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ТУРИНСКОГО ПОЛИТЕХНИЧЕСКОГО УНИВЕРСИТЕТА В ГОРОДЕ ТАШКЕНТЕ

ACTA
OF TURIN POLYTECHNIC UNIVERSITY IN TASHKENT

ВЫПУСК
EDITION 4/2023

TOSHKENT SHAHRIDAGI TURIN
POLITEXNIKA UNIVERSITETI
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ACTA TTPU

Preface

Dear readers! I am pleased to announce the publication of a new edition of ACTA TTPU, the journal of Turin Polytechnic University. It is an № 4 issue to be published in 2023 year which includes selected articles submitted to the editorial board. Since the beginning of the year, we have seen an increase in the number of articles submitted to our journal, and I believe that the growing popularity of the journal is partly due to the excellent work of the editorial board. We will continue our efforts to improve the quality as well as the submission requirements and simplify the selection procedures in order to raise the quality to a higher level.

I am very grateful to our editorial board for their contribution to the quality of our journal and to all authors for their submissions. We are always open to any criticism and suggestions to improve the readability and content of the articles published in our journal.

Editor-in-chief
DSc., Professor J.Sh.Inoyatkhodjaev

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UNDERGROUND LASER TACHEOMETRIC NAVIGATION SYSTEM OF A TUNNELING COMPLEX WITH A SOIL LOAD "HERRENKNECHT"

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Abstract– This article discusses the basic principles and implementation of innovative technologies of the latest underground laser navigation system of the Herrenknecht tunnelling complex in the field of underground construction of the second Yunusabad line of the Tashkent metro.

Key words– navigation, tacheometer, mechanized tunnel-boring achines (TBM), tubing ring, polygonometry.

I Introduction

In present days, surveying services of mining enterprises are trying to introduce GPS/GNSS equipment and other modern measuring instruments into their work. From October 2018 to May 2019, the construction of the second Yunusabad Line marked a new stage in the development and transformation of the Tashkent Metro. The utilization of the mechanized tunnel boring system manufactured by the German company "Herrenknecht" has led to effective results in tunnel construction [1]. It should be noted that the mechanized tunnel-boring complex (TBC) performs not only tunneling work, but at the same time strengthens the underground passage, leaving behind a ready-made reinforced concrete tunnel. This complex operates in difficult engineering and geological conditions. The tunnel boring machine is equipped with state-of-the-art navigation electronics developed by the German company VMT GmbH and is capable of excavating a maximum of 12 meters of tunnel per day [3].

GPS/GNSS certainly greatly simplifies the work of a surveyor on the surface, where there is a signal from satellites, but what about specialists in the field of construction and mining underground?

The essence of inertial underground navigation is to determine the acceleration of an object and its angular velocities using instruments and devices installed on a moving object. The advantages of inertial navigation methods are autonomy, noise immunity and the possibility of automating all navigation processes. Due to this, inertial navigation methods are becoming more and more widely used in solving the problems of navigating underground works [5].

Currently, in the construction of tunnels for various purposes, automatic navigation systems are widely used. They allow you to determine the spatial position of the tunneling complex in real time, which significantly increases the speed, accuracy, quality and analysis of the structure under construction [4].

The SLS-SL (Space Launch System) system was developed by specialists of the German company VMT GmbH based on the space system and includes:

- "Robotic total station Leica TS15-1" with built-in laser, automatic aiming at the reflector;
- Prism reflector;
- Active laser target, Electronic Laser System (ELS);
- Radio modem #1 (mobile) and Radio modem #2 (fixed);
- Power cables;
- Central distribution radio modem (switch);
- Industrial computer with original «Tunis» software.

The navigation system SLS-SL is designed for tunneling shields of tunnels with tubing lining, the principle of operation of the system: when the Tunnel Boring Complex is moving, the current position of the target is continuously read from the system automatic total station and, by means of its correlation with the design axis of the tunnel, the exact position of the machine is displayed.

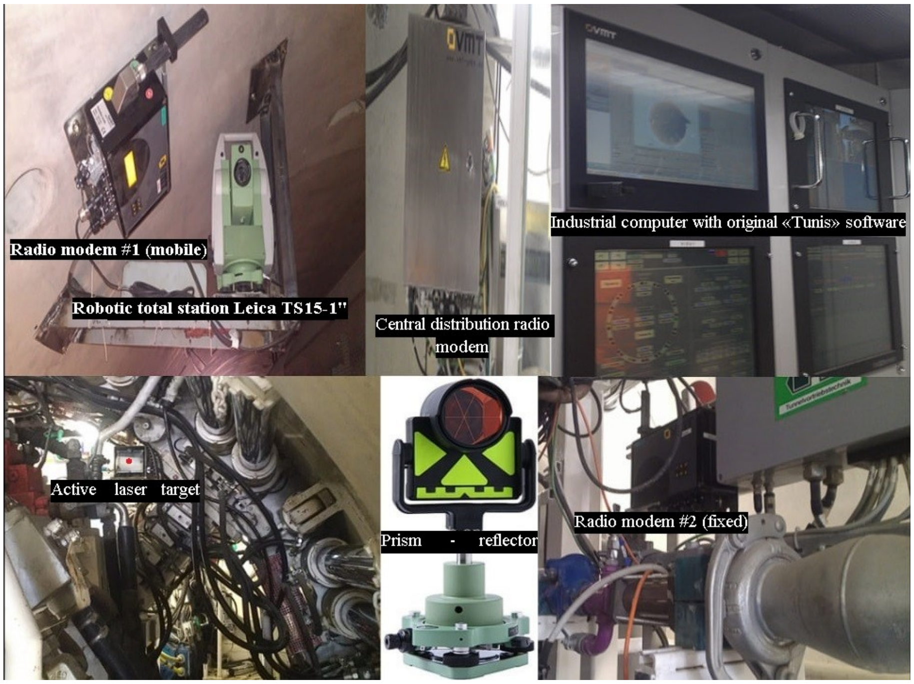

Fig. 1: Technical means of navigation equipment of the SLS-SL system by VMT GmbH

The next step in the construction of tunnels with tubing lining is the construction of the tubing ring itself in the tail of the TBM. The choice of the most suitable ring is of great importance, which determines the quality of the entire tunnel structure in the future. When the machine deviates from the design axis, the program automatically calculates the appropriate correction curve, which ensures that the machine is brought to the planned design axis. In addition to calculating the position of the rings and the order of their construction, as work progresses, the construction of a tunnel with a tubing lining to ensure high quality construction and guarantee its safety [2].

The modern technical means of equipping the navigation system are illustrated in Fig.1. The SLS (Space Launch System) navigation system by VMT, which transmits all the information necessary to move the TBM along a given route at high speed, was designed specifically for this purpose. In addition, it gives out full documentation describing the movement of the shield and a lot of additional information, for example:

- Calculation and representation of the position of the TBM in graphical and digital form;
- Calculation and image of the installed rings, showing the position of the ring after its installation;
- Calculation and display of trends in the movement of TBM (shield diagram);
- Calculation of a correction curve that tangentially brings the TBM back to a given track;
- Preliminary calculation of tubing rings to be installed in the future (based on the route and correction curve);
- Management of system elements from an industrial computer;
- Complete documentation of the shield progress (database, log files, etc.) [2].

Fig.2.depicts the schematic representation of the installation, devices, and equipment of the underground navigation system for the tunnel boring machine "Herrenknecht".

The operation of the system is based on the determination of the active target by electronic pallets relative coordinates of the point of the laser beam, using "Tunis" software which converting them into absolute coordinates and determining the offset from the design positions of the knife, tail and front base point of the shield [8].

"Tunis" is an embedded software platform for data preparation and analysis in tunnel construction projects.

"Tunis" stands for Tunnel and Underground Integrated Software Structure.

"Tunis" includes software modules for any task related to tunnelling, for example:

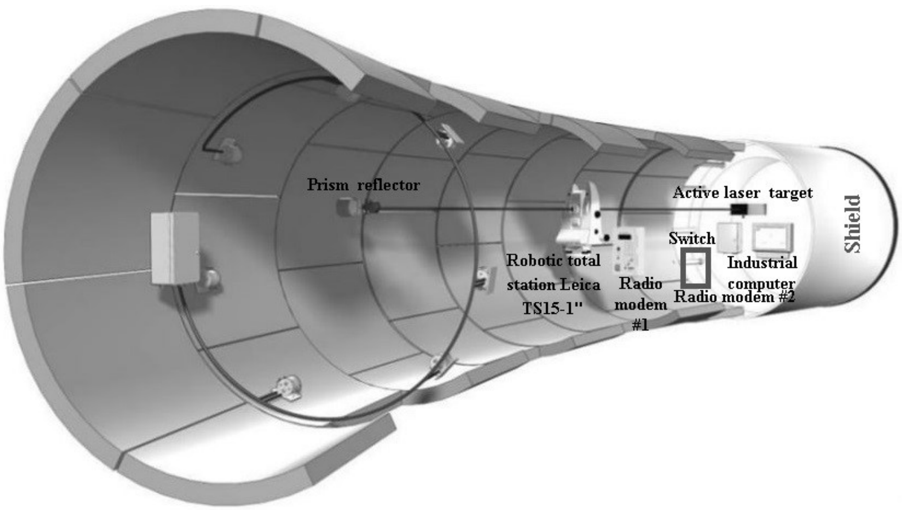

Fig. 2: Schematic diagram of the installation of the SLS-SL navigation system from VMT GmbH

- Registration and preparation of navigational data for far-sighted and reliable navigation of the tunnel-boring mechanized complex;
- Until documentation of all received data.

Tunis is distinguished primarily by a holistic interface and a harmonious concept of data processing.

- Single design and consistent management;
- Documentation of data following general instructions;
- Standard protocols;
- Ability to adapt to customer requirements;
- Tunnel-suitable, rugged and proven hardware security.

Mine surveyors are involved in all stages of tunnel construction, from surveying, designing and ending with construction, operation of an underground structure, which means that a mine surveyor is required to have solid experience in performing surveying work. In Fig.3., surveyor data of the last installed reinforced concrete ring is visible. It is impossible to judge the accuracy of measuring angles and the distance of underground mine surveying points by the result of the TBM navigation system, since it makes a hanging move [7]. The big disadvantage of an inertial navigation system is that its error accumulates over time. This is due to the integrating action of the system itself. Therefore, the results of measurements of the inertial system require periodic corrections. Before starting work, the SLS-SL navigation system is tied to points of the underground mine surveying network with known coordinates using traditional measurement methods using a high-precision electronic total station. The so-called external orientation is measured. In the process of field measurements, spatial information obtained by means of navigation is recorded in the permanent memory of an industrial computer. Surveying work must be carried out in such a way that reliable control is exercised in the process of surveying measurements [6].

The principle of operation of the navigation system "SLS-SL - Tubing" is as follows: when the tunneling complex moves, the current position of the target is continuously read from the automatic total station and by correlating it with the design axis of the tunnel, the exact position of the machine is displayed. The next step in the construction of tunnels with tubing lining is the construction of the tubing ring itself in the tail of the TBM. The choice of the most suitable ring is of great importance, which determines the quality of the entire tunnel structure in the future. However, even experienced tubing teams often cannot predict the situation more than one ring ahead [10]. Each calculation must take into account such parameters as: the translational movement of the tunneling complex, the liner clearance, the type of ring, the location of the machine in relation to the design axis of the tunnel, etc. For these purposes, VMT has developed a special program: "RMP - Program for calculating the position of the tubing ring and the order of building rings". This development allows you to calculate the laying order for several rings ahead, as well as for the entire length of the tunnel. The values obtained during the calculation are documented and stored in the database. When the machine deviates from the design axis, the program automatically calculates the appropriate correction curve, which ensures that the machine is brought to the planned design axis. When constructing a chain of triangles that ensures the construction of this subway line, as a rule, city triangulation signs were used. The

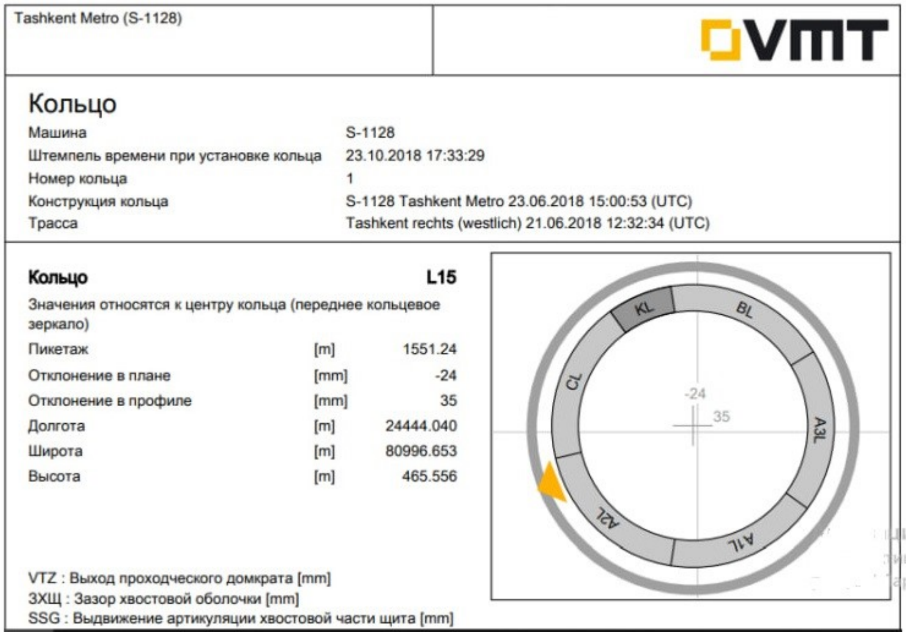

Fig. 3: Displaying the information of the last constructed reinforced concrete ring

