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CONTENTS

ENGINEERING MATERIALS BASED ON MODIFIED INDUSTRIAL THERMOPLASTICS

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Abstract. The mechanisms of formation of the structure of polymer blends with different thermodynamic compatibility of components are considered. A synergistic effect was obtained to increase the parameters of performance characteristics and resistance to thermal-oxidative degradation during the formation of products and functional coatings from industrial polymer blends through the use of plasticizers that increase the segmental mobility of macromolecules in the temperature range of formation of the product and coating, and low-dimensional (including nano-sized) particles of various compositions , structure and production technology, acting as a physical compatibilizer. Nanocomposite materials based on thermoplastics blends have been developed for the manufacture of products and coatings used in the construction of automobile components, technological tool, belt conveyor, fastening elements, elements of road and construction structures.
Keywords: polymer blends, composite material, composite structure, physical compatibilizer, functional coating.

Introduction. Modern mechanical engineering is characterized by an increase in the proportion of functional materials based on industrially produced polymeric and oligomeric binders due to the developed technologies for modifying their structure in order to achieve optimal parameters of stress-strain, tribological, adhesive, etc. characteristics and effective methods of their production and processing into products [1].

Currently, there are a number of effective directions for managing the parameters of the structural characteristics of industrial binders by introducing functional fillers and components into their composition that affect the mechanisms of formation of supramolecular structures, the mechanisms of intermolecular interaction, the kinetics of the course of thermo-oxidative and destructive processes, etc. in the static and dynamic interaction of products made of functional materials with a metal coupled element [1, 2]. At the same time, the development of machine-building production, the improvement of the service system of operated equipment, increased attention to the impact of polymer composites in their production, processing into products and their operation on environmental components put forward new tasks to improve the technology of functional materials based on polymer and oligomeric matrices.

In the applied areas of mechanical engineering, a special place is occupied by composite materials based on blends of industrially produced materials, which have a developed base for their production and processing, which significantly reduces the cost of manufacturing and operating functional products.

The purpose of this work was to study the main directions of formation of functional materials with high performance characteristics based on industrially produced thermoplastics.

Research methodology. Industrially produced thermoplastic polymers of the class of polyamides (PA 6, PA 6.6, PA 11, PA 12), polyolefins (HDPE, LDPE, PP), polyacetals (copolymer of formaldehyde and 1,3-dioxolane (FDO), polyoxymethylene (POM)), polyesters (PET, PBTF), thermoplastic elastomers (thermoplastic polyurethane (TPU), ethylene-vinyl acetate (EVA) copolymer, divinyl styrene thermoplastic elastomer (DST), microcellular polyesterurethane (MPEU)) produced by Belarus enterprises (Filial "Plant Khimvolokno" JSC "Grodno Azot", Plant "Polymir" JSC "Naftan", JSC "Mogilevkhimvolokno") or Russian and Uzbekistan enterprises were selected for research.

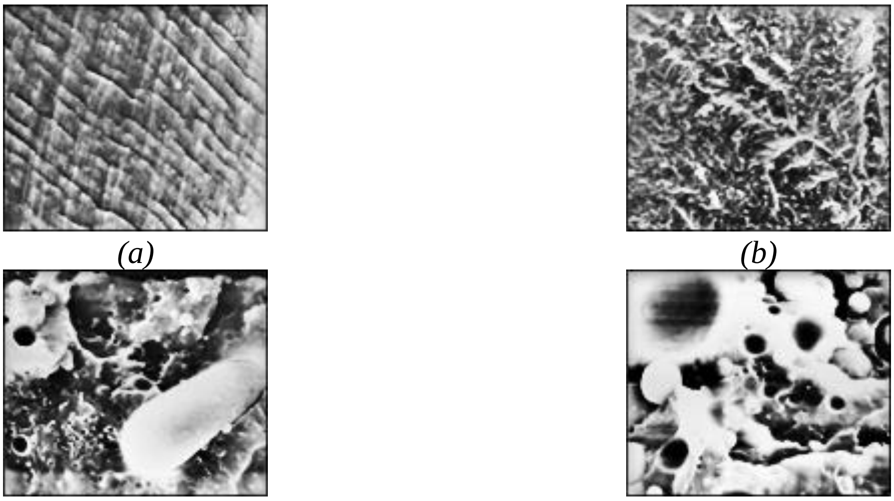
To modify the basic polymers (matrix binders), a developed injection molding technology was used, which is most widely used in mechanical engineering to obtain functional products.

As modifiers of matrix binders, both thermoplastic compounds and dispersed particles of carbon-containing (ultradispersed detonation diamond (UDD), thermally expanded graphite (TEG), colloidal graphite C-1), metal-containing (Cu, Zn, Ni), silicon-containing (clay) components were used.

Analysis of the thermophysical parameters of composite materials was carried out by the DTA method on the Thermoscan-2. The study of the structural features of the materials obtained was carried out by IR spectroscopy (IR Fourier microscope Nicolet iN 10), atomic force microscopy (atomic force microscope NT-206), scanning electron microscopy (SEM microscope JEOL JSM-5610 LV with electron-probe energy dispersion X-ray microanalyzer EDX JED-2201). The parameters of the stress-strain characteristics of composites were evaluated on standard samples according to generally accepted methods.

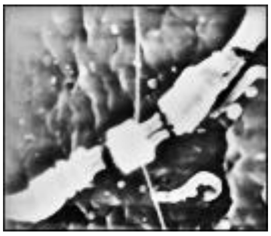
Results and discussion. In the formation of the structure of composite materials based on the blends of thermoplastic components, the most significant contribution is made by the parameters of the molecular structure and mass, which determine the thermophysical, stress-strain and rheological characteristics of the matrix and modifying polymer, which form the basis of their thermodynamic compatibility.

When combining components with a similar structure of the molecular chain and a molecular weight of the same order, the rheological characteristics of the matrix and modifying polymer are of decisive importance in the formation of the structure of the composite with the necessary and sufficiently stable parameters of performance characteristics. The difference in viscosity leads to the formation of a heterophase structure of various types. When a high-viscosity polymer (FDO, DST, TPU, HDPE, ABS) is introduced into a low-viscosity (PA 6, PP), a heterogeneous structure is formed with a pronounced separation of the phases of the alloying component in the matrix binder [2]. Dispersed fragments of the modifier melt under the action of shear stresses during rotation of the mixer screw are distributed in a low-viscosity matrix with formation of a characteristic structure. With such a combination, the formation of interfacial layers at the boundary of the "matrix – modifier" section is fragmentary in nature and does not determine the values of the performance characteristics (tensile strength σ_{uts}, impact strength α, compressive strength σ_c) (Fig. 1).



(a) *(b)*

(c) *(d)*



(e)

(f)

Figure 1. Characteristic type of chips in liquid nitrogen (a–d) and fracture surfaces after uniaxial stretching (e, f) of samples from PA 6 (a), FDO (b), compositions PA 6 + 5 wt. % FDO (c, e) and PA 6+50 wt. % FDO (d, f). 100×

Dispersed fragments of a modifying polymer with a size of 10–150 μm perform the function of a reinforcing (FDO, ABS) or structural modifier that reduces residual stresses in a composite sample due to pronounced chain flexibility and a lower melting point (TPU, DST, HDPE). The degree of dispersion of the alloying polymer in the matrix polymer is determined mainly by the mixing parameters (temperature, time, intensity (speed) of the screw movement) and the ratio of the components. At the ratios of matrix polymer : modifier 1 : 0.01–0.10, a fairly homogeneous heterophase structure is formed with high parameters of performance characteristics (Fig. 2) [2].

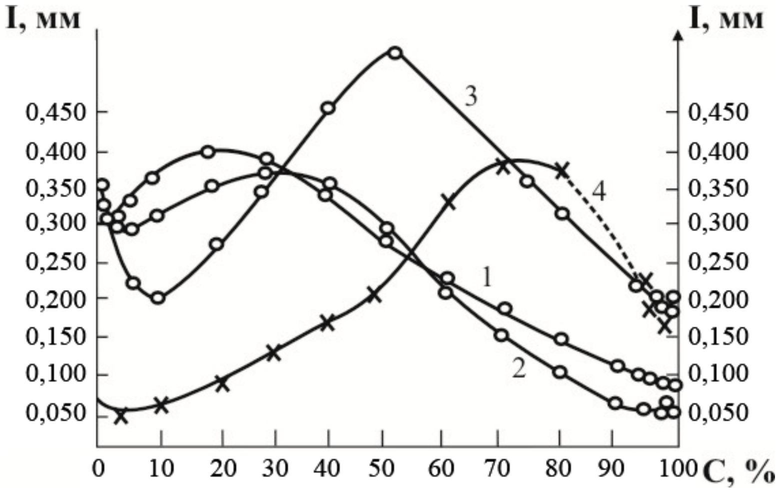


Figure 2. Dependence of the wear intensity of FDO (1–3) and PA 6 (1) on the content of MPEU (1), TPU (2) and DST (3, 4)

The content of the phase formed by the mechanochemical interaction of the components with the formation of a copolymer product is insignificant. Nevertheless, there was an increase in the parameters of the thermophysical characteristics of mixed composites of this type (activation energy $E_{act.}$, heat resistance, resistance to thermal oxidative destruction) due to the destruction of weak areas of macromolecules in the process of thermomechanical action and the formation of copolymer products [2–4].

When a relatively low-viscosity modifier (PA 6, FDO, ABS) is introduced into a highly viscous matrix (TPU, DST, MPEU), a heterophase structure with a high degree of homogeneity is formed, a characteristic feature of which is the formation of modifying elements of various shapes and sizes. Relatively viscous modifiers (ABS, FDO) form fragments in the matrix binder (TPU, DST, MPEU) in the size range of 1–120 μm with pronounced localization (Fig. 3). These fragments, the size of which depends on the ratio of the matrix and alloying components have a predominantly spherical shape, due, obviously, to the correlation of melting points (transition to a viscous-fluid state).

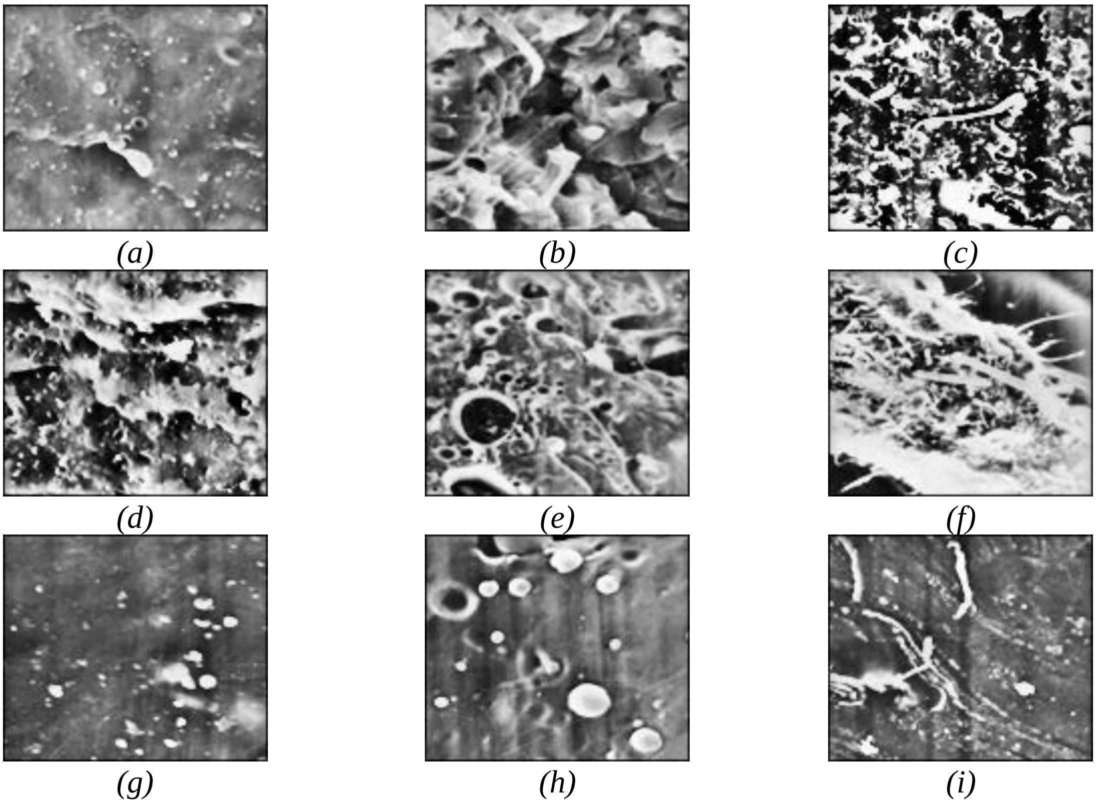


Figure 3. Characteristic appearance of the surface of chips in liquid nitrogen and fracture surfaces after uniaxial stretching of samples based on DST (a, b, c), MPEU (d, e, f), TPU (g, h, i), modified 5 wt. % PA 6 (c), 5 wt. % FDO (e), 50 wt. % PA 6 (f) and 50 wt. % FDO (h). 100×

In the composite "high-viscosity polymer (DST) – low-viscosity modifier (PA 6)" the formation of alloying component aggregates of a predominantly arbitrary shape is observed, due to the low viscosity of the PA 6 melt and the possibility of its dispersion when combining components in screw mixers. The intensity of thermomechanical action on the mixture DST – PA 6 significantly affects the parameters of stress-strain and thermophysical characteristics [2, 3].

Blends of thermodynamically incompatible polymers PA 6 – FDO, PA 6 – HDPE, PA 6 – DST, TPU – FDO, TPU – ABS, HDPE – ABS, HDPE – FDO in the field of ratios of matrix and alloying components 1 : 0.01–0.10 wt. %. are characterized by a heterophase structure with a sufficiently high macrohomogenicity, which determines the increased values of the parameters of their stress-strain, tribological, adhesive characteristics [2].

Materials can be obtained using common screw mixers without the use of special functional components that regulate compatibility parameters – compatibizers. Thermomechanical combination is intensified by introducing low-molecular plasticizers (petroleum and vegetable oils, tars, etc.) into the composition [2]. With thermomechanical combination of matrix and alloying components with a similar structure of the molecular chain and the value of the molecular weight - aliphatic polyamides (PA 6, PA 6.6, PA 11, PA 12), polyolefins (PP, HDPE, LDPE, EVA), fluoroplastics (polytetrafluoroethylene (PTFE), ultradispersed polytetrafluoroethylene (UPTFE), fluorine-containing oligomers) – a heterophase structure with increased homogeneity is formed. The close structure of the molecular chain, correlating molecular weight values create the prerequisites for the correlation of the rheological characteristics of the melts of the matrix and alloying components.

When the elements of the mixer are exposed to a mixture of melts of the components, they are dispersed to form a structure with a transition layer formed as a result of the interdiffusion of macromolecules with a similar molecular structure and segmental mobility, which provides increased thermodynamic compatibility of the matrix and alloying components with the formation of a three-phase system – "matrix polymer – transition layer – alloying polymer". Such composites are a combination of the copolymer phase formed as a result of the interaction of radical products of thermo- and mechanodestruction, and a mixture of macromolecules formed as a result of the interdiffusion of macromolecules of the matrix and alloying components with similar values of molecular weight, molecular chain structure and segmental mobility. The presence of a transition layer creates the prerequisites for the implementation of the characteristic features of each component in the composite material – stress-strain, thermophysical, energy, adhesive characteristics.

