes over time. The order of derivation of computational equations, there are also large errors in the application of the third type of boundary conditions.

Therefore, the development and application of computational solutions based on multi-stage computer modeling techniques will be more optimal. It begins with modeling the distribution of concentration within a body of material.

**Modeling of the extraction process in quasi-layers of a material particle.** Taking the above assumptions, we construct a mathematical model of the mass transfer in the inner and middle quasi layers of the particle, as well as in the quasi layers in direct contact with the solvent. It is known that in the quasi layers of the leaves of the mint plant, the substance passes through the molecular diffusion to the surface in contact with the solvent.

Equation of material equilibrium in the middle quasi layer of a particle:

$$\frac{dM_{max3}}{dt} = G_{qk3} - G_{surf3} \quad (3)$$

Here $G_{qk3}$ is the arrival of a valuable component in the quasi-layer of the leaf particle of the mint plant (m$^3$/s); $G_{surf3}$ is the consumption of the valuable component through the quasi-layer of the mint particle, (m$^3$/s).

It is known that the amount of $M_{max3}$ valuable component passing through the middle quasi-layer to the outer layer is equal to the product of the amount of $M_{qk3}$ solution passing through this layer to the concentration of the valuable component in this layer $a_{max3}$:

$$M_{max3} = M_{qk3} \cdot a_{max3} \quad (4)$$

In this case:

$$\frac{d(M_{qk3} - a_{qk3})}{dt} = G_{qk3} - G_{surf3} \quad (5)$$

The following is an analysis of a mathematical expression describing a change in the concentration of a valuable component in a solution:

$$\frac{da_{3}}{dt} = \frac{1}{m_{3}} \cdot (G_{qk3} - G_{surf3}) \quad (6)$$

The results of experiments conducted on a computer model of the process of extraction of extractive substances from mint analyzed the changes in the concentration in the solvent and quasi-layers (Fig. 3). It is known that over time, the concentration of the valuable component from each layer decreases.
As can be seen from Fig. 3, intensive extraction of extractives from the raw material continued for 3000 s from open holes and capillaries. Subsequently, the process proceeded more slowly and approached equilibrium after 8100 s. The nature of the change in diffusion coefficient over time in the study does not contradict modern ideas about the mechanism of obtaining a porous structure from plant raw materials.

**Список литературы:**

ИСПОЛЬЗОВАНИЕ ФОСФОГИПСОВ В СИЛИКАТАХ

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ABSTRACT

Today, as in the rest of the world, our country needs to use waste as secondary raw material. Of course, this is due to the growing demographics and the declining supply of ore-rich raw materials. In this era of trends, finding helpful solutions for the use of phosphogypsum and its introduction into the industry is always relevant. Here are some results of this problem and discuss the possibilities of using world experience.

АННОТАЦИЯ.

Сегодня, как и во всем мире, наша страна нуждается в использовании отходов в качестве вторичного сырья. Это, конечно, связано с ростом демографии и сокращением поставок богатого рудой сырья. В эту эпоху тенденций поиск эффективных решений по использованию фосфогипса и внедрение его в промышленность всегда актуальны. Приведем некоторые решения этой проблемы и обсудим возможности использования мирового опыта.

Keywords: phosphoric acid, wet process, phosphogypsum, compost, ceramic filler.

Ключевые слова: фосфатная кислота, мокрый способ, фосфогипс, компостирование, керамический наполнитель.

Phosphoric acid (H₃PO₄) is produced from phosphate ores by wet or thermal methods. The world’s 80% of phosphoric acid obtained by the wet process. The wet method involves chemical reactions, filtration, and evaporation (increasing the concentration). The phosphate rock is first ground and mixed with sulfuric acid in a reactor vessel. As a result of the reaction, tricalcium phosphate of the phosphate rock convert into phosphoric acid and an insoluble salt called gypsum, calcium sulfate (CaSO₄).

\[
\text{Ca}_3(\text{PO}_4)_2\text{F} + 5\text{H}_2\text{SO}_4 + n\text{H}_2\text{O} = 5\text{CaSO}_4\text{nH}_2\text{O} + 3\text{H}_3\text{PO}_4 + HF↑
\]

Keeping the concentration of sulfuric acid at 93-98% affects the reaction rate and crystallization of gypsum. In addition, controlling the concentration of sulfuric acid reduces the energy demand for evaporation and ensures optimal production.