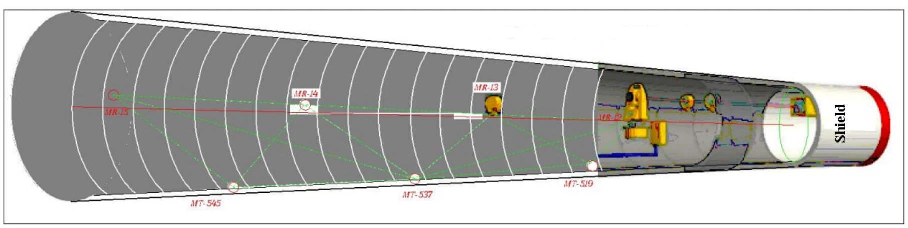

Fig. 4: Installations and application of linear-angular networks in the construction of tunnels

development of underground polygonometry was carried out through a vertical shaft by direct adjacency to the points of the ground geodetic base. After each successive orientation, all measurements by underground polygonometry were repeated again and the necessary calculations were made. The length of one-way tunneling was 1.5 km. , therefore, the underground polygonometry was laid in the form of triangles, with such a system, the working underground polygonometry with sides from 25 to 50 m was observed, the main underground polygonometry with sides from 50 to 100 m, and the main underground polygonometry with sides 150-200 m. [6]. Improved consoles for forced centering of points of the main and main tunnel polygonometry are for the installation of a robotic electronic total station TBM. The proposed design is designed for a rational location along the design metro route. Creation of a geodesic-surveyor linear-angular network for underground construction of the subway to provide TBM navigation. In Fig.4., a diagram of the linear-angular network is presented, which is used for the surveyor justification of tunnel construction. The control over the geometric parameters of the structure has to be carried out throughout the entire movement of the TBM, starting from the ground support geodetic-surveying base [9].

The CREDO DAT and CREDO NIV software was used to facilitate and improve the work for pre-calculation, processing and adjustment of the linear-angular network of the underground main and main polygonometry and leveling. Office processing was performed by the specialists of the State Unitary Enterprise "O‘zGASHKLITI".

An optimal linear-angular network for laying the underground main and main polygonometry has been created to introduce a correction in the coordinates and elevations of the console with forced centering of the TBM. Estimates of the accuracy of the positions of points based on the results of the adjustment are given in Table 1.

The most accurate point among those presented in Table is MT193 in terms of $(M_x; M_y)$, while in terms of height (Mh), it is MK309.

The vertical transmission of marks to the horizon of the subway penetration was applied with a Leica DISTO laser

Survey points	**Root Mean Square (RMS) error of point measurements** (M), m	**Root Mean Square Errors of Point Position along Coordinate Axes,** m		**Correction Equation Coefficients,** m		**Directiona Angles** (α), $deg., min., sec.$	**Mean Square Error of Elevation,** $(Mh), m$
		M_x	M_y	**a**	**b**		
1	2	3	4	5	6	7	8
MK309	0.008	0.005	0.006	0.007	0.004	129°34’27”	0.010
MR-16-302	0.007	0.005	0.005	0.006	0.004	128°31’08”	
MR-17-333	0.009	0.006	0.007	0.008	0.004	130°37’11”	0.016
MR15	0.006	0.004	0.004	0.005	0.003	127°16’39”	0.017
MT93							0.046
MT123							0.040
MT158							0.036
MT193	0.002	0.002	0.001	0.002	0.001	31°57’36”	0.034
MT226	0.003	0.002	0.002	0.002	0.002	122°44’30”	0.027
MT258	0.005	0.003	0.004	0.004	0.003	123°38’15”	0.023

TABLE 1

rangefinder twice and with two compared steel tapes. The main technical effect of the practical application of the developed methods for substantiating the technological parameters of transferring marks to the horizon of the metro mine with a high-precision electronic-laser rangefinder "Disto", development and practical application of forced centering consoles, as well as the method of a linear-angular network with processing in the Credo.Dat software during the construction of the metro in Tashkent, is to increase the productivity of penetration, the safety of mine surveying [11].

Fig. 5: Successful exit of the TBM into the dismantling chamber

When the tunneling is completed, surveyors and builders demonstratively excavate the final centimeters of the tunnel. This event, depicted in Fig.5. is referred to as "finishing" or "completing the tunnel.".During the excavation of workings in the Quaternary loam zone, the developed soil was pressed in the TBM screw conveyor into large blocks, which ultimately led to an emergency stop of the conveyor. The experience gained showed the need for a more thorough study of mining and geological conditions along the subway tunnel route for the timely determination of conditioning compositions. The developed methods have been fully applied and used in the sinking of the "Second stage of the Yunusabad line of the Tashkent metro". In the future, it is planned to develop it and increase the functionality during the construction of the metro. The complex of these methods made it possible to control with high accuracy and introduce timely amendments to the navigation of a robotic laser electronic total station, which made it possible to enter the closure chamber at PK 29+43.30 with a plan error of +3 mm. and 0 mm in height. Modern underground navigation technologies, high-tech equipment and ambitious projects, which are often on the verge of the possible - all this leads to the emergence of new developments that make the construction of subway tunnels safer, more economical and of higher quality.

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MATHEMATICAL MODEL FOR ESTIMATING THE LIFE CYCLE OF MOTOR OILS.

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Abstract– The paper presents an approach to get a mathematical model for describing a life cycle of motor oils an internal combustion engine (ICE). The numerical analysis of this mathematical model considering the variables of the process, is a very hard task. In this case, we propose the determination of this model using a temperatures regime of engine, in order to determine the vary quantity of parameter that effects the resources of the lubricant used an ICE. Our approach based on data uses the I. D. Rodziller theory for the identification of the mathematical model, which follows at varying temperatures of engines to solve the problem. The result data were collected from an used oil well. This paper presents the results of the training phase and of the generated models after several iterations of gasoline and hydrogen blends. Additionally, the paper analyses the differences between the generated theory, according to the number of variables considered, the complexity of the expressions, and the error.

Key words– ICE-internal combustion engine, Kinematic viscosity, mixture density, concentration, velocity intensity, velocity field, interpenetration, interaction, single-phase jet.

I INTRODUCTION

The load mode of operation of the engines is set depending on the designed temperature parameters and operating conditions of the vehicles. In this case, the optimal resource consumption of both the machine as a whole and the lubricant in particular is maintained. [1,2] The increased intensity of operation leads to significant loads on the power plant, which in turn leads to an increase in the temperature conditions of its operation, a decrease in the technical and operational life of mechanical systems and lubricants. The temperature regime of engines is the determining parameter that affects the resource of the lubricant used, and is estimated by the temperature of the coolant and oil at the engine outlet. The assessment by the thermal parameter of the oil is not carried out on all vehicles, machines and mechanisms. As a result, the coolant temperature remains the main evaluation parameter [3,4].

The main signs of a malfunction are engine overheating, low pressure in the lubrication system, contamination of the lubricant and its high waste consumption. Violation of the lubrication system performance reduces the resource of the lubricant and is the main cause of emergency equipment failure with further long-term impossibility of its operation. A decrease in oil pressure in the engine lubrication system can be caused by its insufficient quantity, overload or wear of parts of the cylinder-piston group, contamination of oil coolers that disrupt heat dissipation, and malfunction of oil pump pressure reducing valves. During the period of starting the engine in the cold period, oil at low temperatures is poorly pumped in the system, it lingers longer in the gaps of mating parts, which leads to increased wear of parts due to the absence of an oil film on their surfaces. [5,6]

II FORMULATION OF MATHEMATICAL MODEL

The blending of hydrogen in the composition of gasoline acts in the hydro and property of extracting hydrogen at high temperature. With increasing temperature, the hydro percentage of engine oil increases. The value of the dilution factor for the discharge of hydrogen and 85% mixing of gasoline is determined by the formula of I. D. Rodziller. [7].:

$$v = \frac{1 - e^{-\alpha \sqrt[3]{l}}}{1 + e^{-\alpha \sqrt[3]{l}} \frac{Q}{q_{hydrogen}}} \tag{1}$$

Where: *V=the value of dilution ratio, Q=gasoline capacity, q=hydrogen capacity.*

The dilution ratio of hydrogen in the most polluted gasoline is determined by the formula:

$$n_i = \frac{(q_{hydrogen} + \gamma Q)\partial b}{q_{hydrogen}} \tag{2}$$

Where: *n=nominal quantity of hydrogen, Q=gasoline capacity, q=hydrogen capacity. γ=is the dilution factor.*

The dilution ratio of hydrogen in minimally polluted gasoline is determined by the formula:

$$n_k = \frac{(\beta q_{hydrogen} + Q)}{\beta q_{hydrogen}} \quad (3)$$

Where: *n=minimal quantity of hydrogen, Q=gasoline capacity, q=hydrogen capacity.* β *is the turbulent diffusion coefficient.*

The mixing ratio of hydrogen with gasoline shows what part of the gasoline consumption is mixed with hydrogen [8,9,10].

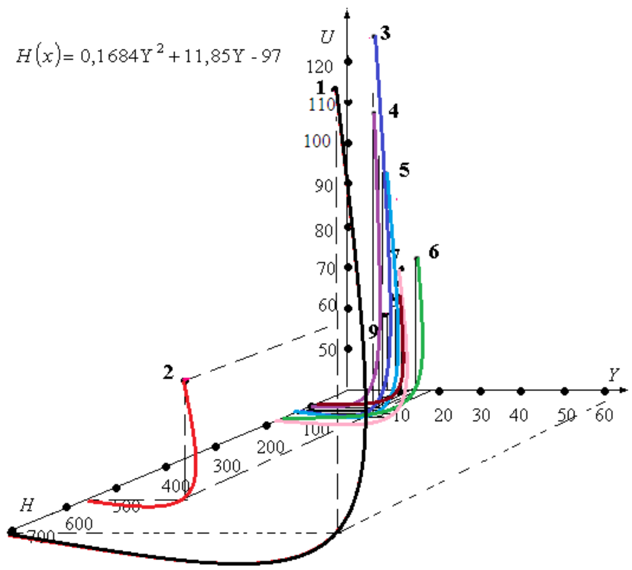

Fig. 1: Entry of hydrogen into gasoline mixtures, increase in hydro and determination of elimination limits.

This coefficient is determined by the formula:

$$\beta = \frac{1 - e^{-\alpha(\sqrt[3]{l} - \sqrt[3]{l_0})}}{1 + e^{-\alpha(\sqrt[3]{l} - \sqrt[3]{l_0})} \frac{Q}{q_{cm}}} \quad (4)$$

Where: β*=coefficient of hydrogen, Q=gasoline capacity, q=hydrogen capacity, l=refers to the distance.*

Under L - means the distance at which hydrogen is supplied. To determine the dilution ratio of gasoline with hydrogen [11,12,13], the following formula is proposed:

$$n_p = \frac{S\varphi H}{Ax(B-L)lgRe_\delta} \quad (5)$$

Where:

$$Re_\delta = \frac{\vartheta H}{D} [here \quad D = \frac{\vartheta g H}{2mC}, \quad 2m = 0,7C + 6] \quad (6)$$

Where: *D=diffusion Reynolds number. V=velocity of diffuse of hydrogen,* R_e*=Reynolds number,* n_p*=normal quantity of hydrogen, g=gravitational acceleration.*

$$A = \frac{S_{eks}}{S_{lab}} \quad (7)$$

[here S_{lab} is determined by the formula at A=1]
coefficient of proportionality, changing from 0.9-2;

$$\varphi = \frac{l_{eks}}{l_{lab}} \quad (8)$$

Where: φ*=tortuosity coefficient (from outlet line to design line), x=-distance from the end of the release, B= is the width of the dissolved part of gasoline; L= the length of the scattering outlet, H=average depth of flow over outlet, V=average flow velocity over outlet. [14,15,16,17].*

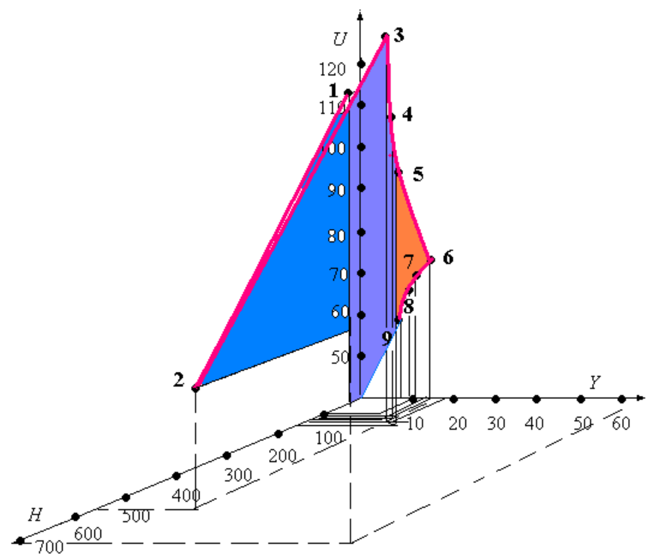

Fig. 2: Engine oil life cycle graph and find out of life cycle limits.