When combining aliphatic polyolefins with various thermophysical parameters (melting point T_m, oxidation temperature T_{ox}, destruction temperature T_d) and a similar molecular structure of polyamides PA 6, PA 6.6 with PA 11, PA 12, it is possible to implement two characteristic features. Alloying of high-melting polyamide (PA 6, PA 6.6) with low-melting (PA 11, PA 12) allows to reduce residual stresses in the sample (or coating) due to the preservation of the liquid-phase state of the alloying component after matrix crystallization. For example, in the system PA 6 (PA 6.6) + PA 11 (PA 12), the crystallization processes of the matrix occur in the temperature range of 180–200 °C while maintaining the melt phase of the alloying component. After reaching a temperature of 140–160 °C, the crystal structure of the composite is cooled, at which the crystalline component of the modifier retains increased deformability, acting as a stabilizer of shrinkage processes that reduces residual stresses in the sample or coating.

The experimentally considered mechanism of influence of a low-melting modifier in the PA 6 (PA 6.6) – PA 11 (PA 12) system is confirmed by an increase in the parameters of the deformation and strength characteristics of the composite compared to the characteristics of the matrix polymer when introduced into the composition of a component with deliberately lower values of parameters σ_{uts}, σ_c, E, tribological and the adhesive characteristics of composite coatings on metal substrates (Tables 1 and 2, Fig. 4) [4].

Table 1

Parameters of stress-strain characteristics of blends based on the aliphatic polyamides (testing for stretching)

Composite material, wt. %	Parameter characteristics				
	σ_m, MPa	ε_m, %	σ_b, MPa	ε_b, %	ε_{fb}, %
PA6.6(94%)+PA6(5%)+PA12(1%)	77,71	4,3	53,4	–	23,60
PA6.6(90%)+PA6(5%)+PA12(5%)	75,58	5,9	49,0	23	20,87

Table 2

Parameters of deformation-strength chemicals of composite materials based on mixtures of aliphatic polyamides (testing for exposure)

Composite material, wt. %	Parameter characteristics				
	σ_m, MPa	ε_m, %	σ_b, MPa	ε_b, %	ε_{fb}, %
PA6,6(84,5%)+PA6(10%)+PA12(5%)+ colloidal graphite C1(0,5%)	78,84	3,9	76,0	3,8	6,3
PA6.6(84.5%)+PA6(10%)+PA12(5%)+ carbon nanotubes (CNT) (0.5%)	54,19	2,1	54,2	2,1	–
PA6,6(84,5%)+PA6(10%)+PA12(5%)+UDD(0.5%)	77,78	3,8	74,1	3,7	12

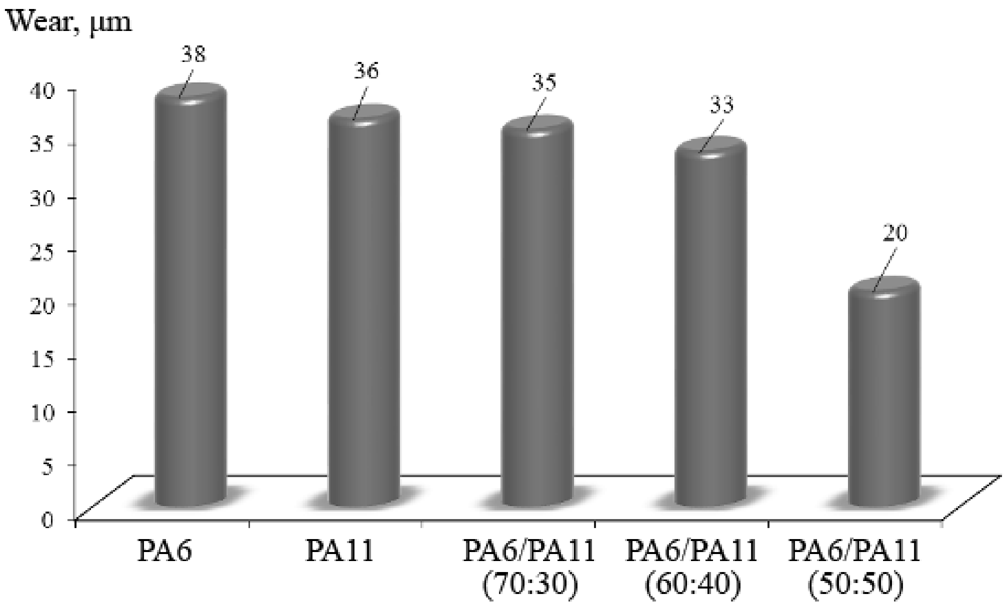


Figure 4. Wear resistance of polyamide coatings under friction without external lubrication

Similar effects were noted for compositions PA 6.6 – PA 6, PP – HDPE, PP – LDPE, HDPE – LDPE [4, 6].

When a high-melting modifier with a close molecular chain structure is introduced into a matrix polymer with a lower melting point due to thermomechanical combination in the range of temperatures exceeding the melting point of the modifier, a system is formed in which the alloying component performs the function of a reinforcing additive. Due to the close values of molecular weight and rheological characteristics, a transition layer is formed in the system, which ensures the compatibility of components and the formation of a heterogeneous structure with increased parameters of stress-strain and tribological characteristics. Composites of LDPE – HDPE, LDPE – PP, HDPE – PP, EVA – PP, PA 6 – PA 6.6, PA 11 (PA 12) – PA 6 (PA 6.6) are superior in parameters to σ_{uts}, σ_c, Brinell hardness *HB* matrix binders due to the reinforcement of components with increased strength. A characteristic feature of such composites is the possibility of forming products not only with thermomechanical combination using screw mixers or injection molding machines with a screw plasticizer, but also coatings for various purposes (protective, decorative, tribological, insulating) by deposition from fluidized bed or gas-thermal spraying [4].

Additional effects in the formation of products and functional coatings from blends of thermodynamically compatible polymers can be achieved by using plasticizers that increase the segmental mobility of macromolecules in the range of temperatures of product formation and coating, and low-dimensional (including nanoscale)) particles of different composition, structure and production technology that change the mechanisms of interphase interactions at the interface of the "matrix – modifier" section due to the formation of physical connections of the adsorption type with the active centers of the matrix and alloying components (Fig. 5) [5].

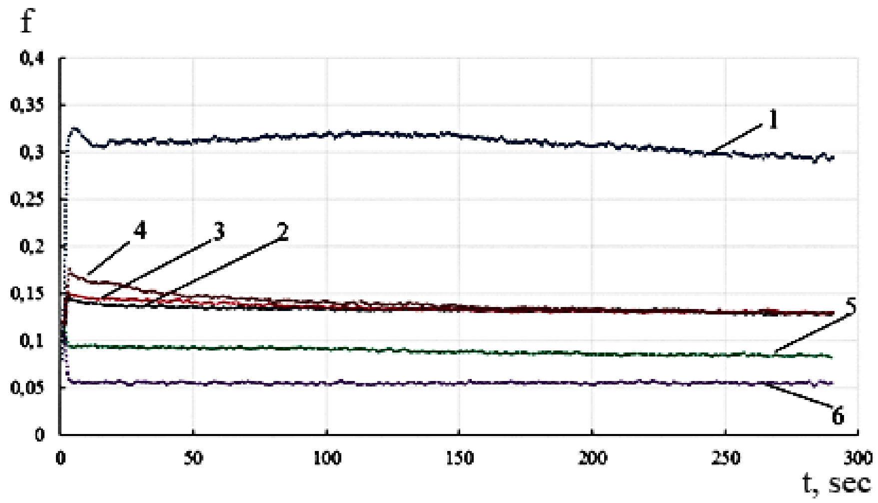


Figure 5. Dependence of the coefficient of friction on the operating time for coatings from composite materials based on aliphatic polyamides:
1 – PA 6; 2 – PA 11; 3 – PA 6/PA 11 (50:50) + 0,1 wt. % C-1;
4 – PA 6/PA 11 (50:50) + 0,5 wt. % C-1;
5 – PA 6/PA 11 (50:50) + 0,1 wt. % CNT;
6 – PA 6/PA 11 (50:50) + 0,5 wt. % CNT

Low-dimensional particles that exhibit nanostration due to size, structure or energy treatment perform the function of regulators of rheological characteristics due to the formation of both intra- and intermolecular bonds, including intermolecular bonds in the boundary layer [4, 5]. This leads not only to an increase in the parameters of deformation and strength characteristics, but also resistance to thermo-oxidizing destruction (Fig. 6).

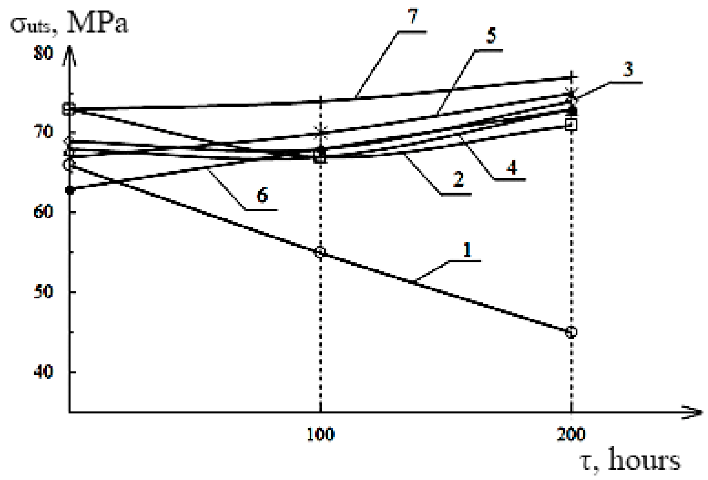


Figure 6. Dependence of the strength dimension at contraction from the thermal oxidation time at 150 °C:
1 – PA 6.6; 2 – PA6.6 (94 wt. %) + PA6 (5 wt. %) + PA12 (1 wt. %);
3 – PA6.6 (90 wt. %) + PA6 (5 wt. %) + PA12 (5 wt. %);
4 – PA6,6 (85 wt. %) + PA6 (10 wt. %) + PA12 (5 wt. %);
5 – PA6.6 (84.5 wt. %) + PA6 (10 wt. %) + PA12 (5 wt. %) + C-1 (0.5 wt. %);
6 – PA6.6 (84.5 wt. %) + PA6 (10 wt. %) + PA12 (5 wt. %) + CNT (0.5 wt. %);
7 – PA6.6 (84.5 t. %) + PA6 (10 wt. %) + PA12 (5 wt. %) + UDD (0.5 wt. %)

At the same time, the energy treatment of the surface layer of the product and dispersed particles makes it possible to realize their special structure, which exhibits characteristic signs of nanostate, which determines the achievement of some specific properties, for example, bactericidality [5], which can be used for the manufacture of special-purpose products.

Conclusion. The proposed methodological approaches to the creation of composite materials with specified parameters of functional characteristics based on industrially produced thermoplastics make it possible to expand the brand range of composites using traditional manufacturing and processing technologies.

The considered aspects of the mechanisms of formation of the structure of composite materials based on polymer mixtures with different thermodynamic compatibility of components made it possible to develop a range of engineering materials for the manufacture of structural and tribological products and coatings used in the construction of automotive components (cardan shafts, brake chambers, automotive shock absorbers), technological equipment (lathe cartridges), belt conveyors for transportation of bulk and lumpy materials (metal-polymer roller supports), fasteners (dowels), elements of road and building structures (marker posts, curbs, elements of floor and ground coverings) [3, 6].

Regulatory legal and technical documentation regulating the processes of manufacturing and processing of composite materials based on polymer blends with different thermodynamic compatibility of components has been developed.

The developed materials based on industrial thermoplastics of domestic production provide the necessary performance parameters of metal-polymer systems for various functional purposes and are a full-fledged alternative to imported analogues.

Acknowledgments. The given research was carried out within the framework of integrated assignment 5.6 "Research of the processes of creation and use of polymer packaging materials to ensure the quality and safety of food products" of R&D "Investigation of the processes of structure formation of thermoplastic nanocomposites for obtaining film semi-finished products with increased parameters of characteristics" included in the subprogram “Food security” of the State programs for scientific research “Agricultural technologies and Food security” in 2021-2025.

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ANALYSIS OF THE AMOUNT OF EXHAUST GASES OF THE ENGINE

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Abstract. This article analyzes the fuel-air mixture, the amount of oxygen in the air, the air-fuel ratio, and the excess air ratio using scientific sources, and calculates solutions. Several methods of calculating the amount of waste gases are presented and compared. At the same time, the methods of calculating exhaust gases were analyzed.
Key words: carbon, hydrogen, molecular masses, oxygen, volume of air, temperature, density, pressure, chemical reaction, complete combustion, air content, air-fuel ratio, air excess coefficient.

INTRODUCTION

Today, along with test methods, the assessment of cars is developing with calculation methods. It is allowed in foreign and state standards and regulations. This article is devoted to the creation of an ecological accounting method. The analysis of existing methods was necessary in creating the accounting method. It shows that the amount, proportion, composition of gases and other things are accepted differently. Why is this accepted? How do they affect the results of the calculation? Studying these things is an urgent issue.

The process of carrying out scientific research works was studied by several literatures. There are many factors that contribute to the development of the method of calculating the environmental pollution of cars. For example, areas such as engine calculation, fuel and air volume, exhaust gas composition, gas trapping or toxicity reduction devices. We divided the sources into small groups: according to the engine calculation method [11], [12]; according to the method of calculation in the evaluation of exhaust gases [6], [7], [9]; according to the account in a special program [10].

The main goal of the research is to identify toxic gases, reduce their damage to the environment, ensure less emissions into the atmosphere, improve the efficiency of use of internal combustion engines and fuels, and ecological classes of fuels [1]. Along with other developed countries, the gradual introduction of the requirements of the EURO-4 standard has started in Uzbekistan. According to the decision of the President "On approval of the concept of environmental protection of the Republic of Uzbekistan until 2030", from January 1, 2022, motor fuel of an ecological class below EURO-3, from January 1, 2023 and from January, it is prohibited to import engine fuel with environmental class lower than EURO-4 [2]. Many calculation and test methods have been developed by scientists and experts.

METHODS OF RESEARCH

Sources of fuel and air mixtures have been considered in the article. The reason is that the calculation of exhaust gases is an indicator related to the amount of fuel, air, and oxygen entering the cylinder directly.

Based on the conducted scientific research, the following accounting methods were compared:
1. In internal combustion engines, the amount of oxygen and the amount of combustion products theoretically required for the combustion of 1 kg of fuel (when carbon is completely and partially burned);
2. AFR-air fuel ratio calculation;

The following sources were considered for the calculation methods of exhaust gases:

3. Mass calculation of harmful substances.
4. Calculation of the quadratic formula of exhaust gases by the effect of air temperature.

1. B. A. Sharoglazov and others theoretically calculated the amount of oxygen required for the combustion of 1 kg of fuel and the amount of combustion products on the basis of the chemical reactions of C and H [4].

In ICE, the main elements of the fuel are given by mass or volume: C - carbon; H - hydrogen; O_f - oxygen in fuel (kg)
The equation of the mass fractions of separate chemical elements for 1 kg of liquid fuel is as follows:

$$C + H + O = 1$$

Table 1.

Mass shares of chemical elements

Liquid fuel	C	H	O_f
Petrol, kg	0,855	0,145	-
Diesel, kg	0,870	0,126	0,004

The chemical reactions of carbon (C) with oxygen (O) during complete combustion are as follows:

$C+O_2 = CO_2$ (molecular mass is placed. $m_c = 12$; $m_o = 16$),
12 kg (C) + 32 kg (O_2) = 44 kg (CO_2)

For 1 kg carbon (divide by 12)
1 kg (C) + 8/3 kg (O_2) = 11/3 kg (CO_2)

For C kg carbon:
C kg(C) + (8/3)C kg (O_2) = (11/3) C kg (CO_2)

The reaction of burning hydrogen:

$$2H_2 + O_2 = 2H_2O.$$

In mass fraction:

4 kg (H_2) + 32 kg (O_2) = 36 kg (H_2O).

For H kg of hydrogen:
H kg (H) + 8H kg (O_2) = 9H kg (H_2O).