The next step is filtration, in which solids are separated and washed. Finally, the extract is evaporated to obtain commercial phosphoric acid. High levels of phosphoric acid used in the food, pharmaceutical, and cosmetic industries will need to be refined [1]. The production of phosphoric acid from natural phosphate rock by the wet method results in an industrial by-product called phosphogypsum (PG). The production of one ton of phosphoric acid produces about 5 tons of PG and provides an increase in PG reserves worldwide of 100-280 million tons per year. This additional product is disposed of without any processing, mainly by disposing of large stocks. These areas are usually located in areas close to phosphate acid plants, which occupy large areas of land and cause serious damage to the environment. Phosphogypsum is mainly composed of gypsum, but also contains high levels of compounds such as phosphates, fluorides and sulfates, natural radionuclides, heavy metals, and other trace elements. All this hurts the environment and places many restrictions on the widespread use of PG. Up to 15% of PG in the world is used as additional raw material in the production of building materials, soil modification, and the production of Portland cement (Table 1). In particular, the use of PG is prohibited in many countries. The US Environmental Protection Agency classifies PG as a “Technologically Enhanced Naturally Occurring Radioactive Material” [2].

Radioactive substances found in nature are found everywhere throughout the earth's crust; mining, ore processing, fuel extraction, and other industries. The presence of radioactivity in the waste increases the risk of human exposure. The chemical industry can emit large amounts of radioactive substances into the environment, which leads to the spread of radiation. These industries include mining, phosphate processing, metal ore processing, heavy mineral sand processing, pigment production, fuel extraction and combustion, construction materials, thorium compounds production, aviation, and scrap metal processing [3].
In many coastal countries, industrial by-products are located along the coast, resulting in marine changes. Phosphogypsum is also a solid by-product formed in the production of phosphoric acid using similar traditional synthesis methods. Dissolution of raw phosphorite, which is about 50 times more radioactive than ordinary soils, in dilute sulfuric acid produces the primary product, phosphoric acid, and additional phosphogypsum. Reactive hazardous elements and natural radionuclides bind to PG. An insignificant portion of PG is in the form of nanoparticles (<0.1 μm). However, PG is a harmful by-product in many countries [5].

Due to the high content of phosphate, sulfate, and calcium in phosphogypsum, there have been several attempts to change it from soil to soil. In particular, PG was used in composting. Composts are produced by mixing olive oil and coffee bean waste into PG. Two concentrations of PG were tested, and composts formed after fermentation were used in field experiments to grow potatoes. The plants were grown in the field and composts were added as fertilizer and compared to commercial compost and cattle manure. Yields of potatoes grown in composts with the addition of phosphogypsum increased by 55.17% and were recommended for use in the production of high-quality food products [6].

There are also opportunities to use PG in the production of environmentally friendly non-combustible ceramic wall tiles. In particular, the possibility of using phosphogypsum as a binder in ceramic tiles is given below. To increase the bending strength of the slab, glass fibers were added in conjunction with PG and the experimental inspection determined the optimal amount of water, fiber content, compression pressure, and compression number. Using an intermittent pressurized hydration process, phosphogypsum and fiberglass-based non-combustible tiles were produced for optimal ratios. The mechanical and durability properties of the phosphogypsum and fiberglass coated tile were tested. The main component of PG is CaSO$_4$ · 2H$_2$O, which is well compatible with glass fiber in the hydration process. Phosphogypsum and fiberglass-based tiles have also been found to be slightly more acid-resistant than traditional tiles. [7].

In addition to the above, PG can be used as additional raw material and filler in many other areas. Examples, the use of phosphogypsum to improve the sorption capacity of ceramic composites, the use of clay as a binder, and the use of ceramic glass [8].