For the initial dilution in an arbitrary section of an axisymmetric hydrogen jet,[68] we have the formula:

$$n_H = \frac{0,258}{1-m}\left(\frac{d}{d_0}\right)^2 \left[\sqrt{m^2 + 8,1(1-m)\left(\frac{d_0}{d}\right)^2} - m\right] \quad (9)$$

Where: n_H*=the quantity of hydrogen,* $m = \frac{\vartheta p}{\vartheta 0}$ *is the ratio of the calculated flow rate to the outflow rate of the gasoline jet, d=- jet diameter at an arbitrary distance from the outlet,* d_o*=the diameter of a single falling jet of gasoline.*

The limiting value of the initial dilution is observed in the section where the maximum jet diameter reaches a value equal to the depth of the gasoline flow. For this case, formula (5) takes the form:[18,19,20]

$$n_H = \frac{0,258}{1-m}\left(\frac{H}{d_0}\right)^2\left[\sqrt{m^2+8,1(1-m)\left(\frac{d_0}{H}\right)^2}-m\right] \quad (10)$$

To calculate the dilution of gasoline with hydrogen [6], there is a formula:

$$n_{tot} = \frac{(q_{cm}+Q)}{q_{cm}+Qe^{-\beta(\frac{1}{R})^{\frac{1}{4}}}+Q_H} \quad (11)$$

for lowest total dilution

$$n_{tot} = \frac{(q_{cm}+Q)}{(Q-Q_H+q_{cm})e^{-\beta(\frac{1}{R})^{\frac{1}{4}}}+Q_H} \quad (12)$$

Where: Q_H*=is the consumption of a mixture of gasoline and hydrogen in the initial dilution section:*

$$Q_H = n_H q \quad (13)$$

Based on the analysis given in table, we will compile a function of changes.

	U	***Y***	***H***
1	116,6	66,8	705,83
2	111,52	15,97	5656
3	109,75	14,39	139,9
4	108,94	14,2	138,2
5	96,29	14,58	143
6	79,93	13,7	131,2
7	76,82	11,6	102,8
8	76,81	12,88	118,7
9	75,9	11,43	3457

TABLE 1

Based on these parameters and using a 1-table, we write Newton's interpolation formula in the form [21]:

U and Y = kinematic viscosity at 40^oC and 100^oC; H = the value determined on the basis of a special table, if it is higher than 70 mm^2/s at 100^oC, it is determined by the following formula:

$$H = 0.1684Y^2 + 11.85Y - 97 \quad (14)$$

$$L(x) = y_0\frac{(x-x_1)(x-x_2)}{(x_0-x_1)(x_0-x_2)} + y_1\frac{(x-x_0)(x-x_2)}{(x_1-x_0)(x_1-x_2)} \quad (15)$$

$$L(x) = 0,1684x^2 + 11,85x - 97$$
$$H(x) = 0,1684Y^2 + 11,85Y - 97$$

III MATERIALS AND METHODS

Green hydrogen is defined as hydrogen produced without releasing any hazardous emissions. Using an electrolysis process that uses a car battery as electricity, green hydrogen is created from water.

For the research development, a spark-ignition engine was used, with a compression ratio of 9.5:1, displacement of 2.0 L and natural aspiration. Additionally, air-hydrogen mixer was used in engine intake manifold system.

Engine oils from the three different manufacturers were used in research. All oils were of the different viscosity grade and were applied to 3 vehicles (one each oil). Which were operated in similar conditions. The tested cars were operated mostly on gasoline blend with hydrogen gas. The FTIR methods are used to analysis changes of viscosity index, total acid number (TAN), total base number (TBN), and flash points of engine oils.

Obtained practical analysis result were used to determine functional dependencies, describing the kinetics of the formation of specific characteristics of oil. Newton interpolation formula was used as a measure of error. In the analysis, the model is based on the 2nd order polynomial regression. When all the test indicated have yielded non-significant result, the procedure was completed.

IV RESULT

The propagation speed of the mixture of diffusion of gasoline and hydrogen along the O_x axis also decreases across the cross section, which means an increase in the vortex mixture. A decrease in oil pressure in the engine lubrication system can be caused by an increase in vortex zones and insufficient oil. It is proposed to increase the speed of the jets of a mixture of gasoline and hydrogen under strict conditions.

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ECONOMIC LOSS DURING VEHICLES ARE DELAYED AT THE CROSSROADS

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Abstract– The article calculates economic losses when vehicles are delayed at regulated intersections. The studying aims to calculate the economic costs for various methods of regulation at intersections. Studies of the traffic flow have been carried out, transport delays and economic losses have been calculated. The results of the studying show how it is important to optimize traffic regulation.

Key words– road transport, regulated intersection, delaying, socio-economic consequences.

I INTRODUCTION

The growth of the country's car park, along with a positive impact on the economy, can make worse the working conditions of drivers due to the oversaturation of the road and street network with vehicles or cause negative socio-economic consequences (traffic accidents, reduced vehicle speeds, etc.).

The social effect is characterized by the improvement of social relations, changes in the ecological environment, conditions and labor protection, and the comprehensive development of the individual. The economic effect, in this case, is characterized by an increase in national income obtained by improving the organization of traffic, as a result of scientific and technological progress.

However, the economic and social effects can grow at different rates. In addition, a positive economic effect may be accompanied by a negative social effect. Therefore, the main task in the field of organization and road safety is the implementation of such measures and the development of such technical means that would provide positive values for both types of effect.

II PUBLICATION ANALYSIS

The analysis of the existing types of classification of intersections showed that they have a purely formal division and do not take into account the characteristic features of the intersection, the geometry, the characteristics of the development area of the intersection, stopping points for urban passenger transport, as well as the traffic intensity of pedestrian and traffic flows. In most cases, the class of the transport hub is determined by the technical category the city streets that form it.

The basis of the study was theoretical and practical works in the field of regulation and ensuring road safety of scientists, including V. Silyanov, M.B. Afanasiev, D. Drew, M.J. Beckman, F.V. Webster, K.Kh. Azizov, Zh. Sodikov, A.Ernazarov and many other specialists [1-8].

It should be noted that all existing models to determine transports delays either limitations or do not take into account specific road conditions or require a large number of different parameters and coefficients, which leads to errors in calculations and, as a result, reduces their practical significance. Delayings create the basis for suboptimal traffic signals, reduced service levels and capacity at intersections, increased emissions of harmful substances into the environment, travel time at a regulated intersection, excessive fuel consumption by cars.

III RESEARCH METHODS

One of the important problems in evaluating the effectiveness of measures aimed at improving the organization of traffic is the identification and determination of socio-economic losses associated with the imperfection of the organization of traffic. Improvement of the constructive safety of cars, the technical condition and arrangement of roads, and the professional training of drivers can have a significant impact on their reduction.

In a general video about the effectiveness of activities that improve traffic management, patterns:

- Reducing vehicle time loss;
- Reducing the loss of time for passengers in public and individual transport;
- Reducing the loss of time for pedestrians at the intersection of streets and highways;
- Reducing the level of traffic noise;

№	Crossroads	Number of phases in a cycle	Cycle time (Sec.)
1	The intersection of I. Karimov Avenue with the street Mustaqillik	4	96
2	The intersection of I. Karimov Avenue with the street Bainalminal	4	68
3	The intersection of I. Karimov Avenue with the street. S. Khamrokulova	2	32
4	The intersection of I. Karimov Avenue with the street Shifokor	3	48
5	The intersection of st. Tukimachilik to I. Karimov Avenue	2	32
6	The intersection of I. Karimov Avenue with the street Ortikova	2	32
7	The intersection of I. Karimov Avenue with the street Kaliya	4	72
8	The intersection of I. Karimov Avenue with the street Tashkent	4	82

TABLE 1: CHARACTERISTICS OF INTERSECTIONS.

- Improving the sanitary condition of the air basin (reducing the concentration of air pollutants);
- Reducing the concentration of harmful substances polluting the roadside.

Measures to organize traffic, making specific changes either to the condition and length of the road and street network, or to the conditions for the movement of vehicles, passengers and pedestrians on an existing network, affect the level of transportation costs in road transport and the loss of transportation costs for road transport and losses in industry, agriculture, construction associated with insufficient satisfaction of transportation needs. In addition, the sphere of economic influence of measures for the traffic management also includes an increase in net output in the sectors of material production that do not belong to the transport industry, cost reduction or profit growth in non-production organizations while meeting the corresponding social needs [12]. In addition to the economic effect, traffic management activities cause some types of socio-economic effect, mainly reducing the losses of the national economy and society as a whole while reducing the number of road accidents and losses associated with the time spent on the journey of pedestrians and passengers using both public passenger transport and individual vehicles. In the latter case, the side effect is expressed in the reduction of traffic fatigue during the journey of passengers (which contributes to the growth of labor productivity and higher quality products), as well as in the economic assessment of the saved free time of passengers.

IV RESEARCH RESULTS

At the period July-August 2021, the studying of the traffic flow along the entire length of I. Karimov Avenue (Jizzakh city) was carried out. This urban transport highway was chosen as the busiest, connecting the main transport routes of the city of Jizzakh, through further both intra-city routes for vehicles and urban inter-city routes.

The total length of I. Karimov Avenue is 7197 m.. The width of the carriageway is 23 m.;

Number of lanes in each direction – 3.

Number of intersections with traffic lights – 8 (Figure 1).

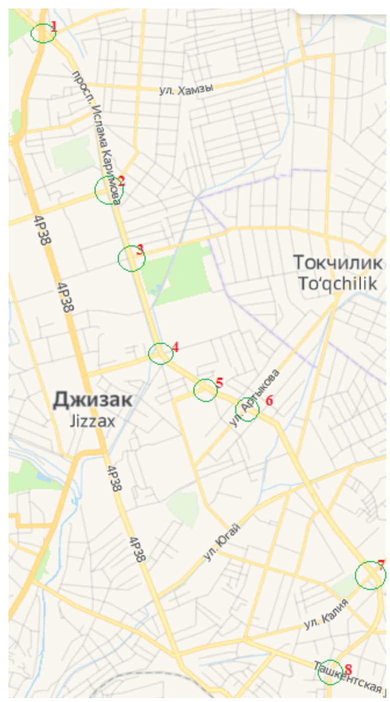

Fig. 1: Regulated intersections on I. Karimov Avenue.

On the avenue, there are intersections of various types, as well as a different types of the traffic flow throughout the entire avenue.

For regulated intersections, the frequency of operation of traffic lights is determined, taking into account the action of the prohibiting ("red") and allowing ("green") traffic light signals. An example of the intersection of avenue I Karimov with the street. Mustakillik (Figure 2).

Counting of vehicles passing through intersections on the

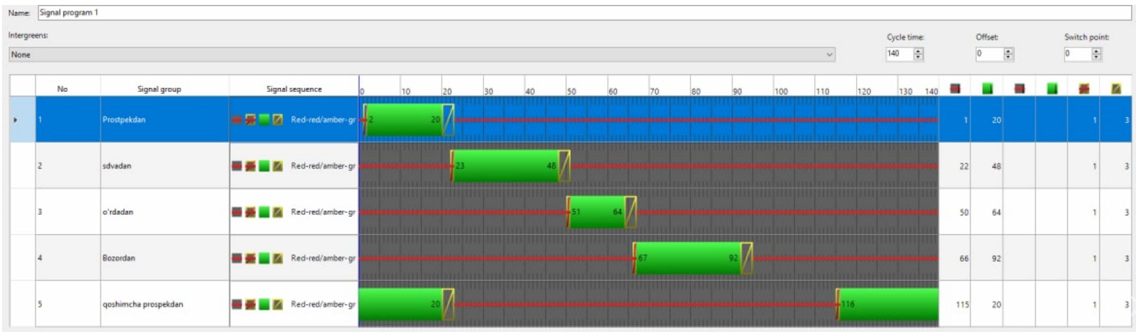

Fig. 2: Cyclogram of the intersection of I Karimov Avenue with Street Mustaqillik.

avenue was also made. The calculation was carried out on a weekday from 7-00 to 19-00. Results in Table 2.