It follows from the formulas that the theoretical amount of oxygen needed for complete combustion of 1 kg of fuel is determined by the formula

$$O_2' = \frac{8}{3}C + 8H - O_f; \quad \text{kg oxygen/ kg fuel}$$

Taking into account that air contains 23.2% oxygen by mass, the theoretical amount of air required for complete combustion of 1 kg of fuel is determined by the following ratio:

$$L_0' = \frac{O_2'}{0{,}23} = \frac{\frac{8}{3}C + 8H - O_f}{0{,}23} = 14,95 \quad \text{, kg oxygen/ kg fuel}$$

We looked at carbon when it is completely burned, i.e. C+O2=CO2.
How would the amount of air change if the carbon is incompletely burned? We will consider it according to the formula of premature combustion. The equation below is:

$$2C+O_2=2CO$$

Let's calculate the same as the formula developed above.
$2C+O_2=2CO$ (molecular mass is placed. $m_c = 12$; $m_o = 16$)
2*12 kg (C) + 16*2 (O_2) kg = 2*(12+16) kg (CO)
24 kg (C) + 32 kg (O_2) = 56 kg (CO)
For 1 kg carbon (divide by 24)

1 kg (C) + 4/3 kg (O_2) = 7/3 kg (CO)

For C kg carbon:

C kg(C) + (4/3)C kg (O_2) = (7/3) C kg (CO)

The reaction of burning hydrogen remains unchanged. The amount of air theoretically required for partial combustion of 1 kg of fuel is determined by the following ratio:

$$L_0' = \frac{O_2'}{0{,}23} = \frac{\frac{4}{3}C + 8H - O_f}{0{,}23} = 10 \quad \text{, kg oxygen/ kg fuel}$$

Let's look at the main difference, that is, when 1 kg of fuel is completely burned, the theoretical amount of air is 14.95 kg, and when it is incomplete, it is 10 kg. It made a difference of 4.95 kg. Pre-burning of fuel affects the coefficient of air excess (α), corresponding to the type of very lean mixture α >1.2.

$$\alpha = \frac{l_x}{L_H} = \frac{15}{10} = 1.5$$

In this case, the actual mass of air participating in the combustion of 1 kg of fuel Lx (when the value of Lx = 15), the theoretical mass of air required is measured by L_H ($L_H = L_0'$).

Based on this, there are five different types of combustible mixture: normal (a = 1), poor (a = 1.1...1.15), very poor (a>1.2), rich mixture (α=0.85...0.9), very rich mixture (α<0.85). It is an indicator that represents the engine power and fuel consumption.

2. AFR-air fuel ratio calculation

The air-fuel ratio is defined as the ratio of air to fuel in the mixture prepared for combustion [15].

Internal combustion engine air-fuel ratio (AF or AFR) is defined as the ratio between the mass of air ma and the mass of fuel mf used when the engine is running:

$$AFR = \frac{m_a}{m_f}$$

This formula was used by the author Shamil Ahmed Flamarz Al-Arkawazi in his scientific research[8].

The inverse ratio is called the fuel-to-air ratio (FA or FAR), and it is calculated as:

$$FAR = \frac{m_f}{m_a} = \frac{1}{AFR}$$

The ideal (theoretical) air-to-fuel ratio for complete combustion is called the stoichiometric air-to-fuel ratio. The stoichiometric air fuel ratio for a petrol engine is around 14.7:1. This means that we need 14.7 kg of air to completely burn 1 kg of fuel.

Table 2.

Air-fuel ratio

Type of fuel	Chemical formula	AFR
Diesel	$C_{12}H_{23}$	14.5:1
Petrol	C_8H_{18}	14.7:1
Propane	C_3H_8	15.67:1
Metan	CH_4	17.19:1
Hydrogen	H_2	34.3:1

Stoichiometric air-fuel ratio for Petrol was calculated considering that Petrol consists of iso-octane (C_8H_{18}).

$C_8H_{18} + O_2 \rightarrow CO_2 + H_2O$

Let's equalize the balance:

$C_8H_{18} + 12.5 \cdot O_2 \rightarrow 8 \cdot CO_2 + 9 \cdot H_2O$

Molecular mass is put:

For fuel $m_f = 8 * 12 + 18 * 1 = 114\ g$

For oxygen $m_o = 12.5 * 16 * 2 = 400\ g$

We calculate the mass of air, taking into account 21% oxygen in air:

$$m_a = \frac{100}{21} * m_o = \frac{100}{21} * 400 = 1904.7\ g$$

We calculate the air-fuel ratio:

$$AFR = \frac{m_a}{m_f} = \frac{1904.7}{114} = 16.7$$

In the indicator in Table 2, the value is 14.7, in the formula it is 16.7, it is different by 2.

RESULTS

We will calculate by equating the petrol formula C_6H_6:

$C_6H_6 + O_2 \rightarrow CO_2 + H_2O$

Let's equalize the balance:

$C_6H_6 + 7.5 \cdot O_2 \rightarrow 6 \cdot CO_2 + 3 \cdot H_2O$

Molecular mass is put:

For fuel $m_f = 6 * 12 + 6 * 1 = 78\ g$

For oxygen $m_o = 7.5 * 16 * 2 = 240\ g$

We calculate the mass of air, taking into account 21% oxygen in air:

$$m_a = \frac{100}{21} * m_o = \frac{100}{21} * 240 = 1142.85\ g$$

We calculate the mass of air taking into account 23% oxygen in air:

$$m_a = \frac{100}{23} * m_o = \frac{100}{23} * 240 = 1043.47\ g$$

We calculate the air-fuel ratio using 2 different values:

Assuming 21% oxygen,

$$AFR = \frac{m_a}{m_f} = \frac{1142.85}{78} = 14.65$$

Assuming 23% oxygen,

$$AFR = \frac{m_a}{m_f} = \frac{1043.47}{78} = 13.37$$

In Table 2, 14.7 is given as an ideal value, and our calculated C6N6 Petrol value is 14.65. The difference between them was proved to be 0.05.

3. The method of calculating the mass of harmful substances is given by B.I.Bazarov.

The mass (daily or annual) of hazardous substances of category j released into the atmosphere of a certain model of vehicle is determined by the following formula [5].

$$M_{jd} = k_j \cdot G_j \cdot \rho_{av} \cdot k_{tc} \cdot k_{cc} \cdot L_{av} \cdot 10^{-3},\ \ m$$

$$M_{ja} = M_{jkun} \cdot D_{cd} \cdot \alpha_p \cdot A_{an}\ ,\ \ \ m$$

where k_j is the approximate coefficient of specific gravity of the j-substance in the exhaust gas during the combustion of 1 kg of fuel;

G_j – Fuel consumption per 1 km, l/km;

ρ_{av} - average fuel density, g/sm^3;
L_{av} - average daily mileage of the car, km;
k_{tc} - average age and effect coefficient of technical condition;
k_{cc} - the influence coefficient of natural and climatic conditions depending on the exploitation category;
D_{cd} - number of calendar days in a year;
α_p - car production rate per line;
A_{an} - average number of vehicles per year.

It is possible to determine the value of exhaust gases through such calculation methods. In some sources, depending on the composition of the gases, different styles, graphs and drawings are given.

4. The quadratic formula for the calculation of harmful substances was obtained from the dissertations and compared.

A.S. Gavayev gave the following method of calculation. A change in air temperature affects α, which leads to an increase in the *CO, CnHm* and NOx content of the exhaust gases. It follows that the change in air temperature TV affects the mathematical model of harmful substances X_{CO}, $X_{C_nH_m}$, X_{NO_x} and is described by the following quadratic formula[13]:

$$X_{CO} = X_{CO(opt)} + S_{t_{CO}}\left(t_F - t_{CO(opt)}\right)^2 ,$$
$$X_{C_nH_m} = X_{C_nH_m(opt)} + S_{t_{C_nH_m}}\left(t_F - t_{C_nH_m(opt)}\right)^2 ,$$
$$X_{NO_x} = X_{NO_x(opt)} + S_{t_{NO_x}}\left(t_F - t_{NO_x(opt)}\right)^2$$

This is where;

$X_{CO(opt)}, X_{C_nH_m(opt)}, X_{NO_x(opt)}$ – CO, C_nH_m, NOx respectively optimal composition of, %:

$S_{t_{CO}}, S_{t_{C_nH_m}}, S_{t_{NO_x}}$ - CO, C_nH_m, NOx parameters of sensitivity to air temperature changes according to the composition of, %/ºC:

$t_{CO(opt)}, t_{C_nH_m(opt)}, t_{NO_x(opt)}$ - CO, C_nH_m, NOx the optimal air temperature at the engine inlet according to the composition of, ºC:

t_F - actual engine inlet air temperature, ºC.

After determining the volume content of CO, CnHm, NOx in the exhaust gases, the comparative calculation of these substances is calculated based on GOST 51832-2001.

The following calculation method was given by E.M. Chikishev. The author, like A.S. Gavayev, used a quadratic formula to calculate exhaust gases[14].

$$X_{CO} = X_{COmin} + St_{CO}(t_v - t_o)^2 , \qquad X_{C_nH_m} = X_{C_nH_m min} + St_{C_nH_m}(t_v - t_o)^2 ,$$
$$X_{NO_x} = X_{NO_x max} + St_{NO_x}(t_v - t_{vmax})^2$$

This is where;
$X_{COmin}, X_{C_nH_m min}$ – CO, C_nH_m the minimum composition of, %:

$X_{NO_x max}$ – NOx the maximum composition of, %:

St_{CO} , $St_{C_nH_m}$, St_{NO_x} – parameters of sensitivity to changes in air temperature at the engine inlet according to CO, CH, NOx content, respectively, %/ºC:

t_o - CO, C_nH_m the optimal air temperature at the engine inlet according to the composition of, ºC:

t_{vmax} – the value of the air temperature at the engine inlet in terms of the maximum amount of NOx, ºC.

Most of the remaining calculations were made based on GOST R 41.49-2003.

The following conclusions can be drawn from the method of calculation. The authors A.S. Gavayev and E.M. Chikishev used a quadratic formula, the difference is in the values of CO, CnHm, NOx, in the change of air temperature in the engine inlet, in the standard type used.

DISCUSSION

Our goal in carrying out research is to compare the given accounting methods and to take them into account in future accounting work. According to each method of calculation:

In method 1, the amount of air needed for fuel (1 kg of Petrol) in ICEs is calculated, the air amount is expressed in kg. In ICEs, the calculation of the combustion process is carried out in 2 different ways, that is, the amount of air in complete and partial combustions is shown. These values are one of the main factors that affect engine power and fuel consumption.

It was calculated based on the chemical formula of petrol in the 2nd method. The ideal value for air-fuel ratio is 14.7 kg. In the study, 16.7 kg came out, and in our calculations, we got 14.65 kg.

In the 3rd method, the researcher used values such as fuel consumption, daily mileage of the car, number of cars, coefficients of natural and climatic conditions to calculate the exhaust gases.

In the 4th method, exhaust gas composition (optimal and minimum), air temperature indicators, exhaust gas temperature values were used in the research.

The reason for determining such methods of calculation is that the electronics of modern new cars or engines are adjusted by the method of calibration of environmental performance. It is done in the test method. Is it possible to do it with account style? Our goal is to learn this.

CONCLUSION

In the article, the calculation methods of 6 sources were analyzed, the differences in the methods of 4 sources were determined, and the reasons were indicated. Calculation results of different calculations differed from each other by 0.25 kg according to the amount of oxygen in the air, the difference of 4.95 kg was calculated according to the value of the combustible mixture when it was fully and partially burned. In the last 2 sources, the methods of calculating exhaust gases are given.

Will lambda be involved in the reaction equations? Or to study the effect of the equipment installed in the system to reduce environmental damage, such as a catalyst, neutralizer, EGR system sensor, etc., on the calculation method.

This article will be the basis for the development of the model of the calculation method of environmental pollution of the car in our future research works.

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CONSTRUCTION OF HIGHWAY PAVEMENT STRUCTURE ON THE BASIS OF TREATMENT WITH CEMENT AND BITUMEN EMULSION

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Abstract. Particular importance is connected to the use of cost-effective, high-quality structures and improved construction technologies, taking into account resource limitations, environmental impacts, in order to ensure long-term high-quality service of highways in the world. Problems of the modern highway system are considered to increase the quality of building materials, reduce labor and energy costs, and receive materials with predetermined characteristics. In many countries, large amounts of investment are spent on the repair, construction and expansion of roads and highways. Statistics show that in the last fifty years, the most investments on the roads were directed compared to other general infrastructures. Long years of experiments show that roads built by traditional methods are affected by the intensity of movement and an increase in firing loads, defects appear before reaching the specified service life. Thus, improved construction technologies must be developed and adopted to increase the load-bearing capacity of roads, improve their quality, extend their service life and reduce their impact on ecology.
Keywords: Base, Cement-bitumen emulsion treated base, Construction method, Recycling, gravel-sand mixture, Cement, bitumen emulsion

INTRODUCTION

Stabilization is one of the common methods of strengthening and processing materials used for the base [9-12].

In the case of an existing destroyed, unsuitable or not meeting the technical requirements of the roadway, on-site reinforcement and machining with binders are becoming increasingly common [12].

The main objectives of this study was based on theoretical and experimental studies, substantiating the advantage of using cement-treated gravel-sand mixtures with the addition of bitumen emulsion for road base, improving the existing construction technology.

METHODS

Microscopic analysis of the dispersions of cement and bitumen emulsion was carried out to confirm the theoretical hypothesis presented in the second section of the dissertation on the basis of experimental studies, in which the binders form a structure in the mixture and work together. Together with this, one of the main methods of studying the structure and properties of bitumen emulsion is optical microscopy.

For microscopic analysis, an electron microscope of the Motic 210 brands was used (figure 1).

Figure 1. An overview of Motic 210 brands of electron microscopy

X-ray phase analysis of the mixtures was carried out on XRD-6100 diffractometer (figure 2), irradiation-Cu , Co , Fe , Cr-filter. X -ray generator maximum power-3 kW, scanning radius-185 mm.

Figure 2. XRD-6100 diffractometer

Scanning electron microscopy (SEM) and quantitative element tests were carried out in order to study the results of changes in the micro structure of the addition of bitumen emulsion when treating GSM with cement, to obtain practical results of the theoretical hypothesis posed. These tests were carried out using a scanning electron microscope branded Jeol JSM-IT200LA (figure 3).

Figure 3. Scanning electron microscope on Jeol JSM-IT200LA model

In order for a cement-treated bitumen emulsion to achieve high physico-mechanical character, the added gravel-sand mixture (GSM) must first achieve optimal moisture and thus maximum density. Determining the optimal moisture content and maximum density of the mixture was carried out according to paragraph 6.8 of GOST 23558-94 and GOST 22733-2016 (Proctor).

Using the specified optimal moisture content selected of sand-gravel mixture treated with cement - bitumen emulsion the composition of the mixtures. Samples were prepared based on GOST 23558, GOST 10180 to determine the strength indicators.

The samples were stored until the previously planned age of 7 and 28 days (GOST 23558), and test work was carried out according to GOST 10180 using a hydraulic press. On the basis of each combination, no less than 6 units (each series) of samples were tested to determine the strength indicators of 7 days and 28 days. The strength factor of the samples was calculated based on the expression as below:

$$R = \alpha \frac{F}{A}$$

where: F - index of press, N;
A-working surface of sample, mm^2;
α -is the coefficient of measurement.

The results obtained showed that the average arithmetic strength of sequentially tested samples in the sample series based on item 8.4 of GOST 10180 is based on the following expression:

$$R_{o`rt} = \frac{R_{n-1} + R_{n-2} + R_{n-3} + R_{n-4}}{4}$$

where: $R_{n-1} \geq R_{n-2} \geq R_{n-3} \geq R_{n-4} > R_{n-5} > R_{n-6}$.