In short, the efficient and economical use of industrial waste is a task of economic and social importance. At present, the use or recycling of phosphogypsum remains a problem for new or existing chemical plants. Although a lot of scientific research has been done in the field of complex processing of raw materials and some achievements have been made, the problem of using phosphogypsum is still on the agenda. Many world experiments using PG have been discussed and analyzed above, and the results have been presented. Of course, it is not possible to use them 100%, but it is advisable to apply them to the development of the most effective solutions.

References:


PRODUCTION OF POLYETHYLENE TEREPHTHALATE

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ABSTRACT

The article analyzes the methods of obtaining polyethylene terephthalate from petroleum and coke chemical processing products, which play a leading role in the creation of a new generation of polymer materials in the polymer industry.

The chemistry and technology of polymeric materials is an important technology of modern development, and the possibility of obtaining new properties of materials based on a given combination of known polymers is very important.

Today, in the polymer industry, the creation of a new generation of polymer materials based on the achievements of innovative technologies in world practice is leading.
Figure 1. General connection scheme for PETP

PETP production raw materials

The main raw materials for the production of PETP are terephthalic acid and ethylene glycol. They are derived from petroleum and coke chemical products.

Terephthalic acid is a crystalline substance that is less soluble in water and organic liquids than dicarboxylic acids (phthalic acid and isophthalic acid), which are isomers to it.

Terephthalic acid is oxidized to \(\text{p-xylene}\). P-xylene is obtained by catalytic reforming of the gasoline fraction. Oxidation of P-xylene is carried out in air in a solution of acetic acid at a pressure of 125–275°C and up to 40 atm in the presence of catalysts (cobalt and manganese acetates) and promoters (bromine, mainly sodium bromide-containing compounds). The solvent in this case is actively involved in the oxidation process. Acetic acid activates oxygen, shortens the induction period and increases the rate of formation and decomposition of hydroperoxides.

Changes in the oxidation of p-xylene occur in the following sequence (Figure 2): p-xylene 1 → p-toluene acid 2 → p-toluene acid 3 → p-carboxybenzaldehyde 4 → p-benzodicarboxylic acid (TPA)

<table>
<thead>
<tr>
<th>CH₃</th>
<th>CH₃</th>
<th>CH₃</th>
<th>CHO</th>
<th>COOH</th>
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<tr>
<td>CH₃</td>
<td>CHO</td>
<td>COOH</td>
<td>COOH</td>
<td>TPA</td>
</tr>
</tbody>
</table>

Figure 2. Sequence of changes in the oxidation of p-xylene

Ethylene glycol is a hygroscopic, odorless liquid with a clear colorless light oily consistency when purified. It mixes with water, various alcohols, acetone, glycerin in different proportions, is insoluble in aromatic hydrocarbons, chloroform, carbon sulfide.

Direct oxidation of ethylene glycol with air or pure oxygen in a silver catalyst to ethylene oxide, followed by hydration of ethylene oxide at 10 atm and in the presence of 0.1-0.5% sulfuric and orthophosphate acids is obtained by. (Figure 3)
Hydration is carried out with a large amount of excess water to minimize the formation of other glycols. When the reaction is carried out within 1 hour, the yield of ethylene glycol reaches ~ 90%.

Small amounts of diethylene glycol and isophthalic acid are used as modifiers in the esterification and pre-polycondensation stages of PETP to form specific properties [1].

Diethylene glycol (DEG) gives polyester its elasticity and clarity properties. Isophthalic acid (IPA) prevents premature crystallization when blowing products from preforms, which reduces the breakdown of items from cracking.

The general formula of the modified PETF is shown in figure 4.

Properties of preparation of TPA suspension in ethylene glycol

In ethylene glycol, the TPA suspension is prepared in a molar ratio of EG: TFK 1: 1 to 2: 1. For convenience, we denote the ratio of goods by the Latin letter f. For example, when f = 2, 2 moles of ethylene glycol in suspension with a concentration of TFK of 57.23% (Table 1).

Table 1.