№	Crossroads	Number of vehicles
1	The intersection of I. Karimov Avenue with the street Mustaqillik	59 138
2	The intersection of I. Karimov Avenue with the street Bainalminal	52 707
3	The intersection of I. Karimov Avenue with the street S. Khamrokulova	32 841
4	The intersection of I. Karimov Avenue with the street Shifokor	57 735
5	The intersection of st. Tukimachilik to I. Karimov Avenue	28 198
6	The intersection of I. Karimov Avenue with the street Ortikova	26 354
7	The intersection of I. Karimov Avenue with the street Kaliya	36 822
8	The intersection of I. Karimov Avenue with the street Tashkent	32 314
	Total:	**326 109**

TABLE 2: THE NUMBER OF VEHICLES CROSSING INTERSECTIONS IN 12 HOURS.

Calculation of the average delay of cars at a controlled intersection t_p is determined as a weighted average of those calculated for each phase [10]. Determination of delays for an intersection with a four-phase cycle by the formula:

$$t_p = 0.9\left[\frac{T*(1-\lambda)^2}{2(1-\lambda\chi)} + \frac{\chi^2}{2N(1-\chi)}\right] \quad (1)$$

$$t_p = 0.9\left[\frac{55*(1-0.327)^2}{2(1-0.3327*0.9)} + \frac{0.9^2}{2*0.796(1-0.9)}\right] = 19,2s$$

Delay definitions for a dual zone traffic intersection:

$$t_p = 0.9\left[\frac{46*(1-0.395)^2}{2(1-0.3395*0.7)} + \frac{0.7^2}{2*0.548(1-0.7)}\right] = 12,2s$$

Based on the results of the calculations, you can calculate the total daily delay of cars.

According to the results of the calculations, it can be seen that vehicles crossing the intersection on I. Karimov Avenue have a total of 120 hours of delay in one hour. Calculate losses from vehicle delays on I. Karimov Avenue

The cost of one machine-hour ($C_{(m-h)}$) must be determined, taking into account the additional costs of vehicle owners, per hour of lost time. These expenses include additional wages of the driver (except for vehicles owned by individuals), depreciation deductions, additional costs for fuel and lubricants [11].

The salary E_w can be determined based on the data on the average monthly earnings of drivers. E and the monthly fund of working hours F, which averages 170-180 hours:

$$E_w = k\frac{E}{F} \quad (2)$$

where $k = 1,26$ - coefficient taking into account deductions for a single social contribution [106]. Depreciation deductions for one hour Ea are calculated on the basis of the standard service life of vehicles T_n (available within 8-10 years), the annual fund of working hours F_w (1800-2000 hours) and the market value of the vehicle C_v :

$$E_a = \frac{C_v}{T_n F_w} \quad (3)$$

№	Crossroads	The number of intersections within 1 hour	Average vehicle delay (sec)	Vehicle delay within 1 hour
1	The intersection of I Karimov Avenue with the street Mustaqillik	4549	19,2	24,3
2	The intersection of I. Karimov Avenue with the street Bainalminal	4054	19,2	21,6
3	The intersection of I. Karimov Avenue with the street S. Khamrokulova	2526	19,2	8,6
4	The intersection of I. Karimov Avenue with the street Shifokor	4441	19,2	23,7
5	The intersection of st. Tukimachilik to I. Karimov Avenue	2169	19,2	7,4
6	The intersection of I. Karimov Avenue with the street. Ortikova	2027	19,2	6,9
7	The intersection of I. Karimov Avenue with the street Kaliya	2832	19,2	15,1
8	The intersection of I. Karimov Avenue with the street. Tashkent	2486	19,2	13,3
	Total	**25085**		**120,7**

TABLE 3

Additional costs for fuel and lubricants E_f per hour of vehicle operation are determined taking into account fuel consumption rates per 100 km of run R_c, average technical speed V_t and the cost of 1 liter of fuel F_l:

$$E_f = \frac{R_C V_t F_l}{100} \tag{4}$$

In order to obtain real values of E_w, E_a, E_f, statistical data on these values for 2021 was processed using the example of an Isuzu bus $C^{bus}_{(m-h)}$ is 87 thousand soums/hour.

The cost of one machine-hour of operation of passenger cars can be used from the data given in, $C^{pas}_{(m-h)}$ 38 thousand sum/hour.

The average cost of one machine-hour of vehicles operation, taking into account the composition of the vehicles, is determined by the sum:

$$C_{m-h} = C^{pas}_{m-h} n_{pas} + C^{bus}_{m-h} n_{bus} \tag{5}$$

where n_{pas}, n_{bus} are the number of cars and buses in the traffic flow, respectively.

According to this amount, it is possible to determine the cost of one car-hour of operation of vehicles to obtain a traffic flow, in which, for example, 70% of passenger cars and 30% of buses (trucks):

$$C^{70-30}_{m-h} = 0.7 * 38000 + 0.3 * 87000 = 26600 + 26100 = 52700 \quad sum$$

Calculate the economic losses of vehicles from downtime at the intersection:

$$Losses = C^{70-30}_{m-h} * t_{p-hour} = 120,7 * 52000 = 6276400 \quad sum/h$$

V RESULTS AND DISCUSSION

VI CONCLUSION

The economic efficiency of investments in measures that reduce delays at intersections is determined by comparing the cost savings that the implementation of measures provides with the costs necessary for their implementation.

The cost savings consist of:

- reducing the time spent by vehicles at intersections;
- reduction of losses associated with a reduction in the travel time of passengers and pedestrians;
- reduction of damage from road accidents;
- improving the sanitary condition of the air basin (reducing the concentration of air pollutants);
- the effect of improving the psycho-physiological working conditions of drivers.

Based on the above, it can be concluded that vehicle delays bring great economic losses. Adjustments to the durations of the resolving signals in the control cycle, as well as the number of phases in the cycle, allows you to save money by reducing the total delays of vehicles.

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DECOUPLING DESIGN PATTERNS

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Abstract– The article discusses decoupling patterns that are used as the basis for creating ORM (Object Relational Mapper) technology. Three decoupling patterns are considered: description, the problem that the pattern solves, the advantages and disadvantages of each pattern. Comparative characteristics and SWOT analysis are also shown.

Key words– design patterns, ORM, database

I Introduction

Design pattern - an architectural solution to a task or problem that arises when designing software. Design patterns make it easier to reuse successful designs and architectures. Expressing proven techniques as design patterns makes them more accessible to developers of new systems [1]. Design patterns have a number of advantages: scalability, they are time-tested and experienced by software architects and developers, reduction in design time due to the use of ready-made "templates". Design patterns also form an informal standard and terms (names) for solving known problems. This makes it easier to analyze and study the system if you indicate the name of the pattern used in the design of a particular part of the system. The relevance of database design patterns is determined by the fact that in most cases the system needs to store and process data and thereby use the database. Database design patterns allow you to simplify working with databases, build abstractions between application layers, and define the application architecture when working with data. Typically, a design pattern description consists of the following parts:

1. Name – defines the meaning of the pattern and the standard name for further use. The names form a dictionary of patterns.

2. Description of the problem - indicates the problem or case in which the problem occurs and also defines the statement of the problem.

3. Solution – indicates an architectural solution to a problem, usually using diagrams.

4. Result – shows the advantages, disadvantages, limitations of using the design pattern.

II Literature Analysis and Methodology

One of the fundamental literature on this theme is the book "Patterns of Enterprise Application Architecture" by Martin Fowler [2]. The book covers the theme in the context of using patterns to create enterprise applications. This literature discusses the theme of the object model and relational databases, various problems of interaction of an application with databases, object-based data mapping (use of OOP), and creating layers between the application and the database. Several database patterns are presented, such as: Active Record, Data Mapper, Gateway, Identity Map and others.

Some literature approaches the theme based on specific programming languages. For example, in [3], in the chapter Database Patterns, there are given some patterns with a description, implementation in the programming language PHP and the consequences of using the pattern. The theme is discussed in detail in [4] given such patterns as: Data Accessor (Data Access Object), Active Domain Object (Active Record), Object/Relational Map and others. For each pattern, an implementation in the Java programming language is provided. Data caching patterns are also discussed.

1 Object model and relational mapping

Let us look at interacting with data in an application (data layer) in the context of the OOP paradigm and relational databases. Let's define an object model as a model in which database entities will represent classes (models) and entity data will represent objects. In the case of a relational database, one object will represent one record in the table, and the object's properties store the values of the record's attributes. This model can be called object-relational. Table 1 shows the relationship between the elements of the relational database and the object-relational model.

Figure 1 shows an example of representing a table through a class.

Object-relational mapping (ORM) technology is built on

Relational data model	Informal name	Object-relational model
Relation	Table	Class (Model)
Tuple	Record, Row	Object
Attribute	Column	Property (of an object)
Selection*	Result table	Collection

*This is a relational algebra operation that consists of selecting data

TABLE 1: CORRESPONDING ELEMENTS OF THE RELATIONAL DATA MODEL AND THE OBJECT-RELATIONAL MODEL

the basis of this model. The task of ORM is to ensure work with the database in the application using OOP. Queries to the database are carried out through methods and work with data is carried out through objects. Thus, ORM creates an abstraction and encapsulates working with data and executing queries to the database.

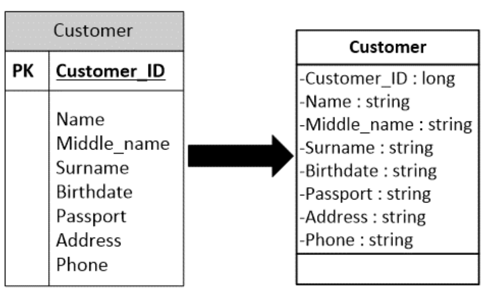

Fig. 1: Representing a database table through a class

Figure 2 shows the interaction diagram of ORM with the database

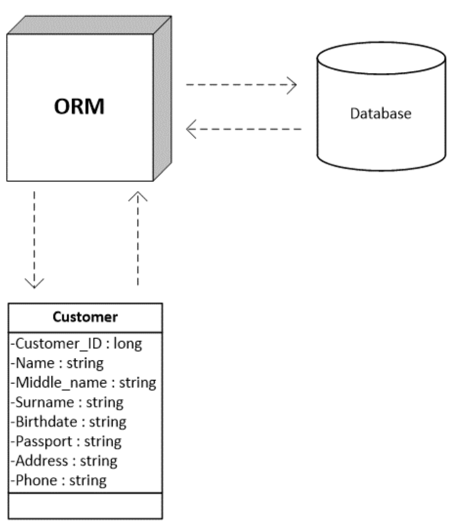

Fig. 2: Interaction between the model and the database

2 *Classification of Database Patterns*

Based on the problems that the pattern solves and the level of abstraction, database patterns can be divided into categories. In this article, we will define and consider some of them.

One of the main architectural problems when an application interacts with databases is to separate a part that works with data from other parts of the application, that is, create a data layer and also provide a way for this layer to interact with the business logic of the application. The most popular scheme is to divide the application into 3 layers: presentation, business logic, data layer (Figure 3).

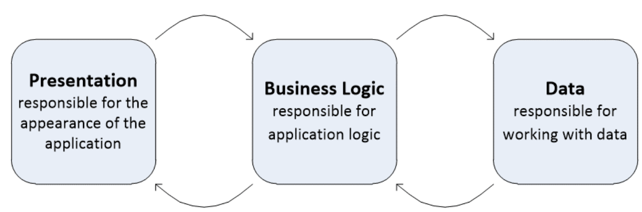

Fig. 3: Dividing the application into layers

To solve this problem, we define a category of decoupling patterns. Decoupling patterns define how application code relates to its data model and data access code. As you decide on an application architecture, you need to consider how much cohesion you want between orthogonal components based on how much you expect them to vary independently. Decoupling components also makes it easier to build and maintain them concurrently [4]. Examples of decoupling patterns include the following patterns: Active Record, Data Access Object, etc.

The next category of patterns is behavioral patterns. Behavioral patterns address issues of object state, identification, and loading. This category includes such patterns as: Unit of Work, Identity Map, etc. Data modeling patterns prescribe the structure and method of organizing data for different contexts. This category focuses on solving architectural problems at the database level. This category of pat-

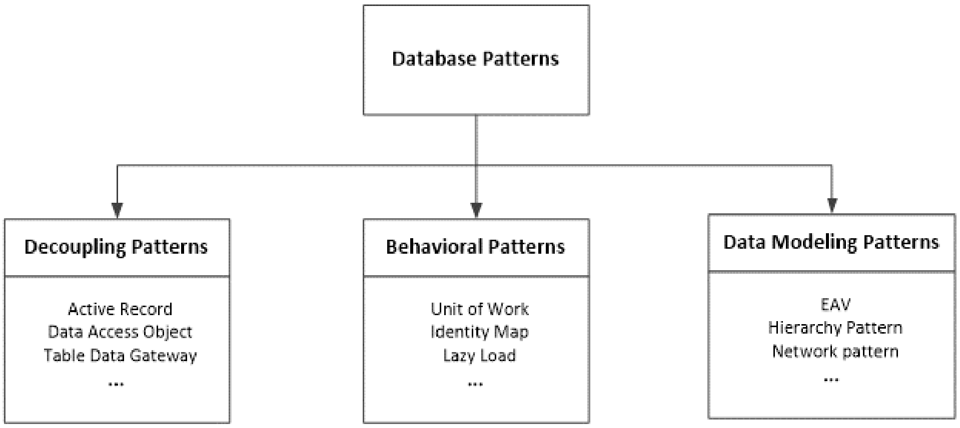

Fig. 4: Incomplete classification of database patterns

terns includes: EAV, Hierarchy Pattern, etc. Also, other categories are indicated in different sources. For example, in [2] are given object-relational mapping patterns *(Metadata Mapping, Query Object),* object-relational structural patterns *(Identity Field, Foreign Key Mapping)* in [4] resource patterns *(Resource Decorator, Resource Pool).* Figure 4 shows a classification diagram based on the three patterns described above.