The frost resistance of the mixture was assessed according to GOST 23558-94, and the test was carried out on the basis of the requirements of GOST 10060-2012. Before the tests, the samples were saturated with water according to the standard method. After the samples were frozen, the samples were taken out of the freezer and placed in (20±2)^{O}C temperature water, with the time the samples were held in the water corresponding to the time of dissolution. After the required number of freeze-thaw cycles, compression strength tests, mass loss, and cracks were investigated.

Shock resistance of samples based [13] on his scientific research, the proposed load was performed in the manner of throwing it from a certain height.

The effect of water absorption on samples was carried out according to GOST 12730.3-2020.

In the course of the research, methods of optimal planning of the experiment were used, which made it possible to apply a mathematical apparatus in the preparatory stages, conduct an experiment and apply the results of measurements in the processing stages.

The presence of coarse errors was checked against the number of samples N and the reliability of the measurements (0.95).

Dispersion describes the uniformity of the measure. The larger the dispersion , the larger the distribution of measurements:

$$D = \sigma^2 = \sum_{i=1}^{n} \frac{(x_i - \bar{x})^2}{n-1}$$

The coefficient of volatility describes volatility. The larger it is, the greater the variability of measurements with respect to average values.

$$k_B = \sigma / \bar{x}$$

To find the limit of the confidence interval at small values (n<30). The method proposed by V. S Gosset was applied:

$$\mu_{CT} = \sigma_0 \alpha_{CT}$$

$$\sigma_0 = \frac{\sigma}{\sqrt{n}}$$

In the process of processing experimental data, a number of gross errors must be excluded. However, before excluding this or that measure, the "three sigma" rule was used to make sure that it was a really gross error, not a deviation due to statistical propagation:

$$x_{\max,\ \min} = \bar{x} \pm 3\sigma$$

To determine the minimum number of measurements, the following expression was used:

$$N_{min} = \frac{\sigma^2 * t^2}{\Delta^2}$$

$$t = \sqrt{n} * \Delta / \sigma$$

RESULTS

Determining the optimal moisture content and maximum density of the mixture was according to paragraph 6.8 of GOST 23558-94 and GOST 22733-2016 (proctor).

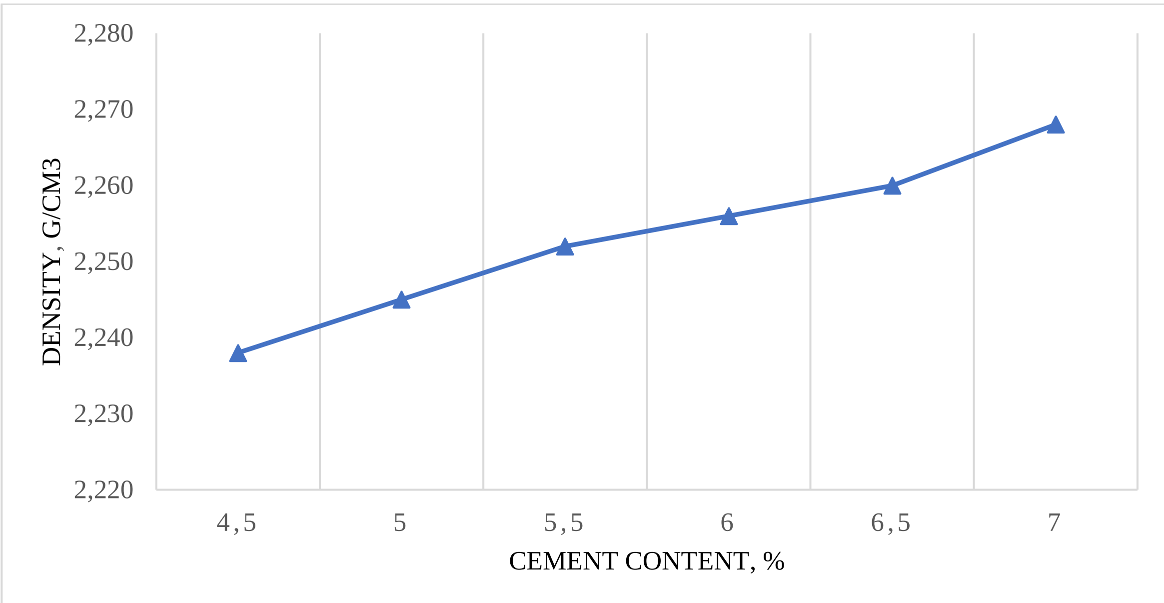


Figure 4. Graph of maximum density and optimal humidity variation in variations of cement quantity

Tests were carried out with the aim of researching the effect of the addition of bitumen emulsion on water absorption when treating GSM with cement. To the GSM 3.0%, 3.5%, 4.0%, 4.5% and 5.0%

cement was added, and in combination with 3% bitumen emulsion to the same amount of cement, mixtures were prepared and samples were made from them. The test was carried out based on GOST 12730.3-2020. The results were given in the Figure 5.

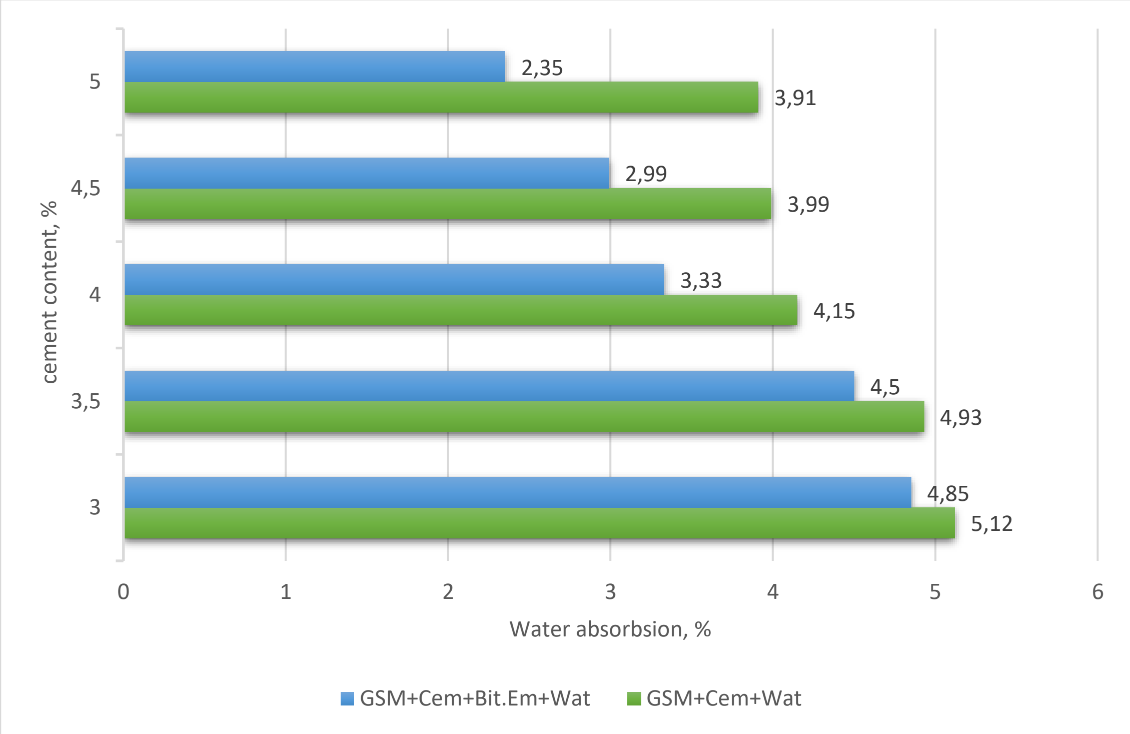


Figure 5. Water absorption grade of samples

A technique proposed by [13] was used to determine the shock tolerance of samples. A load weighing 5 kilograms is thrown from a height of 50 cm into the installed sample at an interval of 3-5 seconds.

The samples were tested at the age of 28 days, and the results were presented in Table 1. The assessment criterion was taken the number of shots in which the formation and breakdown of a crack occurred in the sample.

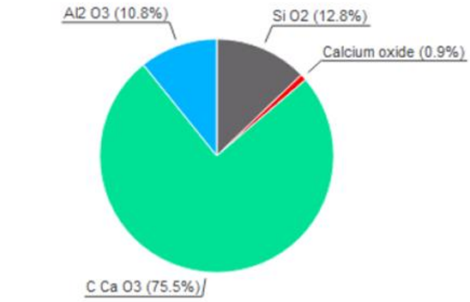
The dependence of the shock tolerance of samples on the content of various bitumen emulsion

Table 1.

Cement content %	*Bitumen emulsion content %*	*Number of strokes (crack formation)*	*Number of strokes (broken)*
4.0	*0.0*	*5*	*8*
4.5	*0.0*	*6*	*9*
5.0	*0.0*	*6*	*11*
4.0	*3.0*	*9*	*13*
4.5	*3.0*	*9*	*12*
5.0	*3.0*	*10*	*15*
4.0	*4.0*	*11*	*16*
4.5	*4.0*	*12*	*15*
5.0	*4.0*	*13*	*17*

4.0% and 5.0% Cement were added to the GSM, and in combination with 3% bitumen emulsion to the same amount of cement, blends were prepared and their samples were stored until the age of 28 days. X-ray phase analysis of these compositions was carried out

Figure 6. presents phase and Element Analysis of cement treated GSM samples.



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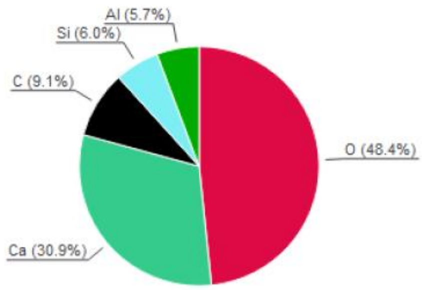

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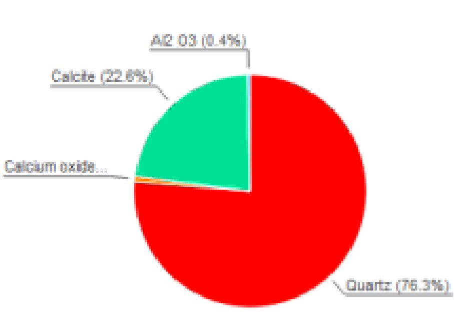

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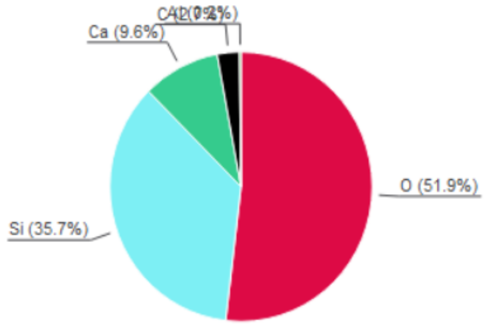

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Figure 6. Phase and Element Analysis of a sample treated with cement content of 4% and 5%: a, c - phase content%; b, d - element content%.

Figure 7. provides phase and Element Analysis of GSM samples treated with the addition of cement and bitumen emulsion

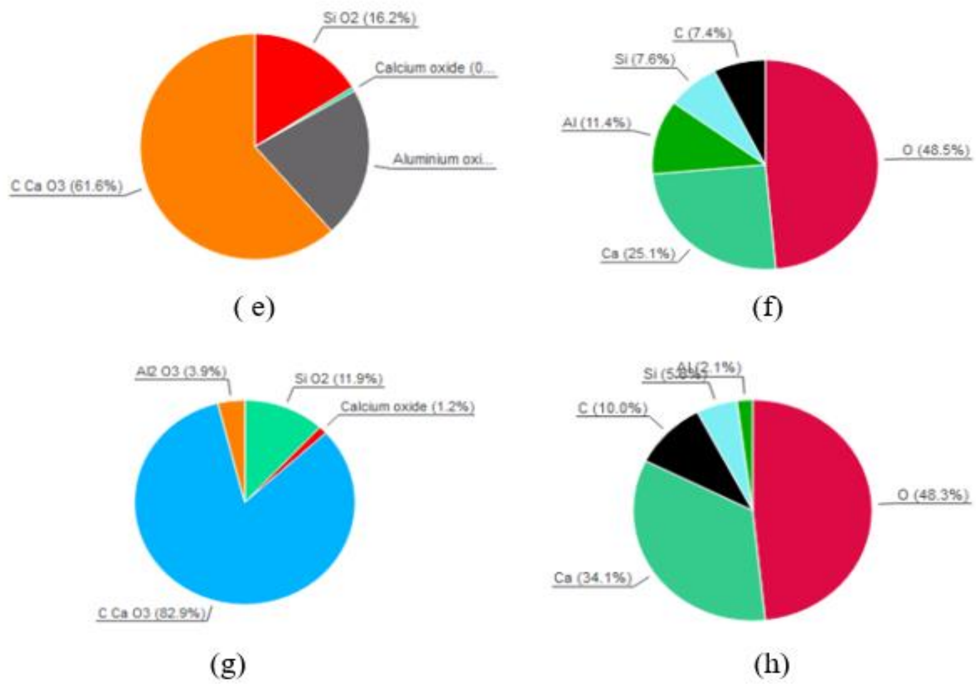
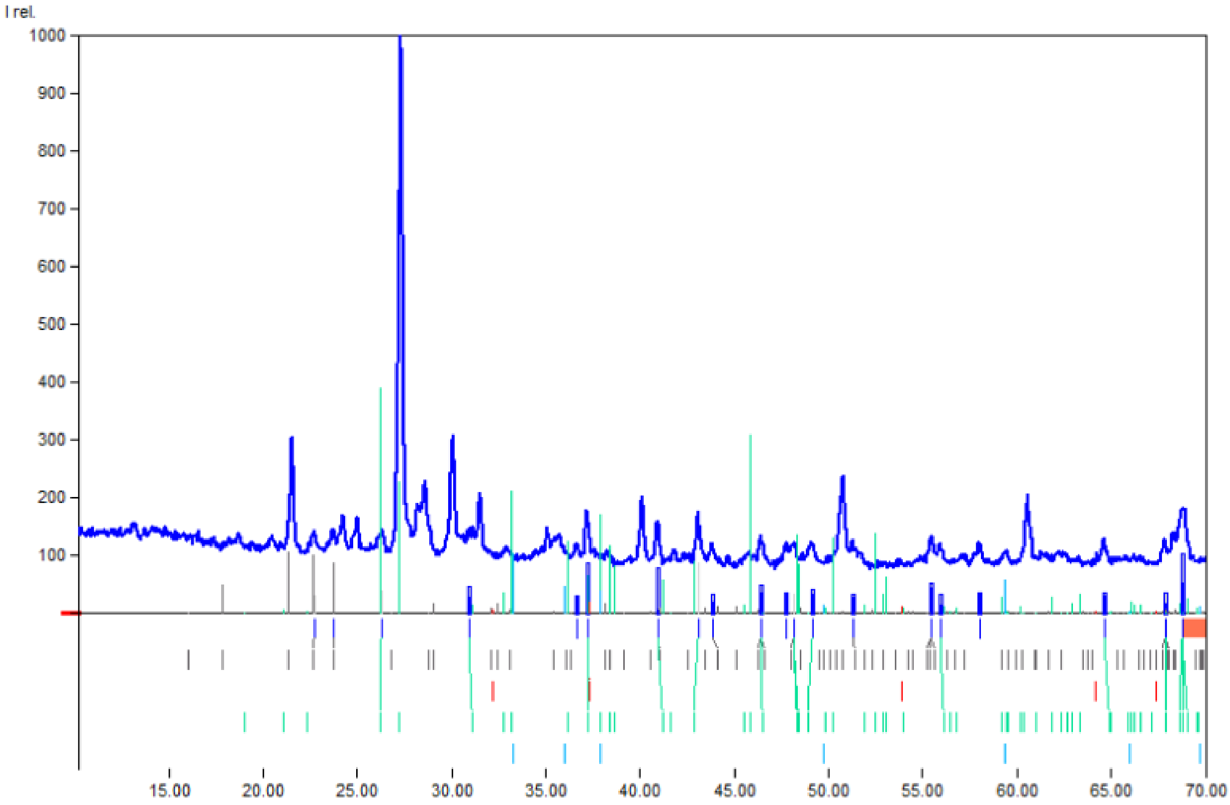


Figure 7. Phase and Element Analysis of the sample processed by adding 3% bitumen emulsion to 4% and 5% cement: e, g - phase quantity%; f, h - element quantity%

The results of the difftractogram of the mixtures are shown in Figure-8.