Characteristics of TPA suspensions in ethylene glycol

<table>
<thead>
<tr>
<th>EG: TFK mole ratios *</th>
<th>f</th>
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<th>Density 20°C</th>
<th>Carboxylic number, mg-eq / kg</th>
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<td></td>
<td></td>
<td>TPA</td>
<td>ethyleneglycol</td>
<td></td>
</tr>
<tr>
<td>1 : 1</td>
<td>1</td>
<td>72,80</td>
<td>27,20</td>
<td>1,3775</td>
</tr>
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<td>70,87</td>
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<td>1,2</td>
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<td>1,3535</td>
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<td>1,4</td>
<td>65,66</td>
<td>34,34</td>
<td>1,3465</td>
</tr>
<tr>
<td>1,5 : 1</td>
<td>1,5</td>
<td>64,08</td>
<td>35,92</td>
<td>1,3398</td>
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<td>1,6 : 1</td>
<td>1,6</td>
<td>62,59</td>
<td>37,41</td>
<td>1,3336</td>
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<tr>
<td>1,7 : 1</td>
<td>1,7</td>
<td>61,16</td>
<td>38,84</td>
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<td>1,8 : 1</td>
<td>1,8</td>
<td>59,79</td>
<td>40,21</td>
<td>1,3220</td>
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<tr>
<td>1,9 : 1</td>
<td>1,9</td>
<td>58,49</td>
<td>41,51</td>
<td>1,3167</td>
</tr>
<tr>
<td>2 : 1</td>
<td>2</td>
<td>57,23</td>
<td>42,77</td>
<td>1,3116</td>
</tr>
</tbody>
</table>
During preparation, the density of the suspension is calculated according to the formula:

\[ C_{sp} = \left( \frac{C_j \cdot C_t}{ct - C_m \cdot Dc} \right) \]

Here:
- \( C_j \) is the density of the liquid, kg/m\(^3\);
- \( C_{sp} \) - suspension density, kg/m\(^3\);
- \( Dc \) - space density difference, kg/m\(^3\);
- \( C_t \) - solid phase density, kg/m\(^3\);
- \( C_m \) is the percentage of solid phase in the suspension.

\( f=2 \) The suspension retains its fluidity and can be driven by special pumps. Other ratios \( f = 1.3–1.6 \) can also be used. Such suspensions, which retain a large amount of solid phase at low internal friction stresses, do not leak, only change their shape. When the internal friction force is higher than a certain value, the suspension starts to flow.

Suspensions that retain large amounts of solid phase are structured over time. The structuring process is caused by the presence of TPA microparticles in the chain, which in turn form spatial three-dimensional networks (networks). The higher the solid phase concentration, the smaller the network cell and the stronger the network as a whole. In the cells there is a liquid phase - ethylene glycol between the particles (network nodes). If such a suspension is constantly stirred, it will have the appearance of a viscous liquid. If mixing is stopped, the suspension will not flow for some time due to the internal structure of the solid phase particles. If this happens in a large-capacity device, it can still be mixed. In practice, the drive reducer often breaks when the agitator is started.

Heating this suspension reduces the likelihood of structuring and makes it easier to mix and blend and drive.

Suspensions are often thixotropic fluids.

These fluids are fluids whose shear stress decreases over time at constant rates of deformation. Thixotropic fluids are able to restore their structure after removing the external force that causes leakage.

In practice, the suspension is prepared by mixing TFK with ethylene glycol at 110–160°C and \( f = 1.6–1.8 \). This creates a technological reserve of suspension for 4-5 hours. At the same time, the suspension is stirred continuously and heated to maintain the set temperature.

Heat the suspension initiates the esterification reaction. For example, at 140°C, the suspension begins to lose its fluidity after 3 hours. At 130°C, this process takes much longer, about 12 hours. Under these conditions, the esterification of TPA is shown in figure 5.

\[
\text{C}_3\text{H}_7\text{COOH} + 3\text{HOCH}_2\text{CH}_2\text{OH} \rightarrow \text{C}_3\text{H}_7\text{COOCH}_2\text{CH}_2\text{CH}_2\text{OH} + 3\text{H}_2\text{O}
\]

\[
\text{C}_3\text{H}_7\text{COOH} + \text{HOCH}_2\text{CH}_2\text{OH} \rightarrow \text{C}_3\text{H}_7\text{COOCH}_2\text{CH}_2\text{OH} + \text{HOCH}_2\text{CH}_2\text{OH}
\]

**Figure 5. Esterification of TPA**

\( f<2 \) insufficiency of ethylene glycol relative to the stoichiometric amount leads to incomplete conversion of TPA, i.e., the formation of a mixture of mono- and diglycol esters.