3 Decoupling patterns

Active Record. In this pattern, an object represents the data of a single row of a database table as in the object model, encapsulates access to the database and also includes business logic. Business logic is included as object methods. Figure 5 shows an example of the Active Record pattern model.

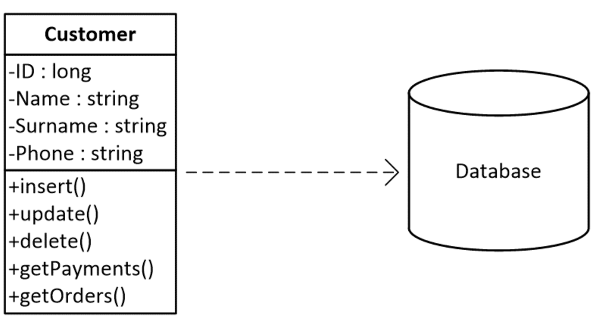

Fig. 5: Model of the Active Record pattern

Problem. As noted above, if there is a need to use a database in an application, the most correct thing is to create a layer for working with data so that other parts of the application do not interact directly with the data (this increases the complexity of the application and the connectivity between components) and also add the ability to define business logic in the process interaction with this layer.

Solution. The Active Record pattern solves this problem by using an object model and incorporating business logic into the object. Based on this, the following are usually included in the Active Record:

- fields corresponding to the table schema, access and modification methods (getters/setters) for them;
- various data transformation methods (mutators);
- methods for inserting, deleting, and updating data;
- data retrieval methods;
- business logic operations associated with this model.

It should be noted that Active Record usually interacts with the interface of a physical database adapter that will execute SQL queries to the database.

Purpose. Active Record is a good choice for business logic that isn't too complex, such as creates, reads, updates, and deletes. Derivations and validations based on a single record work well in this structure. Active Record is used by many ORMs and can be said to be an implementation of ORM.

Results. Using this pattern gives the following results:

Benefits

- Easy to add business logic;
- Simplifies working with data. Creates an abstraction for working with data other parts of the application do not need to know implementation details and can access models;
- Groups related data access code into a single component.

Drawbacks

- Violates the Single Responsibility Principle (SRP). The model will contain both business logic and data processing;
- Active Record is following the Database-First approach. You create a database and then model it in the code. It means that entities do not contain logic;
- When changing the way data is stored, problems with code refactoring may arise.

Data Access Object. An object that encapsulates and abstracts access to data from a persistent store or an external system. The Data Access Object or DAO pattern is used to separate low level data accessing operations from the application or business logic layer. Usually it uses relational databases as the data source, but may use other storage mechanisms and source types.

Problem. We can access source APIs directly to work with data, but this creates a strict dependency on that source or storage mechanism. That is, when changing the source, you will have to make changes to the code base in those places where access to the API is used. Using the Active Record example, it was indicated that it interacts with the interface of a physical database adapter that will execute SQL queries to the database.

Solution. Use a Data Access Object (DAO) to abstract and encapsulate all access to the data source. The DAO manages the connection with the data source to obtain and store data. The DAO provides an interface that ensures the necessary methods for working with a data source. Since the interface does not change, we can change the source quite easily. The DAO creates an abstraction for working with a data source and hides the implementation details. The data source can be relational DBMS, external data storage, files, etc. Following are the participants in Data Access Object Pattern:

- DAO interface - This interface defines the standard operations to be performed on a model object(s);
- DAO concrete class - This class implements above interface. This class is responsible to get data from a data source which can be database / xml or any other storage mechanism;
- Transfer object – This object contains data retrieved from source which are stored in object fields and access methods for this fields (getters/setters). The Data Access Object may use a Transfer Object to return data to the client;
- DataSource - This represents a data source implementation. A data source could be a database such as an RDBMS, OODBMS, XML repository, flat file system, and so forth;
- BusinessObject - The BusinessObject represents the data client. It is the object that requires access to the data source to obtain and store data.

Figure 6 shows the class diagram representing the relationships for the DAO pattern.

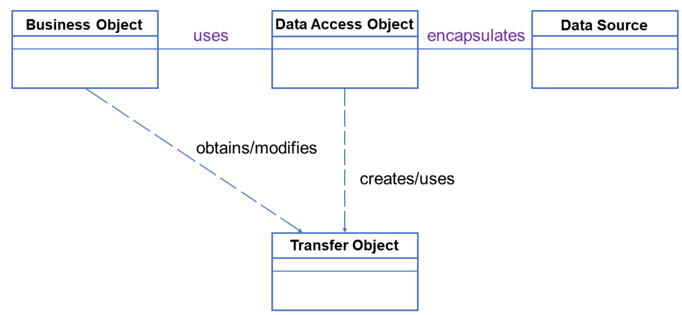

Fig. 6: The Data Access Object structure diagram

Figure 7 shows an example of the DAO class diagram.

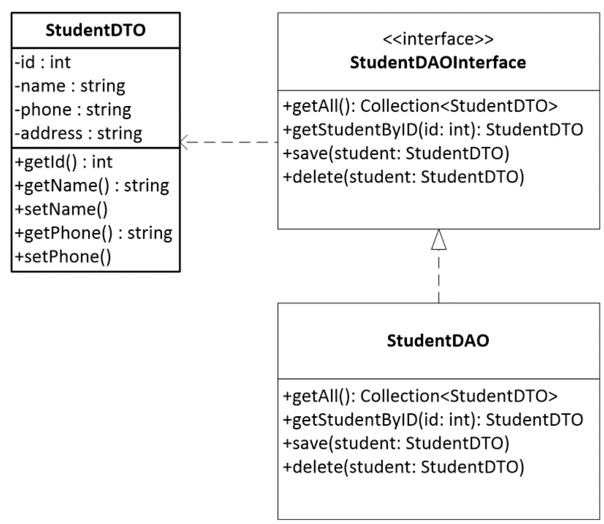

Fig. 7: Example of the DAO

Results. Using this pattern gives the following results:

Benefits

- Enables Transparency. Business objects can use the data source without knowing the specific details of the data source's implementation. Access is transparent because the implementation details are hidden inside the DAO;
- Enables Easier Migration. A layer of DAOs makes it easier for an application to migrate to a different database implementation;

- Reduces Code Complexity in Business Objects. Because the DAOs manage all the data access complexities, it simplifies the code in the business objects and other data clients that use the DAOs.

Drawbacks

- Adds Extra Layer. The DAOs create an additional layer of objects between the data client and the data source that need to be designed and implemented to leverage the benefits of this pattern. But the benefit realized by choosing this approach pays off for the additional effort;
- Needs Class Hierarchy Design. When using a factory strategy, the hierarchy of concrete factories and the hierarchy of concrete products produced by the factories need to be designed and implemented.

Data Mapper. A Data Mapper is a pattern that performs bidirectional transfer of data between a persistent data store (often a relational database) and an in-memory data representation.

Problem. The data we receive from a data source (usually a relational database) can be in different formats. Relational databases store data in the form of tables that consist of rows and columns. The format may differ for other storage systems. As with the object model, we need to map this data as an object and push changes back to the database if necessary. In addition, we may only need part of the data or a different storage structure.

Solution. The approach to solving this pattern is similar to the Data Access Object pattern. In practice, these two patterns provide a similar solution. A layer for working with data is created and a data transfer object is used/generated. But the Data Mapper pattern pays special attention to displaying data in an object and uses an additional EntityManager class. Figure 8 shows the class diagram of the DataMapper pattern.

Results. Using this pattern gives the following results:

Benefits

- Allows flexible customization of the creation of data objects that can come from different sources and in different formats;
- Separates the business logic of the application and the data layer. Separates other parts of the application from working with data and creates a single area of responsibility in the data layer;
- Good testability. The Data Mapper pattern promotes testability by decoupling the domain objects from the database. Since the domain objects are not tightly coupled to the database operations, you can easily write unit tests for the business logic without the need for an actual database connection.

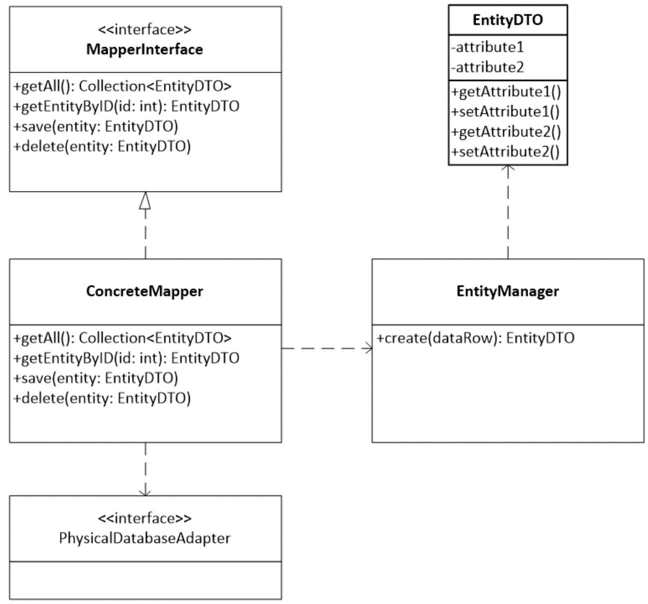

Fig. 8: The DataMapper structure diagram

Drawbacks

- Increased complexity. The Data Mapper adds an extra layer of abstraction, which can make the overall architecture more complex and harder to understand;
- Performance overhead. The data mapper must translate between the domain and the persistence layer, adding a performance overhead.

III RESULTS AND DISCUSSION

Table 2 provides a comparison of the three patterns above. Numerical characteristics are given on a scale from 0 to 5.

Figure 9 shows a SWOT (Strengths, Weaknesses, Opportunities, Threats) analysis of the Active Record pattern.

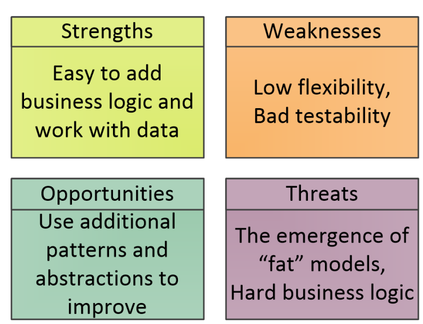

Fig. 9: SWOT analysis the Active Record

Pattern name	Antipattern	Which ORMs use the pattern	Popularity (0-5)	Complexity (0-5)	Related patterns	Flexibility (0-5)	Testability (0-5)
Active Record	Yes	Laravel, Yii2, Django, ActiveJDBC	5	2	Data Accessor, Object/Relational Map, Selection Factory	3	3
Data Access Object	No	Persist, Entity Framework, Hibernate	3	3	DTO, Singleton, Abstract Factory, Command, Table Data Gateway	5	4
Data Mapper	No	Doctrine2, SQLAlchemy, Cycle ORM, Hibernate	4	4	DTO, Domain Object Assembler, Table Data Gateway	5	5

TABLE 2: COMPARISON TABLE OF THE THREE PATTERNS

Figure 10 shows a SWOT analysis of the Data Access Object pattern.

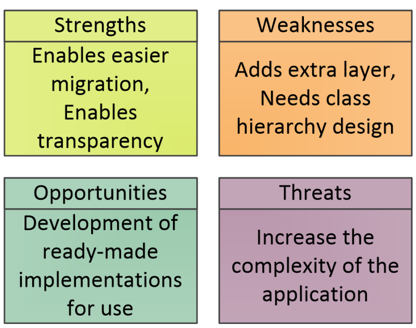

Fig. 10: SWOT analysis the Data Access Object

Figure 11 shows a SWOT analysis of the Data Access Object pattern.

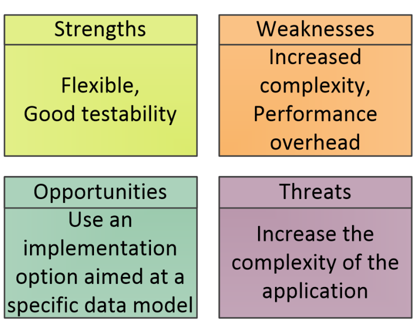

Fig. 11: SWOT analysis the Data Access Object

IV CONCLUSION

The patterns considered are used by most ORMs and are the basis for their creation. However, decoupling patterns do not solve all the problems that arise when creating an ORM. Thus, it is necessary to use additional patterns, architectural solutions, algorithms, and models to build a full-fledged ORM. Which decoupling pattern to choose depends largely on the tasks being solved and the scale of the application. The Active Record pattern is the most popular and easy to use, and we can choose this pattern if the business logic of the application is not too complex. On the other hand, for large applications, it is recommended to use the Data Access Object and Data Mapper patterns. However, they increase the complexity of the application, thereby complicating development. In general, we can say that these patterns are almost equivalent and perform similar tasks.