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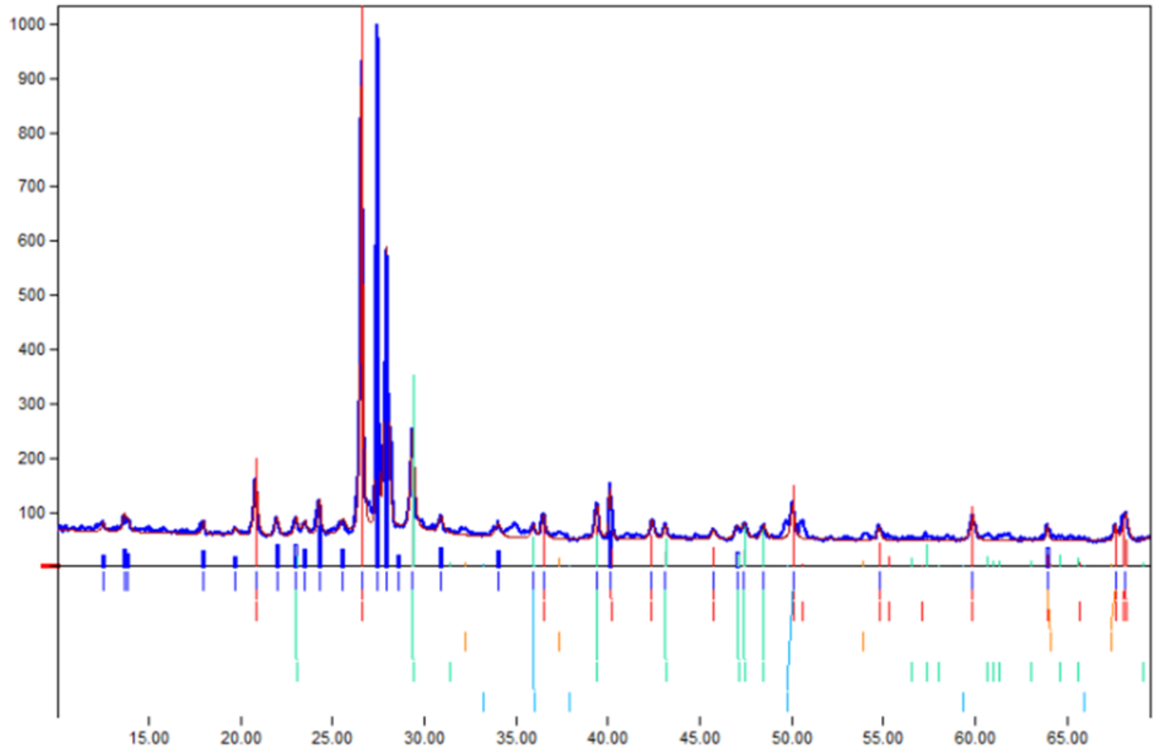
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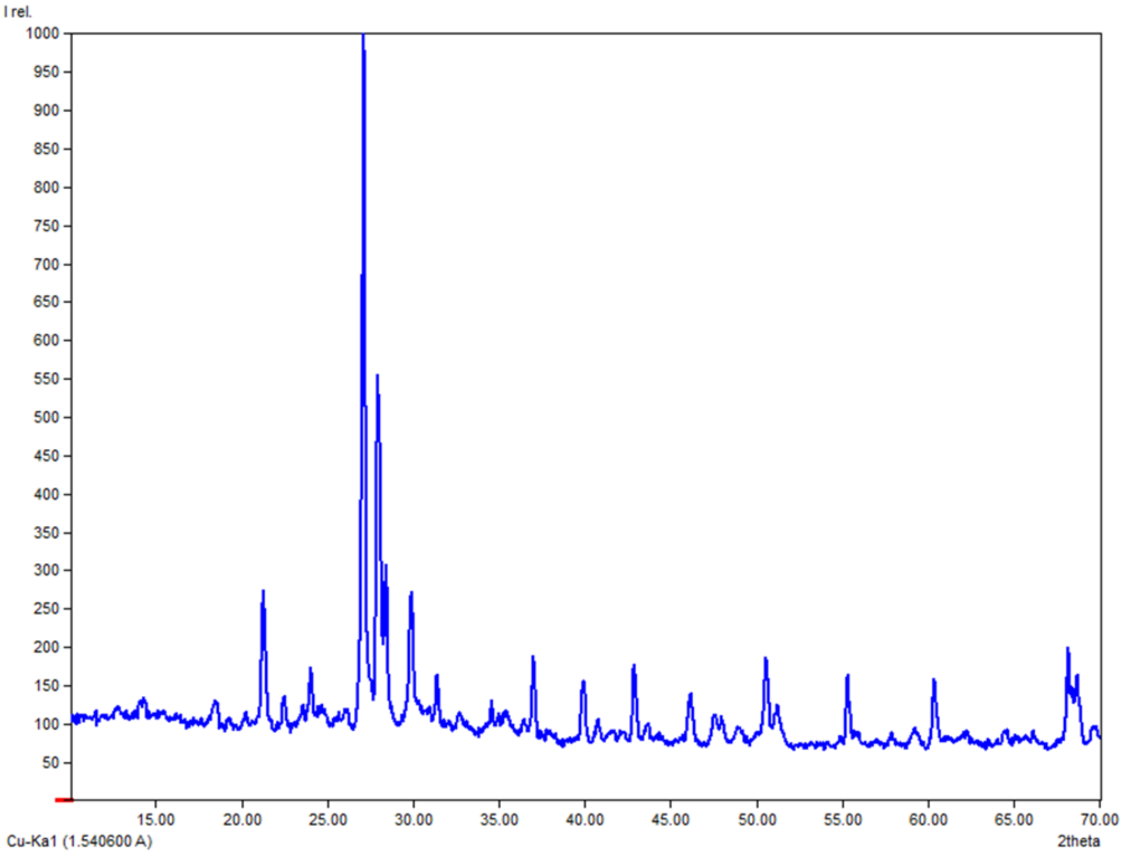
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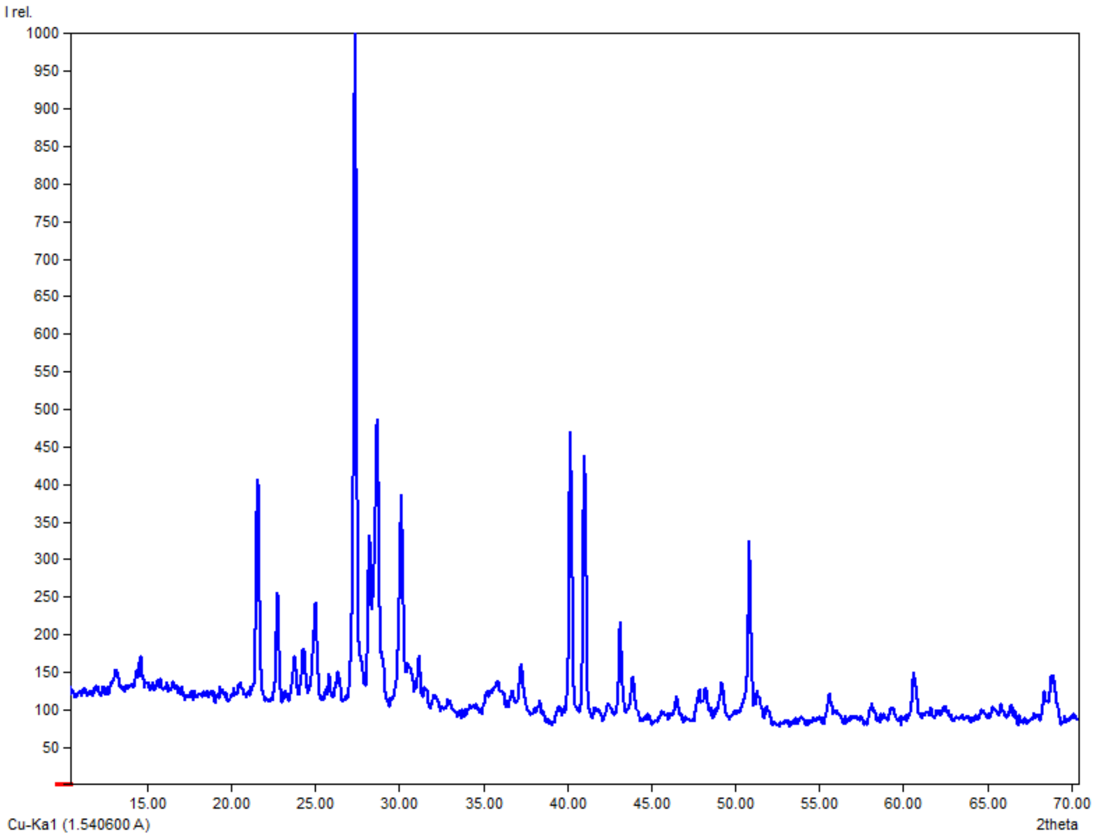

(d)

Figure 8. Diffractogram results of mixtures: samples treated with a - 4% cement, b-5% cement, C - 4% cement and 3% bitumen emulsion, d-5% cement and 3% bitumen emulsion

CONCLUSION

In conclusion, it can be said that during the analysis of the literature, scientific research in different countries was studied and it was convinced that it is necessary to develop separate combinations and technical requirements for each GSM materials.

Test results shows that the addition of 3% bitumen emulsion led to a reduction in water absorption in the samples to an average of 20% -25%. In turn, this increases the frost resistance of the layer.

An increase in the cement content in the mixtures, in turn, indicates a higher maximum density. Mixtures that have reached a high maximum density have high physical and mechanical properties. But from the analysis of the literature, we know that the high content of cement increases the stiffness and the probability of cracking.

In GSM materials treated with bitumen emulsion and cement, shock tolerance is high, increasing the crack tolerance of the layer as a result of various external influences.

The addition of bitumen emulsion reduces the hardness in the mixture and reduces crack resistance. In turn, it is important to determine the optimal amount of cement and bitumen based on GSM characteristics so that the strength indicators do not fall as a result of demand.

In the conditions of Uzbekistan, the treatment of base using this method (cement and bitumen emulsion), along with high results, leads to an increase in the quality of roads, reducing the impact on the environment and reducing construction costs.

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ANALYSIS OF POBLIC TRANSPORT IN THE CITY OF URGANCH

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Abstract. As a result of the acceleration of the urbanization process, the increase in megacities, population growth, the demand and need for public transport are increasing every year. This, in turn, leads to the need to improve the efficiency of public transport, adapt to today's times and conditions. This determines the importance of increasing the efficiency of using the existing transport infrastructure through proper planning and modeling of urban public transport. The article describes the methodology for determining passenger traffic on existing public transport routes (using the example of the city of Urganch). At the same time, the flow of passengers in urban public transport was carried out using modern information technologies by measuring at stops, in bus stations and inside public transport. As a result of the determination of passenger traffic on public transport, the districts of the city of Urganch that require improvement of transport infrastructure have been identified.
Key words: public transport, passenger flow, bus stops, *bus stations, transport*, flight, bus routes.

INTRODUCTION

The rapid development of the economy and the increase in the standard of living of the population require development of the transport sector. In our Republic, exchange of material resources and the rapid growth of population mobility indicators lead to a daily increase in the demand for the use of transport services. At the same time, every newly built facility, new residential areas, manufacturing enterprises, trade, household services and social facilities create additional burdens on the urban public transport system [1,2].

As a result, poorly organized urban public transport systems cannot cope with large passenger flows. It is observed that the time spent by the population on the road increases, excessive fuel consumption and damage to the environment (due to traffic jams) increase the number of road traffic accidents

Today in our republic, 3 mln. about 200,000 motor vehicles are registered, increasing by 6-7% per year on average. This increases the importance of activities such as improving the quality of services in public transport, solving transport problems in big cities, fundamentally revising and expanding passenger transport routes taking into account the needs and preferences of the population, managing the activity of taxis without directions, and building the infrastructure of the bicycle transport system[3,4,5].

OBJECTS AND METHODS OF RESEARCH

In this regard, a number of systematically relevant issues were determined at the extended video selector meeting "On measures to further develop public transport in Tashkent city and regions" under the leadership of the President of the Republic of Uzbekistan on November 30, 2020. In particular, taking into account the current and next 10-year needs for transport services, a clearly targeted measure for the strategic development of the transport system is the development of transport master plans of large and medium-sized cities[6,7,8,9].

Transport problems are mainly solved by a deterministic approach and a physical analogy method based on a systematic approach, with extensive use of extimolar theory and mathematical statistics methods [10,11,12,13,14].

Many scientists have carried out studies on passenger flow determination, analysis, evaluation and forecasting of passenger flow indicators in urban public transport [15,16,17,18]. Based on the analysis, it was shown that the possibilities of modern information technologies are not fully involved in the process of determining the flow of passengers in the process of modeling the public transport of the city, and it is necessary to take into account the characteristics of the territory in the process of determining the flow of passengers [19,20,21,22].

Passenger flow measurement in city public transport is carried out in 3 different types of objects:

1. At the crossroads;
2. At the bus stop;
3. In the direction of public transport.

Measurement of the flow of passengers in the city public transport is carried out with the help of counters. It is necessary to provide the enumerators involved in measuring the flow of passengers in public transport with the necessary equipment and materials.

The monitoring results are recorded based on the classification of buses presented in Table 1.

Table-1

Bus types

№	*Bus types*	*Size, (m)*
1	*Very little*	*Till 5*
2	*Little*	*6-7,5*
3	*Middle*	*8-9,5*
4	*Big*	*10,5-12*
5	*Very big*	*Above 16,5*

Types of measurement:

1 – At the crossroads.

Measurements to determine the intensity of public transport passing through the intersection are carried out from Monday to Thursday from 7:00 to 19:00. The start and end times are clearly written. Exchange times of counters at the metering point may vary depending on their working hours. Measurements should be stopped if there is a problem with the movement of city public transport. In order to save time and costs, measurements at road intersections can be combined with measurements at stations or with daily measurements of private vehicles. In this case, all the requirements for measurement must be met.

2 – At the bus stop.

Measurements at bus stops are carried out at bus stops and bus stations once a week from Monday to Thursday from 7:00 to 19:00, and also on weekends (Saturday, Sunday) from 7:00 to 18:00. At bus stops, measurements are made on both sides of the street. Measurements at junctions are made on one side of the street. Measurements should be stopped if there are any points that could affect the movement of city public transport.

3 – In the direction of public transport.

Measurements in the direction of public transport are carried out from Monday to Thursday from 7:00 to 19:00. Measurements in public transport are recorded separately in the forward and reverse directions of the same flight.

Based on the criteria mentioned above, measurements were made at 12 intersections, 6 bus stops and 14 intra-city buses within the framework of the study of the city of Urganch.

Figure 1 shows the address location scheme of passenger flow measurement points in public transport.

Figure 1. Address location scheme of passenger flow measurement points in public transport

Enumerators standing at 12 points at road intersections visually observed public vehicles passing through the intersection, evaluated the time of passing through the intersection, the degree of occupancy of public transportation in a point system and took pictures. Enumerators at bus stops recorded the time of arrival of buses at the stop, the level of occupancy, and the number of passengers who got on and off the bus.