From the above, the following conclusions can be drawn.

1) When preparing a mixture of TPA in EG, a suspension can be formed in the range of values \( f = 1 ÷ 2 \), which exhibits thixotropic fluid properties of non-Newtonian viscous fluid with non-Newtonian viscous fluid properties.

2) At rest, the suspension can be structured and requires external force to disrupt its internal structure to create flexibility.

3) In the preparation of a suspension of TPA in EG, an esterification reaction is initiated at a temperature
of 110 °C and above. This reaction is maintained until the hydrolysis reverse reaction with water is reached to a steady state.

4) When the suspension is kept in a stirred state for a long time, the solid phase does not break down as a result of mechanical action on the TPA particles. The reduction in particle size occurs due to the esterification reaction that occurs on the surface of TPA crystals, which results in a reduction in their size.

5) The processes that take place during the preparation of the suspension of TPA in EG do not lead to a defective product (waste) in the later stages of production.

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MECHANISMS OF ETERIFICATION OF TEREFTALIC ACID WITH ETYLENGLYCOL

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ABSTRACT

The article presents the mechanisms of the reaction of esterification of terephthalic acid with ethylene glycol, the effects of the chemical structure of the catalyst on the rate constant of the esterification reaction, and the analysis of changes in the number of unresponsive groups during esterification using different catalysts.

АННОТАЦИЯ

В статье описаны механизмы реакции этерификации терефталевой кислоты этиленгликolem, влияние химического строения катализатора на константу скорости реакции этерификации, а также анализ изменения количества нереагирующих групп при этерификации с использованием различных катализаторов.

Keywords: polyethylene terephthalate (PETP, PET), terephthalic acid (TPA), ethyleneglycol (EG), esterification, tetrabutoxytitanium, lead dibutyl phthalate, nucleophilic component, sulfuric acid.

Analyzing the esterification reaction of terephthalic acid with ethylene glycol (Figure 1).

Etherification processes are usually carried out in the presence of catalysts. In practice, acid catalysts (sulfuric acid, p-toluene sulfoxic acid, etc.) and amphoteric catalysts (tetrabutoxytitanate, lead dibutylphthalate, etc.) are used. Sometimes the process is done without a catalyst.

The catalytic activity of strong acids is very large. When used, the reaction rate increases by more than 30 times. This can be seen in the example of the values of the rate constants of the reaction of esterification of TPA with diol in their presence. Table 1 shows the effect of the chemical structure of the catalyst on the rate constant of the esterification reaction.

Table 1. The effect of the chemical structure of the catalyst on the rate constant of the esterification reaction

<table>
<thead>
<tr>
<th>Catalyst</th>
<th>Reaction rate constant $c \times 10^8$ g – equiv / (g s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Without catalysts</td>
<td>7,8</td>
</tr>
<tr>
<td>Sulfuric acid</td>
<td>263,0</td>
</tr>
<tr>
<td>Antimony acid</td>
<td>25,6</td>
</tr>
<tr>
<td>Tetrabutoxytitanate</td>
<td>30,2</td>
</tr>
<tr>
<td>Lead dibutyl phthalate</td>
<td>22,6</td>
</tr>
</tbody>
</table>

However, when strong acids are used in practice as catalysts, they complicate the process due to their simultaneous catalytic acceleration of additional reactions and their interaction with the initial and final products. For example, sulfuric acid sulfates the products of the reaction at high temperatures. Similarly, it catalyzes the intermolecular dehydration reaction of ethylene glycol, resulting in an unacceptable amount of diethylene glycol of 3-5%. Large amounts of 1,4-dioxane were found in the by-products of the reaction.