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Electrochemical Method for Synthesis of Cu, Cu_2O, and CuO Nanoparticles

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Abstract– This article examines several methods for synthesizing copper nanoparticles in solutions using electrochemical reduction. A number of conditions for nanoparticle synthesis are discussed. In particular, studies devoted to the use of different solvents and electrolytes, as well as the investigation of the influence of electrolysis conditions, have been examined. For instance, nanoparticle size can be controlled by adjusting voltage and current strength. The role of stabilizers was also considered; the use of different stabilizers allowed for control over the size and shape of nanoparticles. The influence of the electrolyte pH was studied, revealing its significant impact on the size, morphology, and thermal stability of copper particles. At low pH values $(pH = 5)$, Cu nanoparticles with large sizes and complex shapes are formed. Innovative approaches were proposed, such as using DNA as an electrolyte for nanoparticle synthesis, highlighting the importance of electrolyte selection in determining particle morphology and size.

Key words– copper, synthesizing, electrochemical method, nanoparticles, electrochemistry.

I INTRODUCTION

One of the methods that can be used in the synthesis of Cu, Cu_2O, CuO nanoparticles is the electrochemical method. The electrochemical method has attracted significant attention due to its unique advantages, such as simplicity, direct pathway, low-temperature operation, high current yield, and is an important step towards environmentally friendly methods. For the synthesis of nanoparticles, cyclic voltammetry, potentiostatic, galvanostatic, and pulsed current methods were used, as well as various electrochemical methods [1-11].

The size, shape, and properties of copper nanoparticles synthesized by the electrochemical method are influenced by the following factors:

Solution concentration: Higher solution concentration leads to larger nanoparticle size.

Current: Increasing the current enhances the nanoparticle deposition rate, resulting in a reduction in their size.

Temperature: Elevated temperature increases the nanoparticle deposition rate, also leading to a reduction in their size.

Solvent: The nature of the solvent can influence the shape and size of nanoparticles. For example, in water, copper nanoparticles typically have a spherical shape, while in methanol or acetonitrile, they may have rod-like or needle-like shapes.

Examples of copper nanoparticle synthesis by the electrochemical method.

In the study [12], a cell with copper electrodes and copper sulfate was used. The process involved electrolysis followed by the deposition of Cu nanoparticles on the cathode (Figure 1). The authors synthesized copper nanoparticles in an aqueous solution of copper sulfate. Electrolysis was conducted at a voltage of 15 V and a current of 6 A for 30 minutes. The obtained particles were crystalline and had a spherical shape with a size of 24 nm. Observations of some larger nanoparticles revealed the presence of Van der Waals clusters of smaller objects.

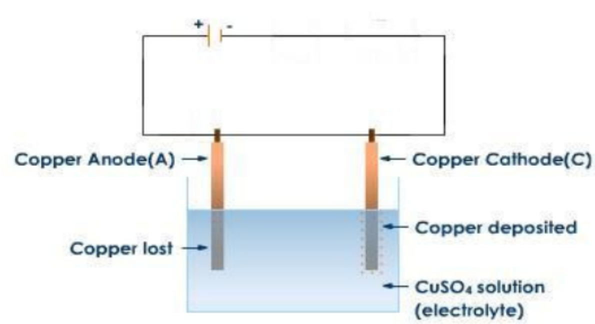

Fig. 1: Deposition of copper nanoparticles on the cathode.

The use of various electrolytes and solvents:

In the study (13), various solvents and electrolytes, including water, acetonitrile, and methanol, were utilized for the synthesis of CuO nanoparticles with different morphologies. Electrolysis was performed using a copper anode and a platinum cathode under different conditions. The authors synthesized copper oxide nanoparticles in an aqueous solution of sodium hydroxide in the presence of various solvents. Sodium hydroxide served as the electrolyte in the electrolytic reactions. Electrolysis was carried out at a voltage of 1.25 V and a current of 100 mA for 2 hours. The resulting nanoparticles ranged in size from 2 to 36 nm. The shape of the nanoparticles depended on the nature of the solvent: in water, they formed clusters, in methanol - a spherical shape, and in acetonitrile (ACN) - honeycomb-like clusters. During electrolysis, $Cu+$ and $OH-$ ions were generated at the anode and cathode, resulting in the formation of CuO_2 and Cu_2O precipitates. Subsequent thermal treatment at 900^oC for 1 hour led to the formation of CuO. Particles obtained in the presence of the water-ACN solvent had the smallest average particle size among the others. CuO nanoparticles obtained in the presence of an aqueous-acetonitrile solvent, upon thermal treatment at 300^oC, showed particle sizes ranging from 5 to 30 nm, while upon thermal treatment of CuO at 900^oC, the particle size ranged from 2 to 36 nm.

In study (14), the authors employed the electrochemical method for synthesizing CuO nanoparticles in an organic environment. A copper metal sheet served as the anode, while a platinum sheet served as the cathode. The solvent used was tetrahydrofuran (THF) with the addition of acetonitrile (ACN) in a ratio of 4:1. Tetraethylammonium bromide (TEAB), tetrapropylammonium bromide (TPAB), or tetrabutylammonium bromide (TBAB) were used as stabilizers. The current density was set at 10 mA/cm^2. As a result of electrolysis, CuO nanoclusters stabilized by TEAB, TPAB, or TBAB were obtained. The nanoparticles exhibited irregular shape and non-uniform distribution. The authors noted that the use of stabilizers during synthesis allows for the control of nanoparticle size. It was also observed that the cluster size decreases with increasing current density. Thus, the electrochemical method proves to be an effective and versatile approach for synthesizing CuO nanoparticles. The utilization of stabilizers enables control over nanoparticle size and shape. In contrast to previous studies where the synthesis of CuO nanoparticles was conducted in an aqueous environment, in the study [21], synthesis was carried out in an organic medium. This allowed for improved nanoparticle dispersion and reduced agglomeration. Additionally, in the work [14], an inert material was used for the electrode. This helped to avoid contamination of nanoparticles with copper oxidation products formed at the anode.

In study (15), the authors synthesized CuO nanoparticles via electroreduction in a nitrogen atmosphere. A copper sheet served as the anode, while a platinum sheet served as the cathode. The electrolyte used was a solution of tetrabutylammonium bromide (TBAB) in a mixture of acetonitrile and tetrahydrofuran (4:1). Upon applying a current density of 6 mA/cm^2, 95% of copper oxide clusters stabilized by TBAB were synthesized.

During the application of electrical current, the anode slowly dissolves, leading to the formation and subsequent passivation of active TBAB particles. The size of the clusters decreases with increasing current density.

SEM analysis revealed that copper oxide nanoparticles exhibit irregular shape and uneven distribution. This is due to the partial solubility of the surfactant in the solvent under these experimental conditions.

XRD analysis showed that the nanoparticles have a crystalline structure. The sharp peaks obtained indicate the monoclinic structure of the CuO nanoparticles, which was found to be highly crystalline in nature. XRD analysis showed that the synthesized nanoparticles had impurities. Bromine (Br) is present in trace amounts due to the addition of TBAB. The average particle size was calculated using the Debye-Scherrer formula and was 9.56 nm.

The result of HRTEM analysis showed that the copper oxide nanoparticles have a spherical shape and a size of 5–10 nm, which shows good similarity with the grain size calculated by XRD methods. The authors performed antibacterial testing for antibacterial activity on CuO nanoparticles and showed that copper oxide nanoparticles acted as excellent antibacterial agents for both Gram-positive and Gram-negative bacteria.

Effect of Electrolyte pH.

In [16], the authors studied the effect of electrolyte pH on the properties of Cu nanoparticles obtained by the electrochemical method. An oxalic acid solution was used as an electrolyte, the pH of which was maintained using sodium hydroxide. Two copper electrodes maintained a current of 0.1 A for 2 hours at 25^oC, and stirring was carried out with a magnetic stirrer. After electrolysis, the resulting nanoparticles were centrifuged, washed with distilled water, dried in air at 90^oC and calcined at 150^oC. As a result, nanoparticles with sizes ranging from 20 nm to 7 μm were obtained. As a result of electrolysis, Cu nanoparticles with different sizes, shapes and properties were obtained depending on the pH of the electrolyte. At pH = 5, Cu nanoparticles had a microrod-like structure with a length of 500-7000 nm and a diameter of 150-250 nm. They consisted of a mixture of 67% $Cu(OH)_2$ and 33% CuC_2O_4. At pH = 6.5-9.5, Cu nanoparticles had a microspherical shape of various diameters. They consisted of $Cu(OH)_2$. At pH = 12.5, Cu nanoparticles had a cylindrical shape with a length of 50-150 nm and a diameter of about 10-20 nm. They consisted of pure $Cu(OH)_2$. Thus, it was found that the pH of the electrolyte has a significant effect on the properties of Cu nanoparticles obtained by the electrochemical method. The size and shape of Cu nanoparticles depend on the pH of the electrolyte. At low pH values (pH = 5), *Cu* nanoparticles with large sizes and complex shapes are formed. At high pH values (pH = 12.5), *Cu* nanoparticles with small sizes and simple shapes are formed. The composition of *Cu* nanoparticles also depends on the pH of the electrolyte. At low pH values (pH = 5), *Cu* nanoparticles contain a mixture of $Cu(OH)_2$ and CuC_2O4. At high pH values (pH = 12.5), *Cu* nanoparticles consist of pure $Cu(OH)_2$. The properties of *Cu* nanoparticles, such as surface area, thermal stability and porous structure, also depend on the pH of the electrolyte. At high pH values (pH = 12.5), *Cu* nanoparticles have the largest surface area and are thermally more stable than particles produced at other pH values.

Thus, the study shows that electrolyte pH significantly affects the size, morphology and thermal stability of copper nanoparticles, which provides opportunities for the controlled synthesis of nanoparticles with desired properties.

In (17), researchers proposed using DNA as an electrolyte to synthesize copper nanoparticles by anodic oxidation. This process involved the use of copper and platinum as the anode and cathode respectively, with copper acting as the dissolving electrode. In this process, the bulk of the metal is oxidized at the anode, and metal cations migrate to the cathode. Negatively charged DNA molecules move towards the anode and bind to metal cations, stabilizing in the form of DNA-copper complexes.

Innovative approaches.

The experiments used DNA from calf thymus as a supporting electrolyte and stabilizer of copper clusters. A copper sheet (99.9%) (2 cm × 1 cm) was used as the anode and a platinum sheet (2 cm × 1 cm) was used as the cathode. Electrolysis was carried out in a plexiglass electrochemical cell at a voltage of 4 V for an hour. After electrolysis, the formed DNA-Cu metal complexes were removed from the cell.

Initially, the resulting nanoparticles were amorphous in nature, but after irradiation with an electron beam they were transformed into discrete nanoparticles of various sizes. Visually, the sample was divided into three regions (a, b, c), with particle sizes ranging from 20–50 nm in region a, 10–20 nm in region b, and 5–10 nm in region c.

The choice of DNA as an electrolyte is explained by its negative charge due to the presence of phosphate groups. When a voltage is applied, the negatively charged DNA molecules orient and move towards the positive electrode, while the oxidized copper ions move towards the negative electrode. This interaction results in the formation of DNA-copper complexes in the electrolyte or on the electrode. The use of DNA as an electrolyte made it possible to obtain nanoparticles with an amorphous structure.

This method represents a unique approach to the synthesis of copper nanoparticles, demonstrating the importance of electrolyte selection in determining nanoparticle morphology and size.

Influence of electrolysis conditions.

In electrochemical synthesis, the size of copper nanoparticles can be reduced by increasing the voltage (18).

Increasing the applied voltage generally increases the rate of reduction of copper ions to copper atoms, which can result in the formation of smaller nanoparticles. This is because at higher voltages, nucleation occurs faster than growth, resulting in the formation of more smaller particles. However, it is important to note that excessively high voltage can also produce by-products or cause particle agglomeration, which can negate the benefits of size reduction. The exact voltage required to produce copper nanoparticles of a certain size depends on the specific electrochemical process conditions, including electrode materials, electrolyte composition, and temperature. An average particle size of 21.55 nm was obtained using a potential difference of 27 V (19).

The electrochemical method for the synthesis of copper nanoparticles has demonstrated significant versatility and efficiency in a number of studies. Important parameters in this process are the type of electrolyte, voltage, current, process duration and stabilizers used. The electrochemical method is a simple and less labor-intensive method with maximum purity of nanoparticles (20). In addition, the electrochemical process is environmentally friendly and opens up new possibilities for the synthesis of metal nanoparticles. The electrochemical method is considered suitable for use in the development of new medical drugs. Although the electrochemical method has a number of advantages, this method also has a number of disadvantages, namely: the reaction that occurs can lead to the attachment of a layer (double layer) to the outside of the electrode, which increases the resulting resistance and reduces the current. (21).