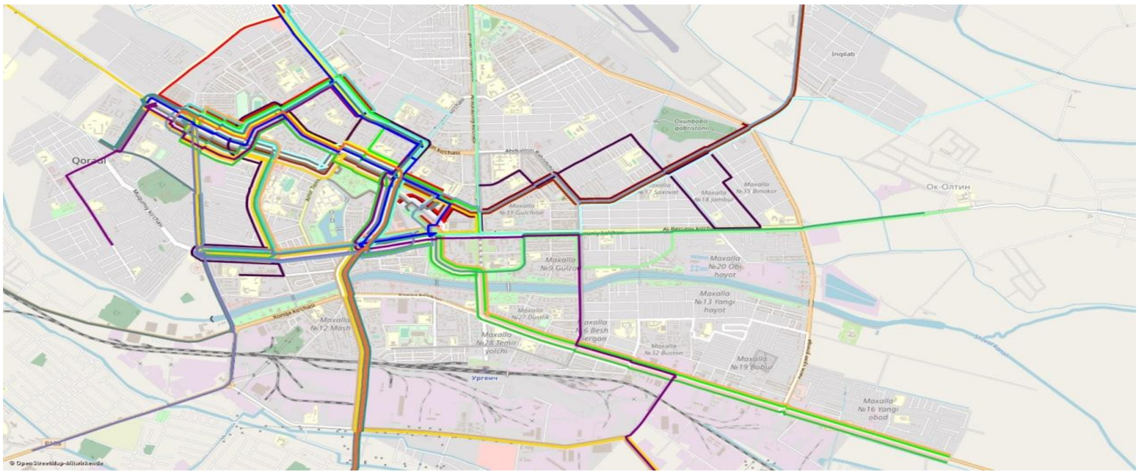

Figure 2. Urgan city public transport route scheme

The flow of passengers on public transport routes was carried out on the public transport routes of Urganch city presented in Figure 2. The flow of passengers on public transport routes in the city of Urganch was recorded by enumerators in the PASSIM program. The PASSIM program records changes in the speed of the bus moving in the direction, the number of passengers in the bus cabin and the number of passengers transported in one trip. The change in the speed of the bus in the PASSIM program is shown in Figure 3.

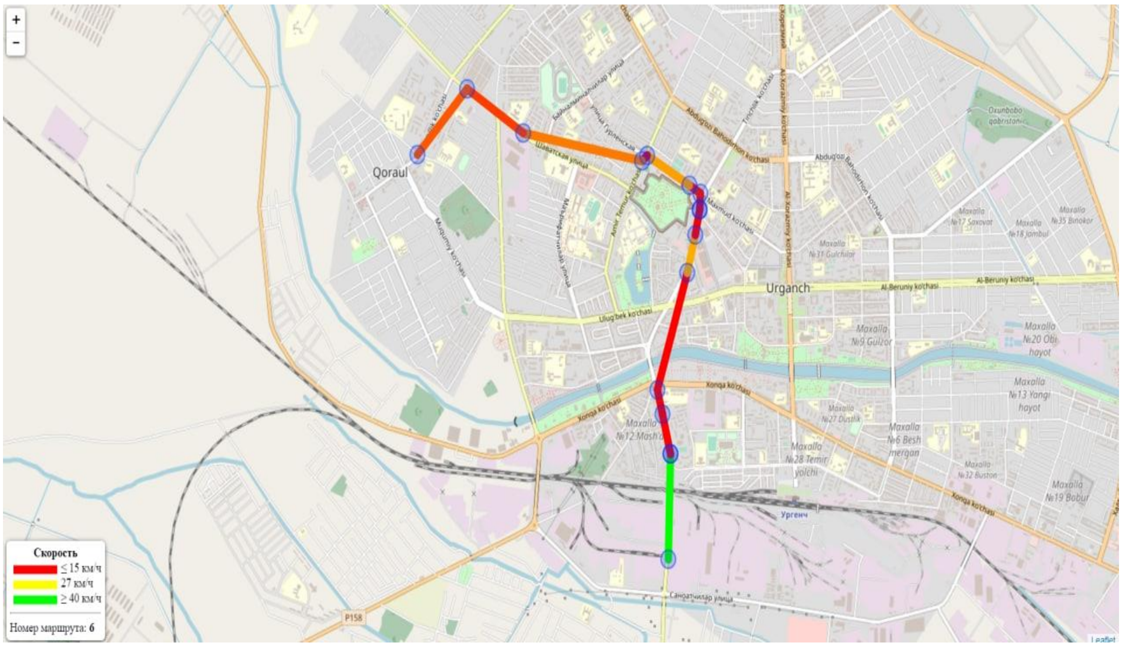

Figure 3. Measuring the speed of the bus on route 6

The number of passengers transported in one trip on the bus running on the 6th route in the city was recorded in the PASSIM program and is presented in Figure 4.

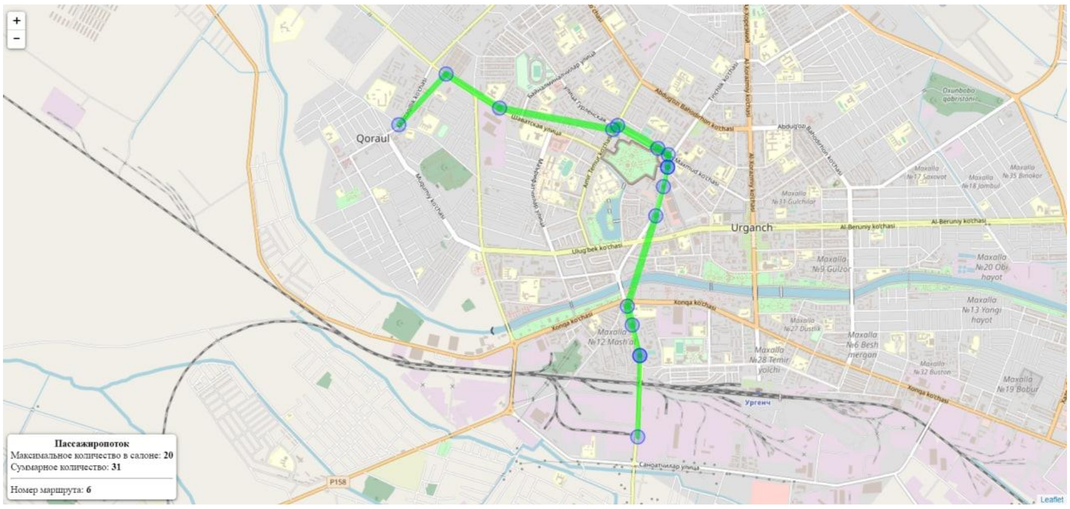

Figure 4. Passenger flow on route 6

RESULTS AND THEIR DISCUSSION

Data collected by enumerators on public transport routes in Urganch city were analyzed and calculated. The average speed of city public transport is calculated from the formula (1).

$$\mathrm{V}_{avarage} = \sum\nolimits_{1}^{n} \mathrm{V}_{avarage}^{direct} / n_{direct} \qquad (1)$$

Here: $\mathrm{V}_{avarage}^{direct}$ - average speed in the direction

n_{direct} – number of directions

The average speed in the direction is calculated in the formula (2)..

$$V_{avrg.}^{dirc.} = \frac{\sum_{1}^{n} V_{avrg}^{travel}}{n_{travel}} \quad (2)$$

Here: V_{avrg}^{travel}- average speed in travel
n_{travel}- number of travels
Average speed of travel is calculated by formula (3).

$$V_{avrg}^{travel} = \frac{l_m}{t_x + t_o} \quad (3)$$

Here: l_m – route length
t_x – time in motion
t_o – stop times

The average speed of public transport in the city of Urganch was calculated by calculating the average speed of public transport routes. Figure 5 shows the average speed of routes and the average speed of public transport in the city of Urganch.

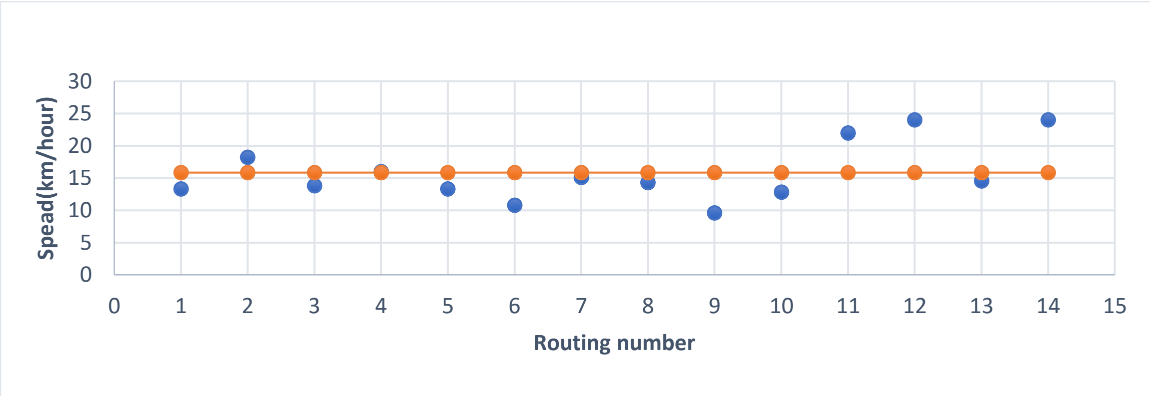

Figure 5. Average speed of public transport in Urganch city

The number of passengers transported daily on the public transport routes of Urganch city was calculated. The total number of transported passengers was calculated as follows (4).

$$Q_{avrg} = \sum_{1}^{i} Q_{trevel} \quad (4)$$

The total number of transported passengers on the route was calculated in the formula (5).

$$Q_{trevel} = \sum_{1}^{i} Q_{flig} \quad (5)$$

Q_{flig}- the number of passengers carried in one journey.

Figure 6 shows the calculation of the number of transported passengers in the cross-section of routes.

Figure 6. The number of transported passengers on the section of routes

At bus stops and intersections, enumerators visually count the flow of passengers in public transport and record the number of passengers on a record sheet. The recorded data was analyzed and the level of public transport in Urganch city was evaluated in a 5-point system during the day in Figure 7.

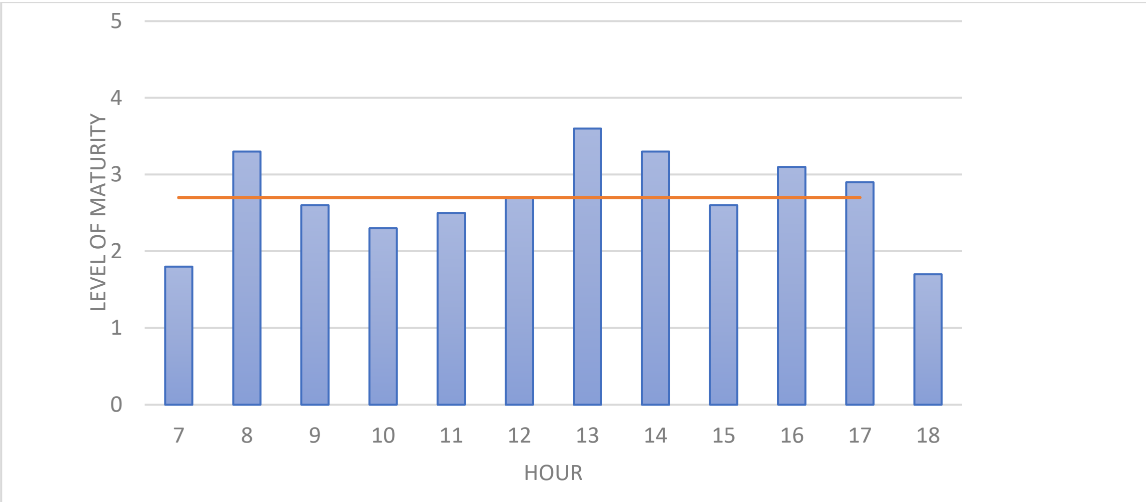

Figure 7. Bus occupancy level

The daily number of passengers carried by Urganch city public transport was calculated by the hours of the day. Figure 8.

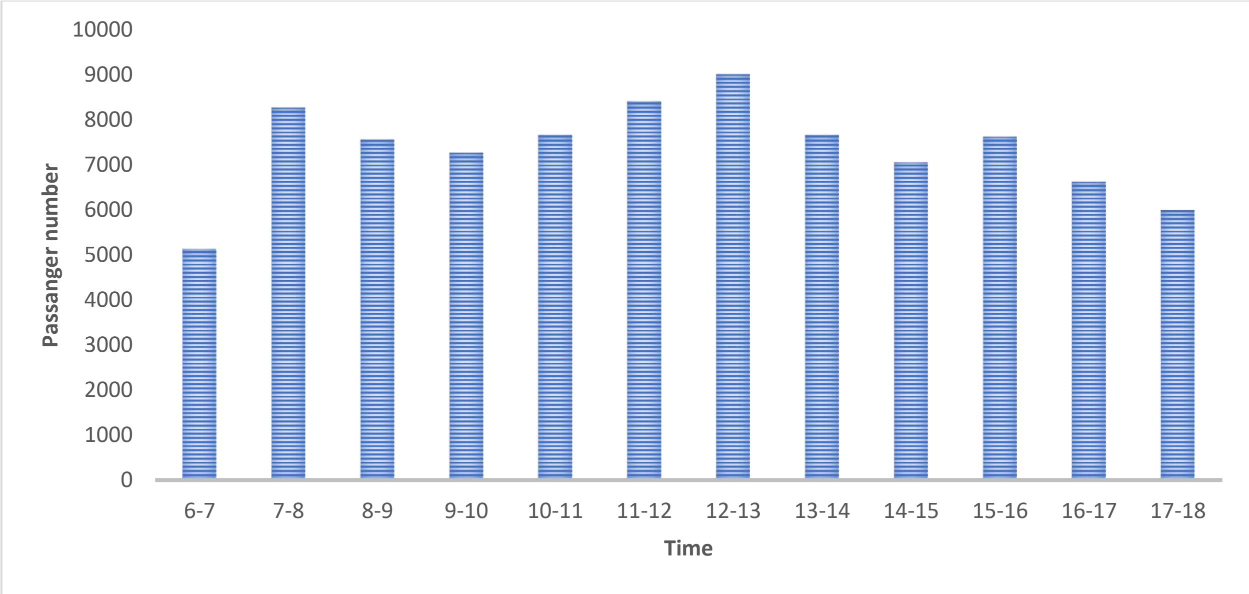

Figure 8. Changes in the number of passengers during the hours of the day

CONCLUSION

Through the method of studying the flow of passengers in public transport, the flow of passengers in public transport of the city of Urganch was determined. According to the results of the research, the average speed of public transport in the Urganch agglomeration was 15.84 km/h. According to the results of the calculation, the least 1563 people were transported on the 2nd bus route, and the most 16822 people were transported on the 7th route. According to the analysis of the hours of the day in public transport, it was found that the flow of passengers increases between 7:00 and 9:00, 11:00 and 13:00 and 15:00 and 16:00. A total of 88121 passengers were transported on 14 public transport routes in the city of Urganch.

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NANOCOMPOSITE MATERIALS FOR FUNCTIONAL COATINGS OF AUTOMOTIVE AND TRACTOR MACHINERY PARTS

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Abstract. The prerequisites and mechanisms of manifestation of the special energy state of the components of materials and metal-polymer systems, which determines the course of the specified processes in interphase interactions with the formation of boundary layers with optimal structure, are considered. The model of the spline joint of the cardan shaft, containing a coating of polymeric material, which allows to assess the factors that determine the stability of the material or coating to technological or operational influences. Criteria for selecting functional components of coatings based on aliphatic polyamides used in the construction of spline joints of cardan shafts are proposed. Nanocomposite materials based on industrial thermoplastics with increased parameters of performance characteristics for functional products (coatings) used in automotive and tractor machinery have been developed.
Keywords: nanocomposite material, metal-polymer system, functional coating, cardan shaft, spline joint, automotive and tractor machinery.