On fig. 2 is a graphical representation of the number of unreacted carboxyl groups as a function of the catalyst used.
When the temperature rises above 230 °C, the reaction rate rises to such an extent that it can be carried out without an external catalyst, but with a rapid release of water.

To synthesize PETP, TPA undergoes a reaction to obtain diglycol ester without an external catalyst. In this case, the role of the catalyst is played by the ion pair - TPA dimer, which is formed by autoprolysis of TPA.

The reaction mechanism is shown in fig. 3 and is in good agreement with classical ideas about the process of esterification of carboxylic acids with alcohols.
Due to autoprolysis, the protonation of the oxygen atom of the carbonyl group of TPA 1 occurs. The protonated molecule carrying the positive charge then undergoes a polycondensation reaction with 1 EG. In the scheme, the structures (1,2,3,4,5 and 6,7,9,10) interconnected by a sharp arrow on both sides are considered saturated. Their rate of transition is so great that they can be detected spectroscopically as if they existed at the same time. However, only carbocation (electrophilic) 2 and 7 are attacked by the nucleophilic component (EG). The resulting structure redirects the proton within 5 molecules, along with the positive charge, to the carbony oxygen atom of the empty carbonyl group. A protonated molecule of the second carbonyl group of TPA monoglycol ester 6 (7) is formed, which interacts with the next molecule of EG. The esterification process continues until the formation of diglycol ester of TPA 11.

In order to reach the end of the reaction, water must be expelled from the reaction area, if no water is expelled, an equilibrium state is created and the reaction stops before it reaches the end. The release of water accelerates the reaction and shifts the equilibrium towards the formation of TPA esters.

The esterification is carried out using a continuous method by delivering a suspension of TPA in the EG to the reaction area and bringing the esterification to the polycondensation stage. The process is so rapid that the TPA suspension has almost complete reaction from the point of its introduction into the reactor until the reaction mass is removed from the apparatus circulation circuit. (that is, the TPA does not remain in the etheric).

Reference:
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ANALYSIS OF IMPORTANCE AND METHODS OF PRODUCTION OF BLOCK SOPOLYMERS BASED ON POLYETYLENTEREPHTALATE

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ABSTRACT

The article analyzes the importance and methods of obtaining polyethylene terephthalate-based copolymers, which play a leading role in the creation of a new generation of polymer materials with properties based on the achievements of innovative technologies in the polymer industry.

Key words: block copolymerization, copolyesters, antipyrenes, modifiers, hydroquinone, terephthalic acid, exchange bisphenols, polyethylene terephthalate

Today in the polymer industry in the world practice is the creation of a new generation of polymer materials with properties based on the achievements of innovative technologies.

The chemistry and technology of polymeric materials is an important technology of modern development, the search for the possibility of obtaining new properties of materials based on a given binding of certain polymers.

One of the interesting ways in this direction is the creation of block copolymers, the macromolecules of which are hybrids of blocks with different chemical structure and composition. The thermodynamic incompatibility of the blocks often leads to a solid microphase layering, which eventually allows the properties of the block-copolymers to combine in an odd way.

Depending on the chemical nature of the blocks, it is possible to obtain structural and properties materials that differ significantly from the properties of the original component, depending on their length, number and sequence of exchange. There is a great potential for this, and they are beginning to be realized. The most typical is the creation of thermoeleastoplasts large-toned polymeric materials, the application of the principles of block-copolymerization in their synthesis allowed to combine the properties of thermoplastics and elastomers in one material. The great potential of block copolymers...
has led to a sharp increase in interest in them in recent years.

At present, all the main problems of polymer physics and physical chemistry in the field of block copolymer testing - the nature of polymer sequencing, phase separation properties in polymers and the influence of basic molecular parameters, phase strength under temperature and force, physical and mechanical properties of microphases and their role in these properties, being investigated.

There are some limitations and unresolved issues in the field of synthesis, analysis, properties description and application of block copolymers. This provides a good incentive for intensive inspections, research and development of relevant industries.

The following three methods are the most preferred methods for the synthesis of block copolymers:

The first method uses polymerization by the addition of monomers one after the other on the mechanism of “living” chains.