II CONCLUSION

Use of various electrolytes and solvents:

A study (13) showed the effect of different solvents on the size of *CuO* nanoparticles. Water-ACN obtained in the presence of a solvent have the smallest average particle size among the others. In work (14), the synthesis was carried out in an organic medium, which improved dispersion and reduced particle agglomeration.

Influence of electrolysis conditions:

The size of the nanoparticles can be controlled by varying the voltage and current. For example, in work (19), increasing the voltage to 27 V led to a decrease in the average particle size to 21.55 nm.

The role of stabilizers:

The use of various stabilizers, as shown in works (14) and (15), made it possible to control the size and shape of nanoparticles.

Effect of Electrolyte pH: (16) investigated the effect of electrolyte pH on the properties of Cu nanoparticles, showing that pH has a significant effect on particle size, morphology, and thermal stability. At low pH values (pH = 5), *Cu* nanoparticles with large sizes and complex shapes are formed.

Innovative approaches: A study (17) proposed the use of DNA as an electrolyte for the synthesis of nanoparticles, which is a unique approach demonstrating the importance of electrolyte selection in determining particle morphology and size. The use of DNA as an electrolyte makes it possible to obtain nanoparticles with an amorphous structure.

Antibacterial activity: Some of the synthesized *CuO* nanoparticles showed antibacterial activity.

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CRITICAL OVERVIEW OF CHARGING PORTS USED IN MODERN ELECTRIC VEHICLES

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Abstract– This article provides a comprehensive review of modern electric vehicle (EV) charging ports, covering the evolution, standards, and global landscape. Beginning with the rise of EVs and the crucial role of charging infrastructure, it explores the transition to standardized charging ports, emphasizing key standards like SAE J1772, CHAdeMO, CCS, and Tesla Supercharger. The analysis extends to AC and DC charging, discussing Level 1 and Level 2 charging, high-speed DC charging, and smart grid integration. The global context is outlined, featuring a comparative analysis of major charging standards. The article concludes with insights into the dynamic charging landscape and considerations for the future, including technological advancements and global standardization efforts.

Key words– Electric Vehicles, Charging Ports, Charging Infrastructure, Standardization, SAE J1772, CHAdeMO, CCS, Tesla Supercharger, AC Charging, DC Charging.

I INTRODUCTION

The global automotive landscape has undergone a transformative shift with the accelerating adoption of electric vehicles (EVs)[1]. Over the past decade, EVs have evolved from niche, experimental vehicles to mainstream options, reshaping the future of transportation. The surge in interest and investment in electric mobility is fueled by a confluence of factors, including environmental concerns, technological advancements, and shifting consumer preferences[2].

The rise of electric vehicles is closely tied to the growing recognition of the environmental impact of traditional internal combustion engine (ICE) vehicles[3]. With concerns over climate change and air pollution, governments and industry stakeholders have sought sustainable alternatives. EVs, powered by electricity rather than fossil fuels, represent a pivotal solution in mitigating greenhouse gas emissions and reducing dependence on finite resources.

As consumers become more environmentally conscious and seek sustainable alternatives, electric vehicles have gained popularity. The allure of lower operating costs, reduced maintenance requirements, and a smoother driving experience has contributed to the increasing acceptance of EVs. Additionally, changing mobility trends, including the rise of ride-sharing services and urbanization, have created a conducive environment for electric mobility.

As consumers become more environmentally conscious and seek sustainable alternatives, electric vehicles have gained popularity. The allure of lower operating costs, reduced maintenance requirements, and a smoother driving experience has contributed to the increasing acceptance of EVs. Additionally, changing mobility trends, including the rise of ride-sharing services and urbanization, have created a conducive environment for electric mobility.

While the adoption of electric vehicles (EVs) has surged, the realization of their full potential hinges on the development of a robust charging infrastructure. Charging infrastructure plays a pivotal role in shaping the user experience, addressing range anxiety, and fostering widespread acceptance of electric mobility. This section explores the critical importance of charging infrastructure within the EV ecosystem[4].

The growth of charging infrastructure is not merely a complementary aspect but a catalyst for the transition to electric mobility. It fosters a positive feedback loop: as more EVs populate the roads, the demand for charging infrastructure increases, leading to further expansion. This symbiotic relationship accelerates the transition away from fossil fuel-dependent vehicles and reinforces the viability of electric mobility on a larger scale[5].

Charging infrastructure presents an opportunity to align electric vehicle usage with renewable energy sources. By integrating charging stations with solar, wind, or other clean energy technologies, the environmental benefits of electric mobility are further enhanced. This synergy contributes to reducing the overall carbon footprint of transportation, a key objective in combating climate change.

II EVOLUTION OF ELECTRIC VEHICLE CHARGING PORTS

a. Early charging methods and standards.

The journey toward the electrification of transportation has a rich history marked by the evolution of charging methods and standards. In the nascent stages of electric vehicles (EVs), diverse approaches were explored to power these pioneering vehicles. This section delves into the early charging methods and standards that laid the foundation for the contemporary charging infrastructure we see today.

Charging methods and standards that laid the foundation for the contemporary charging infrastructure we see today.

1. Direct Current (DC) Charging

In the early days of electric vehicles, direct current (DC) charging emerged as a primary method. Simple and straightforward, DC charging involved connecting the vehicle's battery directly to a power source. However, this method had limitations, primarily in terms of charging speed and efficiency. DC charging stations were often slow, and the lack of standardization led to compatibility issues between different electric vehicle models[6].

2. Alternating Current (AC) Charging

Alternating current (AC) charging was another early method explored for powering electric vehicles. AC charging offered certain advantages, including the ability to use existing electrical infrastructure. However, the charging process was relatively slow, and it struggled to meet the evolving demands of an increasingly mobile society[7], [8].

3. Non-Standardized Charging Protocols

During the initial phase of electric mobility, the absence of standardized charging protocols presented a significant challenge. Different manufacturers adopted proprietary charging systems, leading to fragmentation in the charging infrastructure. Electric vehicle owners faced obstacles when attempting to charge their vehicles at stations that did not support their specific charging interface[9].

4. Pioneering Standards and Protocols

Recognizing the need for standardization, industry stakeholders began to collaborate on establishing common charging standards. The introduction of standards such as the Society of Automotive Engineers (SAE) J1772 for AC charging and CHAdeMO for DC charging marked significant milestones. These early standards laid the groundwork for a more cohesive and interoperable charging infrastructure[10].

In the early stages, charging speeds were relatively slow, and electric vehicles had limited range. This posed challenges for widespread adoption, as drivers were hesitant about the time required for recharging during longer journeys. The need for faster charging technologies became apparent, prompting further research and development in the electric vehicle charging domain.

b. Transition to standardized charging ports

The proliferation of electric vehicles (EVs) brought about a pivotal shift in focus—from diverse and proprietary charging methods to the standardization of charging ports. This section explores the transition to standardized charging ports, a crucial development that streamlined the charging process and laid the foundation for a more accessible and user-friendly electric vehicle charging infrastructure[11].

Recognizing the challenges posed by non-standardized charging interfaces, the electric vehicle industry embarked on a journey toward standardization. The establishment of common charging protocols became imperative to ensure interoperability between different electric vehicle models and charging stations. Standardization not only simplified the charging experience for EV owners but also facilitated the growth of a cohesive charging infrastructure.

The Society of Automotive Engineers (SAE) played a pivotal role in shaping standardized charging interfaces. The SAE J1772 emerged as a key standard for alternating current (AC) charging. This standard defined the physical connector and communication protocol, providing a universal platform for electric vehicle manufacturers and charging station developers. The adoption of SAE J1772 marked a significant step toward a more harmonized charging landscape[7].

Simultaneously, in the realm of direct current (DC) fast charging, the CHAdeMO protocol gained prominence. Originating from Japan, CHAdeMO established a standardized interface for DC fast charging stations. While initially associated with Asian electric vehicle manufacturers, CHAdeMO's global acceptance expanded, contributing to the interoperability of DC fast charging infrastructure [12].

Recognizing the need for a unified standard that could accommodate both AC and DC charging, the Combined Charging System (CCS) emerged as a comprehensive solution. Developed collaboratively by major automakers, including American and European manufacturers, CCS integrated the benefits of SAE J1772 and offered an extension for high-power DC charging. This consolidation addressed the fragmentation in charging standards and paved the way for a more versatile and adaptable charging infrastructure.

In parallel, Tesla, a pioneer in electric vehicles, introduced its proprietary Supercharger network. While initially exclusive to Tesla vehicles, the Supercharger network played a crucial role in normalizing the concept of fast charging. Over time, Tesla began adopting the CCS standard for some of its vehicles, contributing to a more unified charging ecosystem.

The global adoption of standardized charging ports, encompassing SAE J1772, CHAdeMO, CCS, and Tesla's evolving approach, fostered interoperability. Electric vehicle owners could now confidently access charging infrastructure across different regions without compatibility concerns. This harmonization marked a significant milestone, enhancing the convenience and accessibility of electric vehicle charging.

III CLASSIFICATION OF CHARGING PORTS

a. AC charging ports

Alternating Current (AC) charging ports form a fundamental component of the electric vehicle (EV) charging infrastructure. AC charging is primarily utilized for slower charging at residential, workplace, and public charging locations. This section explores the different Types of AC charging ports and their significance in supporting the diverse charging needs of electric vehicles.

Type 1 (Figure 1)charging represents the most basic form of AC charging and is typically associated with standard household outlets. Operating at 120 volts, Type 1 charging provides a convenient option for EV owners to charge their vehicles at home. While the charging speed is relatively slow, Type 1 charging is practical for overnight charging, ensuring that the vehicle is ready for daily use. According to the scheme of Type 1 socket, L1 is “AC phase 1”, N-“AC neutral”, PE-protective Earth (Ground), PP-"Proximity Pilot" which provides a signal to the vehicle’s control system so it can prevent movement while connected to the electric vehicle supply equipment; CP-Control pilot-a communication line used to negotiate charging Type between the car and the EVSE, and it can be manipulated by the vehicle to initiate charging and can carry other information.

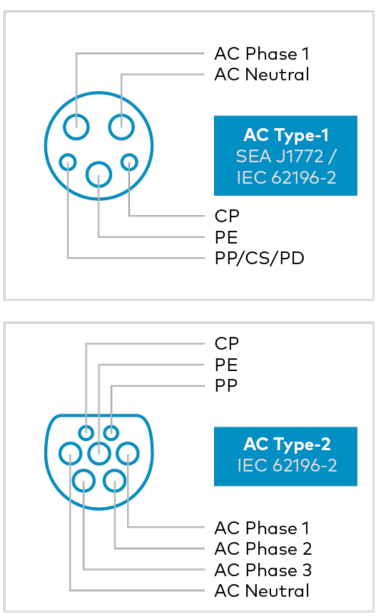

Fig. 1: Scheme of Type 1 and Type 2 AC charging socket (SAE J1772/IEC 62196-2)[13].

Type 2 charging represents a significant advancement in AC charging capabilities, operating at 240 volts. Widely deployed at public charging stations, workplaces, and residential settings, Type 2 charging offers faster charging times compared to Type 1. This level of charging is crucial for meeting the demands of daily commuting and provides a practical solution for EV owners who may not have access to high-speed charging options. Just like the Type 1 socket, Type 2 possesses CP, PP, PE, and N pins. The difference is in the number of phases. Type 1 connector is a single-phase one whereas Type 2 socket has 3 AC phases.

AC charging ports play a pivotal role in the overall charging ecosystem, providing a versatile and accessible solution for a wide range of electric vehicles. Residential charging stations, often equipped with Type 1 or Type 2 capabilities, enable EV owners to conveniently charge their vehicles overnight. Workplace charging infrastructure supports employees in maintaining a charged battery throughout the workday. Furthermore, public Type 2 charging stations contribute to the expansion of charging options, especially in urban areas and along travel routes.

While AC charging is a critical component of the charging infrastructure, it does present certain challenges. The time required for a full charge at Type 1 may be impractical for some users, necessitating the availability of Type 2 charging for faster replenishment. Additionally, as electric vehicles with larger battery capacities become more prevalent, there is a growing need for higher-power charging options to reduce charging times and meet the evolving needs of EV users.