Introduction. In the designs of modern automotive and tractor machinery, elements made of functional composite materials based on polymer matrices are widely used. Thus, the optimal choice of the design solution, as well as the composite materials for the manufacture of cardan transmission elements, largely determine the technical, economic and operational characteristics of the machines and the effectiveness of their practical application [1].

One of the nodes of the cardan transmission, which determines the effectiveness of its use, is a spline connection that provides the process of functioning in dynamic changing load-speed modes and with constant axial movement of elements. To ensure the effective operation of the spline joint of cardan transmissions of various designs, composite materials on inorganic and organic polymer and oligomeric matrices are widely used, which provide high wear resistance in conditions of reverse motion and minimal losses for resistance to frictional forces [1]. In recent years, tribological coatings based on aliphatic polyamides (nylon, polyamide 6, Rilsan) have been widely used in cardan shaft structures, which reduce the intensity of corrosion-mechanical wear of the spline joint and reduce friction losses. To create such coatings, modern methodological approaches based on the use of functional modifiers of various composition and mechanism of action, allowing to purposefully change the structure of composites based on polymer matrices to ensure the implementation of the phenomenon of a low-wearing metal-polymer system [2].

Among the most promising areas for the creation of polymer composites with an optimal structure is the implementation of the nanostate of components, which allows the use of energy parameters to form stable bonds that ensure resistance to the effects of operational factors [3].

The purpose of this work was to develop criteria for the selection of functional components of coatings based on aliphatic polyamides used in cardan shafts.

Research methodology. Thermoplastic polymers were used as binders to obtain composites – polyamide 6 (PA 6), polyamide 11 (PA 11), low-density polyethylene (LDPE), high-density polyethylene (HDPE), polypropylene (PP), polytetrafluoroethylene (PTFE) and thermoplastic elastomers – thermoplastic polyurethane (TPU), ethylene-vinyl acetate (EVA) copolymer, divinyl styrene thermoplastic elastomer (DST).

As the main objects of research, nanodisperse particles of carbon-containing (graphite, ultradispersed detonation diamond (UDD), shungite, carbon fibers), metal-containing (oxides, salts of organic acids) and silicon-containing (mica, tripolite, opal, clay) compounds obtained by technological effects on natural and synthetic semi-finished products produced at industrial enterprises of Belarus, Russia and Uzbekistan were selected. Nanoscale particles were obtained by mechanical crushing and heat treatment of dispersed semi-finished products at temperatures of 673–1473 K.

Polymeric materials were used in the state of industrial supply in the form of granules or powder obtained by cryogenic dispersion of granules at a temperature of 87 K.

The parameters of the structure and characteristics of nanocomposite materials and products from them were investigated using modern methods of physical and chemical analysis: IR transmittance spectroscopy and IR spectrometry of multiply frustrated total internal reflection (Tensor 27, Bruker), X-ray diffraction (DRON 3.0), differential thermal analysis (Q-1500), optical microscopy (MF-2), scanning electron microscope (ISM-50A) and atomic force microscopy (Nanotope III). The energy state of nanomodifiers and composite materials was assessed according to the electron paramagnetic resonance (EPR) spectra and spectra of thermally stimulated currents (TSC) at the original apparatus of the V.A. Belyi Metal-Polymer Research Institute of National Academy of Sciences of Belarus. The dielectric characteristics (energy state) of materials after energy exposure (laser, ionic, temperature) were determined according to standardized methods.

Results and discussion. All types of interfacial processes in various types of contact interaction of components of materials or structural elements (systems) in the formation and operation of products of a certain functional purpose in machines, mechanisms, technological equipment used in various industries are due to the transfer of energy with the formation of a stable thermodynamically advantageous equilibrium state for specific conditions [4]. Multicomponent materials (plastics, composites, alloys), products and structures manufactured with their use are systems whose parameters (deformation-strength, tribological, thermophysical, operational, etc.) depend on the intensity of interphase interactions that determine the course of certain physical and chemical processes in boundary layers with a given intensity and lead to the formation of boundary layers of a given composition, structure and parameters characteristics [2]. For composite materials, the boundary layer parameters determine the aggregate parameters of the service characteristics of the products. In tribosystems, the boundary layer determines the mechanisms and kinetics of friction and wear processes and performs the function of the so-called "third body" separating the contacting components of the tribological system [1–3].

The processes of interfacial interactions lead to the transformation of the initial state of the components of systems (both static and dynamic), causing the achievement of the necessary parameters of strength, wear resistance, corrosion resistance, adhesive strength, heat resistance of the product or structure (systems of various composition, structure and functional purposes) [5]. In the interphase interaction of the components of the system, a complex of physical, physicochemical reactions with a predominance (prevalence) of one or several simultaneously takes place, for which the most favorable conditions are realized, determined by the value of the activation energy parameter.

To ensure the specified parameters of the processes of interfacial interaction during the formation of a boundary or separating layer with a structure adequate to the operating conditions of the system, it is necessary to establish a determining (prevailing) reaction in the contact zone and thermodynamic conditions for its flow at a given speed (kinetics). Such a prevailing (isolated) reaction, the kinetics of which corresponds to the conditions of formation or operation of the system, is a factor determining the stability of the material, product or structure to the effects of technological or operational factors [2, 3, 5].

Of particular importance are the noted aspects in the interaction of metal-polymer systems including a composite coating. To assess these factors, consider the model of the spline connection of the cardan transmission containing a coating of polymeric material.

The technology of applying polymer coatings is quite complex and requires the use of special methods of surface preparation and strict observance of temperature regimes [1].

To determine the technological parameters for the formation of a functional coating on the facejoints, an estimated calculation of its thickness was carried out, which is necessary and sufficient to ensure the specified conditions for contact interaction. The problem of determining the thickness of the polymer coating *h*, at which the alignment of contact stresses occurs, was solved under the assumption that the rigid coating is applied to the elastic base (Fig.).

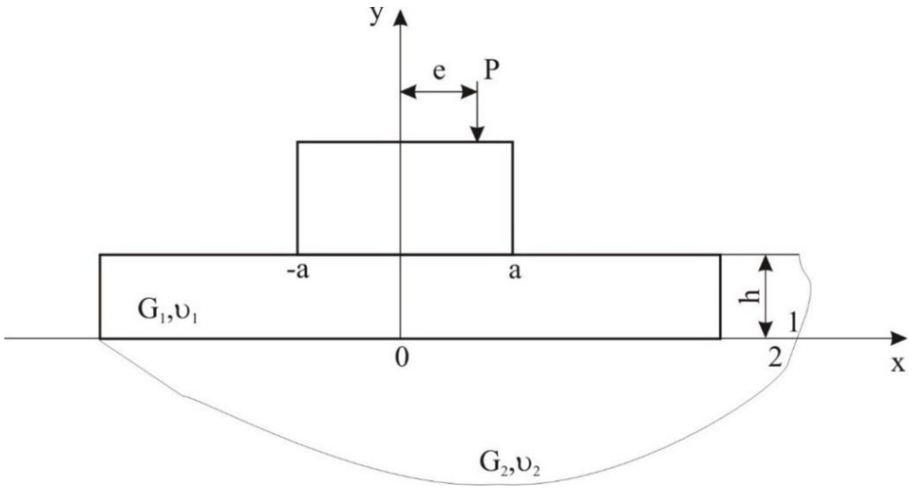

Figure 1. Diagram of loading in the slotted joint of the cardan transmission in the presence of a polymer coating

Let the elastic half-plane surface (y<0) with characteristics G_2, ν_2, be reinforced along the entire boundary (y=0; $|x| < \infty$) by a thin layer h_c characteristics G_1, ν_1. Consider the problem of frictionless alignment by force *P* with the eccentricity of application *e* to the upper boundary of the thin composite base of the stamp with a 2*a* width, the shape of the base of which is described by the function $y = g(x)$ [6].

Let's write down the boundary conditions of the problem in the form of:

$$\text{at } y=h;\ (1) \qquad t_{xy}^{/} = 0(|x| < \infty); \sigma_y^{/} = 0; (|x| > a) \tag{1}$$

$$\nu 1 = -[\delta + dx - q(x)] \quad (|x| \le a)$$

$$\text{at } u=0; \qquad \sigma_y^{x/} = \sigma_y^2;\ \tau_{xy}^{x/} = \tau_{xy}^2;\ \nu_1 = \nu_2; \quad U_1 = U_2 \tag{2}$$

The tension at infinitely distant points are taken to be zero. In expression (1), the $\delta + dx$ function characterizes the rigid movement of the stamp under the action of the applied force *P* and the moment P_e.

Let's assume that the attitude

$$h/a \le 0{,}2 \text{ и } n=\theta_1/\theta_2=O(\frac{a}{h});\ \theta_1=G_1(1-\nu_1)^{-1};\ i=1{,}2$$

Then the polymer coating can be modeled with an overlay [6] described by the equation:

$$2G_1hU_1^{//} = -(1-\nu)(\tau_1-\tau_2)-0{,}5\nu_1 h(\sigma_1+\sigma_2^{/})$$

$$\nu_1(x,h)-\nu_1(x,0)=0;\ \sigma_1-\sigma_2=0, \tag{3}$$

где $\tau_1=\tau_{xy}^{/}(x,h);\ \tau_2=\tau_{xy}^{/}(x,0);\ \sigma_1=\sigma_y^{/}(x,h);\ \sigma_2=\sigma_y^{/}(x,0)$, and the strokes ($^{/}$) indicate derivatives in *x*.

Using formula (3), boundary conditions (1) and (2) can be given the form:

$$\text{at } y=0; \qquad 2G_1hU_2^{//} = (1-\nu_1)[\tau_{xy}^{2}-\nu_1 h(\sigma_y^{//})]^2$$

$$\sigma_y^{2}=0;\ (/x/>a);\ \nu_2=[-\delta+dx-q(x)],\quad (/x/\le a)$$

The half-plane stresses at $x^2+y^2\to\infty$ disappear. Using the Fourier transform, the problem in question can be brought to an integral equation with respect to the contact pressure distribution function:

$$\int_{-a}^{a} q(\xi)k\frac{(\xi-x)}{2nh}d\xi=\pi m\Theta_2+[\delta+dx-q(x)];;$$

$$k(t)=\int_0^\infty \frac{u+m}{u(u+1)}\cos utdu;$$

$$m=n(\xi n-\eta\mu)^{-1};\xi=0,25(3-4\nu_2)(1-\nu^2)^{-2}$$

$$\eta=0,25(1-2\nu_2)(1-\nu_2)^{-1}$$

Based on the assumptions made and the results obtained, it can be shown that the thickness of the polymer coating ($\theta_1<<\theta_2$) should be determined from the condition $h>>d$, where d is the diameter of the contact spot. Using the data of the work [7], it can be concluded that the thickness of the polymer coating should be $h\geq$ 0.1 mm (100 μm). The closer the values *of* G_1, ν_1, the smaller the thickness of the coating.

During the operation of a metal-polymer system, the polymer coating is subjected to a complex effect of factors leading to its corrosion-mechanical wear. Therefore, the most important condition for the formation of a coating with high parameters of operational characteristics is the establishment of a prevailing physical and chemical reaction that determines the mechanism of wear during friction without the supply of external lubricant.

The establishment of the prevailing physicochemical reaction, which determines the kinetics of wear of metal-polymer systems during their operation without external lubrication, made it possible to propose various directions for regulating its kinetics and create conditions for the formation of a boundary separating layer with the properties of an anti-wear component – a wear inhibitor – in the zone of frictional contact [2, 5].

The mechanism and kinetics of physicochemical reactions occurring with the transfer (exchange) of energy of components during their static and dynamic contact determine energy processes. For a stable and directional (regulated) course of the isolated (determining) physicochemical process in the interphase interaction of components with a given intensity, it is necessary to achieve their total energy of the activation energy value under certain conditions of the system's existence.

In accordance with modern ideas about the kinetics of interphase interactions [2–5], the most important parameter for the formation of a system of various composition, structure and purpose, determining the conditions for achieving its optimal structure, is the energy state of the components.

To characterize the energy state of the components, we will use a complex parameter, which is the cumulative result of the transformation of the initial individual parameters (structure, composition, morphology, size) under the influence of technological and operational factors, which is correlated with the value of the activation energy of the selected process of a certain mechanism and kinetics in the interphase interaction and expressed in physical units.

System analysis of the mechanisms for realizing the energy state of components [2, 5, 8] made it possible to establish a functional relationship between the system parameters in the formation of the energy factor of materials science and the technology of systems of various structures – composites, metal-polymer units and structures, including tribological ones. The main task of creating composites and metal-polymer systems with specified parameters of operational characteristics is to form boundary and separating [5] layers with optimal structure parameters. To form metal-polymer systems with specified parameters of operational characteristics, it is necessary to intensify the determining (prevailing) interfacial reactions in the creation of functional composite materials based on high-molecular (polymer, oligomer and combined) matrices and metal-polymer systems (static and dynamic – tribological) by implementing a special state of components, which according to the formed the conceptual apparatus is called nanostate [9–12].

The analysis of the prerequisites for the formation of the nanoconstitution of components of materials based on high-molecular matrices and metal-polymer systems made it possible to develop directions for their practical implementation. Methodological principles for obtaining nanocomposite materials based on industrial thermoplastics have been developed, consisting of:

– established crystal and chemical prerequisites for the selection of natural and synthetic carbon-containing, metal-containing and silicon-containing semi-finished products for the directed formation of active nanoscale particles with specified structural, morphological and energy parameters with optimal technological effects (mechanical, mechanochemical, thermal, laser);

– implementation of the conditions of energy compliance of nanomodifiers with the prevailing mechanism for the formation of the optimal structure of polymeric, oligomeric and combined matrices at various levels of organization – molecular, supramolecular and interphase in a given temperature range;

– providing conditions for the manifestation of the preferred mechanisms of interphase physicochemical interactions of components with the formation of boundary layers of optimal structure, determining the mechanisms of destruction of nanocomposites and wear of metal-polymer systems under the influence of various operational factors.

The developed methodological approaches for assessing the role of the phenomenon of nanostration of composite modifiers and metal-polymer systems were tested [3, 13–19].

For the manufacture of sealing, protective and damping elements of automotive units (brake chambers, automotive shock absorbers, cardan shafts), compositions of nanocomposite materials based on thermoplastic elastomers (EVA, TPU) modified with thermoplastic components (HDPE, FDO (copolymer of formaldehyde and 1,3-dioxolane)) in combination with nanoscale particles (NSP) of silicate-containing minerals of a layered, frame or chain structure obtained by heat treatment of dispersed semi-finished products have been developed.

The introduction of silicate NSP into the matrix ensures the formation of transition layers at the interface "thermoplastic elastomer – thermoplastic polymer" by the mechanism of adsorption interaction of macromolecules of the matrix binder and modifying component with the active centers of the dispersed particle, which performs the function of a physical catalyst. By changing the ratio of the polymer and nanoscale modifier, it is possible to adjust the parameters of the deformation-strength characteristics and abrasion resistance of composite products (membranes, protective casings, damping elements).

Another embodiment of the abrasive-resistant nanocomposite material based on polyolefins (PP, HDPE, LDPE) is the use of mechanized particles of natural silicates, which have increased activity in the processes of adsorption interaction with the macromolecule. The action of the uncompensated charge in the particles of the modifier determines the orientation processes in the melt of the composite with the formation of ordered (quasi-crystalline) structures that play the role of reinforcing nanoblasts. An additional effect of hardening and increasing the abrasive resistance of composites is achieved with orientation single-axis extraction of the semi-finished product in the form of a strand, followed by the introduction of reinforcing elements into the base matrix (PP, LDPE, HDPE). The use of silicate NSP for the modification of polyolefins makes it possible to adjust the parameters of rheological and stress-strain characteristics in a wide range.