The second method is based on the interaction of two initially derived oligomers with functional groups at the end.

The third path is the polycondensation of the second block at the expense of the group at the end of the initially obtained block of the first monomer.

The second and third methods allow the use of a large variety of chemical structures.

Thus, a large number of reactions can be used to obtain block copolymers by attaching loops (cycles) or binding to the macromolecule the blocks synthesized by polycondensation methods due to their opening.

Morphological studies have now been performed on block copolymers that retain two blocks A and B, which differ in nature. For a three-block copolymer that retains three different incompatible block (ABS) n, the manifestation of relatively new morphological structures can be expected, with very little information about such copolymers in the literature.

Simple and complex aromatic polyesters, polycarbonates and polyaerylene ketones have high physical-mechanical and dielectric properties as well as high thermal stability, which is a complex of properties of a number of valuable properties.

Due to the importance of the problem of creating thermogenerated polymers with high flame - and heat tolerance combined with good physical - mechanical properties for various fields of technology, to determine the relationships between composition and properties is important from a scientific and practical point of view.

The synthesis of copolymers and block-copolymers to improve the basic physical-mechanical strength and processability of polymers, in particular, was carried out through the formation stage of oligomers with functional groups that are finally reactive.

As a result of the work, oligomers of different chemical structures - oligosulfon, oligoacetone, oligosulfonate, oligoformals were synthesized and on their basis new aromatic copolymers and block copolymers were obtained.

The obtained ceramic- and block-copolyefirsulfone ketones and polyacrylates based on dichlorohydrides of phthalic acids and 3.5- dibromo-p-oxbenzoic acid chlorohydride and terephthaloid (p-oxbenzoic) acid groups have high mechanical and dielectric properties, high chemical and dielectric properties. In the synthesis of the mentioned polymers, the acceptor catalytic method of polycondensation and the laws of high-temperature polycondensation were studied, the laws between the structure, composition and properties of the obtained polyesters were determined. The block synthesized within the scope of this research - ceramic polyester and ceramic film can be used in various industries of modern industry (automotive - radio-electronic, electrical aviation, electronic, chemical, etc.) as heat-resistant construction and film materials.

Synthesis of copolymers with polyethylene terephthalate (PETP) and other components of p-oxynbenzoic acid can also be performed. It has been found that when copolymers are introduced into a PETP reaction mixture of a two-phase nature, copolymers with a block structure are formed.

The effect of temperature and heating time and heating rate on the properties of ceramic fibers is considered. The glassing temperature increases with increasing heating time. Much of the work has been devoted to the study of the complex of physical and mechanical properties of liquid crystalline copolymesters based on p-oxynbenzoic acid (p-OBK) and polyethylene terephthalate (PETP).

Up to 75% liquid-crystalline (LC) - pure PETP liquefaction and crystallization have been detected in mixtures containing the component. Copolies that retain less than 30% p-OBK are in the isotropic glassy phase, copolies with a much higher content of the second component are in the liquid crystalline state and are characterized by greater dielectric constant than the glassy state. This difference is due to the presence of different orientation distributions on the copolymesters relative to the electric field direction of the main chains in different structural states. Infrared spectral data show that the components of the mixture interact due to the re-esterification reaction in the liquid. An increase in pressure slows down the reaction between its components, reducing the free volume and mobility in the mixture.

In the study, p - OBK / PETP and their mixtures with isotactic polypropylene (PP), polymethyl methacrylate (PMMA), polysulfate, polyethylene - 2,6 - naphthalate (PEN), p - oxynbenzoic acid and 6,2 - oxynaphthoic acid (ONA) copolyester Investigation of the properties of SK based solopholor is underway. The following properties of mixtures with P - OBK / PETP SK – copolymer of PP were expressed by measured-specific volume, coefficient of thermal expansion a (alpha) and compressibility b (betta). High pressure has been found to cause sorting in PP fluid. In the field of liquefaction and crystallization temperatures of PP, an increase in the coefficient of thermal expansion and compressibility for all components of the mixture (100 - 25% PP) was found, with a slight change in these parameters for the SK - copolyester. An increase in the amount of SK-polymer in the mixture significantly reduces the coefficient of thermal expansion, both in its solid state and in the liquid state of PP, which must be taken into account when processing.
the mixture into a product. In a mixture with polysulfon, the SK component is grouped in the form of concentric cylinders of different radii. Under such conditions, it remains responsible for the viscosity properties of the mixtures.