To increase the operational life of heavily loaded friction units of automobile units and technological equipment (cardan shafts, lathe cartridges), compositions and technology of nanocomposite materials based on polyamides have been developed. Modification of the polyamide matrix (PA 6, PA 11) of silicate minerals (mica, montmorillonite, kaolin, tripolite) NSP causes the achievement of the necessary adhesive characteristics of the coating with a significant increase in their wear resistance during operation without external lubrication. The developed patented tribological compositions are an effective alternative to compositions based on the imported analogue of PA 11 ("Rilsan").

Metal-polymer nanocomposite coatings based on polymer binders, obtained when exposed to thermal gas flow on a mixture of thermoplastic polymer (PA 6, HDPE) and metal-containing precursor (formates, oxalates, carbonyls of Cu, Zn, Ni, Fe), are characterized by increased wear resistance, adhesive strength and resistance to thermooxidizing media [19].

To develop composite materials for the application of tribological coatings, polymer thermoplastic matrices produced in multi-tonnage were used, including by domestic manufacturers – PA 6, HDPE, PP. Modification of matrix polymers with functional components (tripolite, flint, kaolin, HDPE) was carried out by mechanochemical activation (MCA) with subsequent grinding at cryogenic temperatures (87 K). Coatings were formed by the method of fluidized layer using the original apparatus of the V.A. Belyi Metal-Polymer Research Institute of National Academy of Sciences of Belarus. Comparative studies (Table) indicate that the developed compositions are not only not inferior to the imported analogue of PA 11 ("Rilsan", France), but also significantly superior to it in wear resistance. At the same time, the compositions of composite materials developed on the basis of polyamide 6 (JSC Grodno Azot, Belarus) have a cost 3–5 times lower than the imported analogue.

Table.

Characteristics of nanocomposite materials for tribological coatings

Characteristic	*Parameter for material*		
	PA 11 "Rilsan", France	*PA 6, JSC «Grodno Azot»*	*Developed composition*
Tensile stress, MPa, not less than	*43*	*50*	*67–78*
Adhesive strength, cm, not less than	*20*	*15*	*27–32*
Brinell hardness, MPa	*90*	*100*	*89–94*
Coefficient of friction	*0.05–0.20*	*0.15–0.25*	*0.10–0.15*

Compositions of materials with MCA components have been successfully tested in the designs of cardan shafts of trucks, lathe cartridges produced at JSC "Belcard" and JSC "BelTAPAZ" (Grodno, Belarus).

Conclusion. On the basis of a systematic approach to the study of the influence of the features of the structure and energy state of nanoscale particles of condensed matter, the mechanisms of physicochemical processes in polymer matrices are proposed, determining the parameters of their structure at the molecular, supramolecular and interphase levels. Methodological approaches to the creation of nanocomposite machine-building materials with increased parameters of deformation-strength, tribological, adhesive and protective characteristics based on industrial thermoplastics and technology of their manufacture and processing into products.

Functional nanocomposite materials with high parameters of stress-strain, tribological, adhesive and protective characteristics based on industrially produced thermoplastics (polyolefins, polyamides, polyurethanes) and technologies for their manufacture and processing into products used in automotive and tractor machinery have been developed.

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STUDYING THE EFFICIENCY OF PASSANGERS TRANSPORTS IN URBAN PUBLIC TRANSPORT

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Abstract: As a public transport busses are spreading out widely not only in cities, but also in rural areas. Busses are used in city, suburban, intercity and international regular services. In most of the small towns, the bus is the only form of public passenger transport. Busses provide transport connectivity throughout the city and contribute to the integration of all districts of the city into a single urban complex.
Keywords: public transport, intercity, passenger flow, station, operating speed, route, bus, intersection, traffic.

INTRODUCTION

Despite the fact that large-scale work has been done to improve public transport in the city of Tashkent, as the population grows, the demands of for modern public transport are increasing day by day.

When President Sh. Mirziyoyev was in the 18th bus shed of the "Toshshahartranskhizmat" join-stock company system on December 13. 2022, he noted that the field of the public transport system is lagging behind the current changes. Taking into account the use of 1 million 300 thousand passengers in the city of Tashkent, as a result of the lack of busses in the system of "Toshshahartranskhizmat" JSC and moral obsolescence, passengers face inconvenience in using the service of this system.

OBJECTS AND METHODS OF RESEARCH

In the winter season, the problems of the continuous operation of the public transport system, meeting the transport requirements of the population were analyzed, and the study of the efficiency of passenger transportation was carried out at the 5th bus place branch of the "Toshshahartranskhizmat" JSC system. A problematic route moving in the city of Tashkent was chosen for the study.

The passenger flow on the selected route was studied and the following problems were identified: exceeding the passenger capacity standards in the morning (7.00- 9.00 am) and evening (5.00-8.00 pm) peak hours of the day, some of the buses passing by stops without stopping, congestion causing disagreements among passengers, buses getting stuck in traffic at intersections, buses moving slowly in order to collect passengers, malfunctioning of the heating system of the bus cabin when the weather gets cold, etc. that the stops on the route do not meet the demand (lack of seats, a lot of waste, being cold in winter and hot in summer).

For the purpose of the study, we tentatively accepted this problematic direction as direction A. Busses of this route were staffed, and the flow of passengers was analyzed at peak times of the day by day of the week.

Table 1. Benchmark information of the selected problem area is presented in

№	*Directions*	*A direction*
1	*Bus type*	*SAZ LE 60*
2	*Bus passenger capacity*	*56*
3	*The total round trip distance of the route, km*	*33,58*
4	*Operating time of round trip, min*	*100*
5	*Number of stops on the route*	*68*
6	*Bus stop time at station 1, min*	*5*
7	*Bus stop time at station 2, min*	*2*
8	*Bus stop time at intermediate stops, min*	*1*
9	*Operating speed of buses, km/h*	*20*
10	*Interval time of bus, min*	*12*

Based on the normative indicators presented in table 1, the interval time of buses was determined by this expression

$$J_a = \frac{t_0}{A_i},$$

Here t_0 - the time of the bus on route min , A_i -the number of busses on the route

$$t_0 = \frac{l_м 60}{\upsilon_э},$$

Here $l_м$ – the length of route km; $\upsilon_э$ - the speed of bus km/h

RESULTS AND THEIR DISCUSSION

In the period from December 19 to December 27,2022, the flow of passengers on conditionally accepted buses of the A route, the intermediate interval time of movement, the delay times from the schedule of the buses, as well as the payment types of the fare were determined.

Table 2

The results of the calculations are presented in table 2.

№	Date	Number of the buses on the route	Number of passengers served		Toll revenue	Maximum delay time of the route, min.	verage interval time
			Cash and validator	Card			
1	19.12.2022	9	4064	1643	5689600	40	35
2	20.12.2022	9	4128	1678	5779200	44	36
3	21.12.2022	9	4107	1745	5749000	30	31
4	22.12.2022	9	4112	1561	5756800	32	32
5	23.12.2022	9	4140	1505	5796000	25	28
6	24.12.2022	8	2917	1009	4083800	26	23
7	25.12.2022	7	1710	430	2394000	24	24
8	26.12.2022	10	4307	835	6155800	20	16

The results of the study were represented by the following diagrams.(Pictures 1-4)

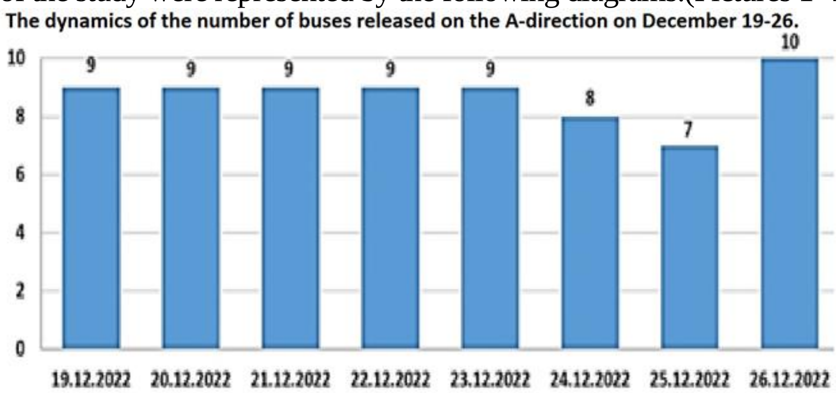

Figure 1. The results of the study were represented by the following diagrams

According to the route standard, there are fewer buses on the route on Saturdays and Sundays due to reduced passenger flow. Based on the analysis of the passenger flow, it was recommended to increase the number of buses on the route on December 26, 2022.

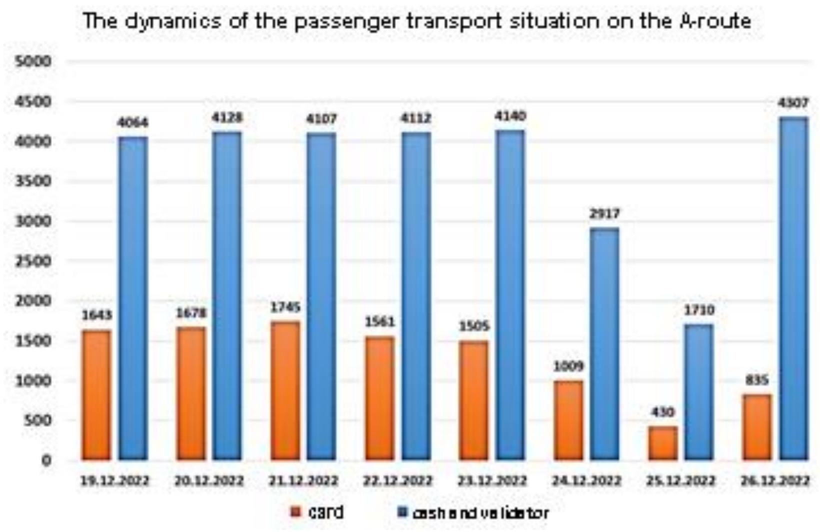

Figure 2. The results of the study were represented by the following diagrams

As a result of increasing the number of buses, the number of passengers traveling on buses of this route has also proportionally increased (picture 2). Also, according to the analysis of the form of fare payment , during the week it was found that cash payment is 2.5-5 times higher than card payment. But considering the existence of corrupt situations in the cash payment system, it is appropriate to explain the advantages of the payment system through travel cards and mobile applications to passengers through various social media. Compared to December 19, the total number of the passengers on December 26 decreased by 565 people, but it is noteworthy that the number of people paying with cash increased by 243 people. The reason why for this is that pupils and students of higher and secondary educational institutions in Tashkent have gone on vacation, and accordingly, the number of card payers has decreased to 808.

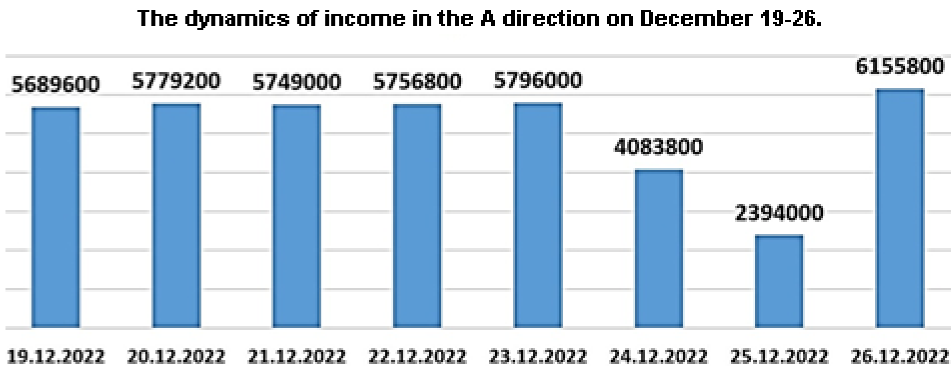

Figure 3. The results of the study were represented by the following diagrams

When weekly income analyzed, it increased by 466,200 soums due to the fact the number of passengers using cash and validators increased by 333 on December 26 compared to December 19 (picture 3).

According to a plan, A-route buses spend 100 minutes to make 1 round trip, but in practice, buses in this route spent 150-170 minutes on average during rush hours, and 120-140 minutes during off-peak times. Interval time of buses between stops is on average 15-25 minutes, which has caused reasonable objections of passengers.

As a result of research, in order to further increase the efficiency of the public services system in directions, to reduce the time between stops, the number of buses going to the routes has been increased from 9 to 10.

As a result, on December 26, it spent 120 minutes during rush hour, 110 minutes during off-peak hours, and compared to the previous week, the average travel time was reduced by 10 minutes.

Also, during the analysis, it was found out that last week, the average travel time of buses on this route between stops was 15-25 minutes, but now it has been reduced to 10-15 minutes.

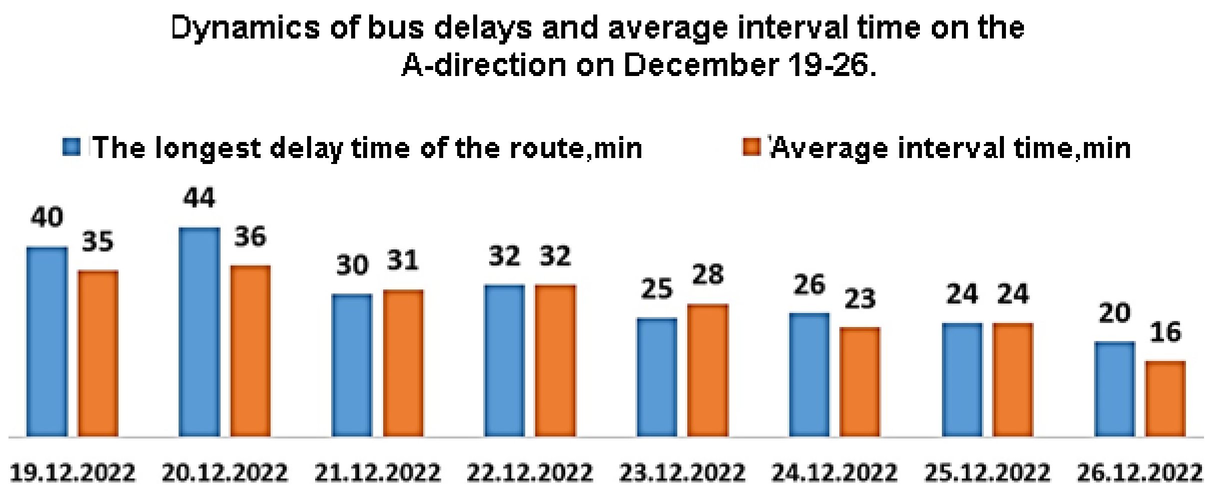

Figure 4. The results of the study were represented by the following diagrams

Along with the analysis of the passenger flow, social questionnaires were conducted with passengers on the conditions created at stations and buses, and existing problems.

On February 16, 2023, the Resolution of the President of the Republic of Uzbekistan “On measure to Reform the Public Transport System” was adopted at a very necessary time, and the rapid implementation of the tasks set in it will serve to eliminate problems in the system faster.

CONCLUSION

The following conclusion were formed on the basis of research carried out in the A direction:

1. Passengers stated that it would be appropriate to place MAN A22 CNG buses with a length of 12 meters, a large capacity (up to 100) and a low floor on the A-route.
2. The analysis of passenger traffic in the morning (7:00-9:00 am) and evening (5:00-8:00 pm) rush hours shows that the number of passengers in the morning hours is 1.6 times higher than in the evening rush hours.
3. Most of the passengers are paying the face in cash. This does not ensure the transparency of the income. Therefore, it is appropriate to explain passengers the advantages of the payment system through travel cards and mobile applications through various social media.
4. In this direction, large-capacity electric buses with a modern interior heating and cooling system, suitable for the elderly and disabled, should be placed, and their number should be differentiated by calculating the flow of passengers.
5. The average operating speed of buses is around 15/h instead of the standard 20km/h. The reason for this is that buses are stuck in traffic jams at problematic intersections, various vehicles are left irregularly in the area of stations, drivers stop for a long time at intermediate stations and pick up passengers in order to fulfill the daily schedule, etc.

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