Piezoelectrics were obtained from p-OBK / PETP and p-OBK / ONA-based SK-polymer. 6, 2 - The temperature range of the time stability and performance of piezoelectrics from oxynaphthoic acid-based polymer is higher than that of PETF-based polymer. Table 1 shows the brands of PETF and p OBK-based ceramic fibers produced in the United States.

### Table 1.

<table>
<thead>
<tr>
<th>Company</th>
<th>Country</th>
<th>Trade name</th>
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<tr>
<td>Eastman Kodak Co</td>
<td>United States</td>
<td>Vectron</td>
</tr>
<tr>
<td></td>
<td></td>
<td>LCC - 10108</td>
</tr>
<tr>
<td></td>
<td></td>
<td>LCC - 10109</td>
</tr>
</tbody>
</table>

It was found that the use of 30% p-OBK / PETP SK copolifier results in a 110% increase in the 30% solubility modulus of PMAA strength, without compromising its recyclability.

The structure and properties of various SK ceramic polyesters are being investigated in the works. For example, copolymers based on p-oxybenzoic acid (p-OBK), polyethylene terephthalate, hydroquinone and terephthalic acid are being studied. The addition of a mixture of hydroquinone and terephthalic acid accelerates crystallization and increases the degree of crystallization of polyesters.

In the study of the flow curves of homogeneous and heterogeneous liquids of PETP and acitoxybenzoic acid-based copolifers, it was confirmed that there are two structural areas of copolifier liquids. At low temperatures, there are highly liquefied crystals in the nematic phase, and at high temperatures, where a homogeneous nematic liquid is formed. SK - fluid flow curves are typical for viscous plastic systems, however, the tendency to have a flow limit increases with increasing molecular mass and decreasing temperature. Extrudates formed from homogeneous liquefaction have much higher values of molecular orientation and strength than extrudates formed from heterogeneous liquefaction. The effect of highly liquefied crystallites on the orientation process of the structure and the decrease in the strength of the exudates increases with increasing proportion of the mesogen fragment in the chain.

Examination of the structure of p-OBK / PETP and m atestoxibenzoic acid-based SK-copolymers by IQ, YaMPN and X-ray diffraction methods at wide angles showed that the degree of orientation in copolymers increases when the amount of p-oxybenzoic units increases from 60 to 75%.

Under the harsh conditions of operation of polymers in the presence of the effect of open flame, oxygen, high temperatures, polymer materials are required to maintain their shape and size under the influence of high fire resistance and high temperature heat fluxes. Extensive research is being conducted on the synthesis of aromatic polyesters with high fire resistance and modification of existing samples of this type of polymer based on the requirements for polymer materials. Currently, the most widely used methods of reducing flammability are:

- Laying fire protection coatings;
- Add fillers;
- Oriented synthesis of polymers;
- Introduction of flame retardants;
- Chemical modification.

A common, technologically easy way to increase the fire resistance of polymers is their chemical modification, which can be carried out directly in the process of copolymerization with a synthetic reactive modifier, for example: exchange of bisphenols, various acids, other oxybrids and reaction of the obtained polymer, by modification during mechanical chemical treatment with additives capable of or during the processing of the polymer liquid.

The most optimal methods of modification of aromatic polyesters in order to obtain high-strength self-extinguishing materials under the influence of aggressive environments are condensing them from halogen-retaining monomers, as well as combining aromatic polyesters with halogen-containing compounds and using halogen-containing sewing agents.

Various compounds (aromatic and aliphatic) are used as modifiers. They inhibit combustion processes and can not only give polymers some new properties, but also improve their physical properties.

Reference:
ДЛЯ ЗАМЕТОК