The integration of AC charging infrastructure with smart grid technologies represents a promising avenue for optimizing energy consumption and grid stability. Smart charging solutions enable dynamic management of electricity flow, allowing for load balancing and cost-effective charging. This integration supports the sustainability goals of the electric vehicle ecosystem and enhances the efficiency of the broader energy grid.

b. DC Charging ports

Direct Current (DC) charging ports represent a crucial advancement in the electric vehicle (EV) charging landscape, offering high-speed charging solutions to address the needs of drivers on the go. This section explores different types of DC charging ports and their significance in providing rapid charging capabilities for modern electric vehicles. Currently the following types of DC charging ports are available on the market:

1. CHAdeMO-Developed in Japan, CHAdeMO (Charge de Move) stands as one of the early DC fast-charging standards. It operates with a specific connector and protocol to deliver high-power DC charging. Initially associated with Japanese electric vehicle manufacturers,

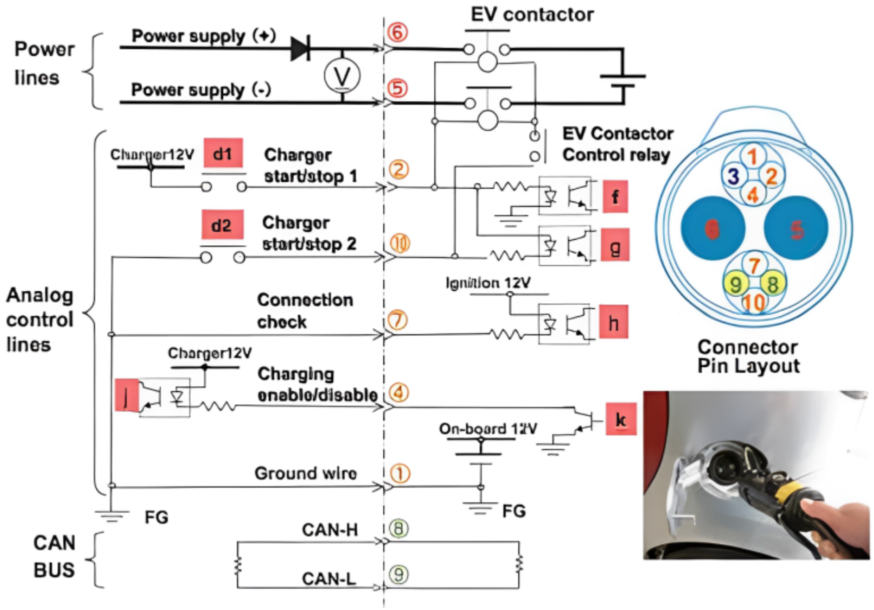

Fig. 2: CHAdeMO charging port layout[14].

CHAdeMO has gained global acceptance, contributing significantly to the development of fast-charging infrastructure.

2. CCS (Combined Charging System). The Combined Charging System (CCS) represents a collaborative effort among major automakers to create a unified DC fast-charging standard. CCS integrates both AC and DC charging capabilities into a single, standardized connector. This adaptability allows electric vehicles to use the same charging port for both slow AC charging and high-speed DC charging, reducing complexity and enhancing interoperability.

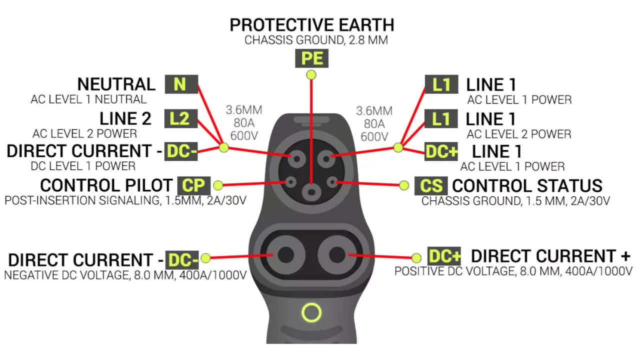

Fig. 3: CCS charging port pin layout[15], [16].

3. Tesla Supercharger Network. Tesla, a trailblazer in the electric vehicle industry, introduced its proprietary Supercharger network. Initially exclusive to Tesla vehicles, Superchargers provide high-speed DC charging, allowing Tesla owners to replenish a significant portion of their battery capacity in a relatively short time. Notably, Tesla has been transitioning some of its newer vehicles to support the CCS standard, aligning with the broader industry trend toward standardization[17].

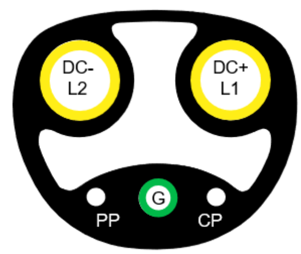

Fig. 4: Pin layout of Tesla supercharger pin layout [16].

4. GB/T (Guan Bo/Tong) in China. In China, the GB/T standard, also known as Guan Bo/Tong, has gained prominence for DC fast charging. Adopted by many Chinese electric vehicle manufacturers, GB/T features a unique connector and protocol designed to meet the specific requirements of the Chinese electric vehicle market. The widespread adoption of GB/T contributes to the growth of fast-charging infrastructure in China.

DC charging ports are characterized by their high-speed charging capabilities, making them particularly suitable for

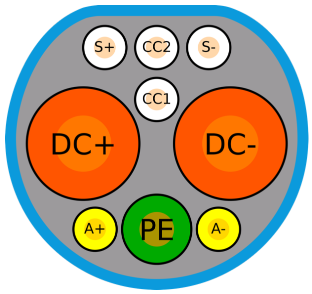

Fig. 5: GB/T charging port layout[18].

long-distance travel and reducing charging times for electric vehicle owners. The development of high-power charging stations, often located along major highways and travel routes, supports the feasibility of electric vehicles for intercity and interstate travel.

IV COMPARISON OF MAJOR CHARGING STANDARDS

As electric vehicles (EVs) continue to gain prominence globally, the landscape of charging standards has evolved, and several major standards have emerged as key players. This section provides a comparative analysis of the major charging standards, shedding light on their key features, advantages, and considerations for the broader electric vehicle ecosystem.

1. CHAdeMO
Features:

- Origin: Developed in Japan;
- Charging Type: DC fast charging;
- Connector: Unique CHAdeMO connector;
- Global Presence: Initially prevalent in Asia, with some adoption in other regions.

Advantages:

- Early adoption and widespread availability, especially in Japan;
- Established network of CHAdeMO charging stations[19].

Considerations:

- Limited global adoption compared to other standards;
- Proprietary nature led to interoperability challenges.

2. CCS (Combined Charging System)
Features:

- Origin: Collaborative effort by global automakers;
- Charging Type: Combines AC and DC charging in a single connector;
- Connector: CCS Type 1 (North America) and CCS Type 2 (Europe and other regions);
- Global Presence: Widely adopted globally, especially in North America and Europe.

Advantages:

- Comprehensive solution accommodating both AC and DC charging;
- Broad industry support, promoting interoperability;
- Extensive network of CCS charging stations.

Considerations:

- Different plug designs for North America (Type 1) and Europe (Type 2) may require adapter use during travel[20].

3. Tesla Supercharger Network
Features:

- Origin: Proprietary network developed by Tesla;
- Charging Type: DC fast charging;
- Connector: Tesla-specific connector;
- Global Presence: Initially exclusive to Tesla vehicles, with ongoing transitions to CCS support.

Advantages:

- High-speed charging capability;
- Exclusive access for Tesla vehicle owners;
- Strategic placement along popular travel routes.

Considerations:

- Initially exclusive to Tesla vehicles;
- Transition to CCS support in some regions may impact the exclusivity of the network[21].

4. GB/T (Guan Bo/Tong) in China
Features:

- Origin: China-specific standard;
- Charging Type: DC fast charging;
- Connector: GB/T connector;

- Global Presence: Predominantly used in China.

Advantages:

- Tailored to the needs of the Chinese electric vehicle market;
- Growing charging infrastructure in China.

Considerations:

- Limited international adoption outside of China;
- Potential interoperability challenges in regions with different standards[22].

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First-order moving average processes associated by interval exchange maps

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Abstract– In present work we investigate the nonlinear first-order moving average processes associated by interval exchange maps h. Let random process $\mathbb{X} := \{X_n,\ n \geq 1\}$ defined by

$$X_{n+1}(h) := h(\xi_n) + \xi_{n+1}\ ,\ n \in \mathbb{Z},$$

where $\widehat{\xi} := \{\xi_n,\ n \geq 1\}$ is independent, identically uniformly distributed on interval $[0,1]$ random sequence. We investigate the random process $\mathbb{X}$ for stationarity and find their distribution function and autocovariance function.

Key words– moving average process, interval exchange map, strictly stationary process, covariance function.

I INTRODUCTION

A Time Series is a sequence of dates indexed by time. Every data is a discrete observation taken from an underlying process. Time series analysis looks at the methods used to create the models from the sampled data in order to study the continuous process. This paper will focus on the first-order moving average process (MA(1)). Notice that the model MA(1) is one of classical models in the theory of time series. It is very important and applied in different problems of practice (see for instance [6], [2],[5],[4]).

Let $a,b \in (0,1)$. Consider the interval exchange map $h : [0,1) \to [0,1)$ defined by (see [1]):

$$h(x) := \begin{cases} a + \frac{1-a}{b}x,\ 0 \leq x < b, \\ \frac{a}{1-b}(x-b),\ b \leq x < 1. \end{cases} \tag{1}$$

The graph of h is shown in Figure 1 on the next page. The map h has two break points $x = 0$ and $x = b$ with **jump ratios**

$$\sigma_f(0) := \frac{f'_-(0)}{f'_+(0)} = \frac{ab}{(1-a)(1-b)},$$

$$\sigma_f(b) := \frac{f'_-(b)}{f'_+(b)} = \frac{(1-a)(1-b)}{ab},$$

Let A^* denote the class of all such maps. Recall that x_0 is called a break point of a map f if $\frac{f'_-(x_0)}{f'_+(x_0)} = \sigma_f(x_0) \neq 1$ and $f_\pm(x_0) > 0$. It is obvious that $\sigma_f(0) \cdot \sigma_f(1) = 1$. Only in the case $a = b = \frac{1}{2}$ we have $\sigma_f(0) = \sigma_f(b) = 1$. Identifying the endpoints of the interval $[0,1)$ we get we get unit circle $S^1 = \mathbb{R}/\mathbb{Z}$. In this case by the map h uniquely can be defined orientation preserving circle homeomorphism.

It is easy to see that the inverse function h^{-1} is

$$h^{-1}(x) := \begin{cases} b + \frac{1-b}{a} \cdot x,\ 0 \leq x < a, \\ \frac{b}{1-a}(x-a),\ a \leq x < 1. \end{cases} \tag{2}$$

Definition 1.1. (see [7], [3]). Let $\mathbb{X} := (X_n), \in T \subset \mathbb{Z}$ be a stationary random process. The **autocovariance function (ACVF)** of $\{X_n\}$ at lag m is

$$\gamma_X(m) = Cov(X_{t+m}, X_t) = E[(X_{t+m} - E[X_{t+m}])(X_t - E[X_t])]$$

The **autocorrelation function (ACF)** of $\mathbb{X}$ at lag m is

$$\rho_X(m) = \frac{\gamma_X(m)}{\gamma_X(0)}.$$

Definition 1.2. The process $\mathbb{X} := (X_n), \in T \subset \mathbb{Z}$ is said to be **weakly stationary** if

1) $E(X_t)$ is independent of t,

and

2)$\gamma_X(t+h,t)$ is independent of t for each h.

Definition 1.3. The random process $\mathbb{X} := (X_n), \in T \subset \mathbb{Z}$ is said to be **strictly stationary** if $(X(t_1),...,X(t_k))$ and $(X(t_1+m),...,X(t_k+m))$ have the same joint distribution for all integers $t_1,...,t_k \in T,\ k \geq 1$ and $m > 0$.

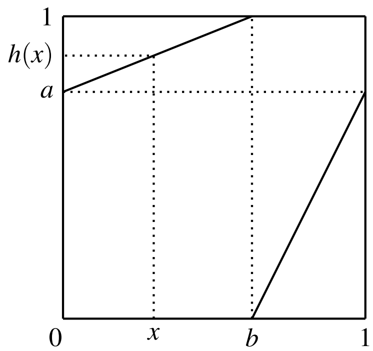

Figure 1

Let (Ω, F, P) be a probability space. Let $\{\xi_n, n \in \mathbb{Z}\}$ be a sequence of independent, identically distributed (i.i.d.) random variables with uniform distribution $[0,1]$ i.e. its **probability density function (pdf)** is

$$f_{\xi_0}(x) := \begin{cases} 1, & x \in [0,1], \\ 0, & otherwise. \end{cases}$$

Next we define the following sequence of random variables associated by map h :

$$X_{n+1}(h) := h(\xi_n) + \xi_{n+1}\ ,\ n \in \mathbb{Z}. \quad (3)$$

The random prosess $\mathbb{X}(h) := \{X_{n+1}(h),\ n \in \mathbb{Z}\}$ is called **first-order moving average or MA(1) random process associated by map *h*.**

We investigate the sequence of random variables $\{h(\xi_n),\ n \geq 1\}$.

Theorem 1.1. If h is the interval map defined by (1) and random variable ξ is uniformly distributed on the interval $[0,1]$. Then the **cumulative distribution function (cdf)** of $h(\xi)$ has form

a) $$F_{h(\xi)}(t) = \begin{cases} 0, \text{ if } t < 0, \\ \frac{1-b}{a}t, \text{ if } 0 \leq t < a, \\ \frac{b}{1-a}t + \frac{1-a-b}{1-a}, \text{ if } a \leq t \leq 1, \\ 1, \text{ if } t > 1. \end{cases}$$

b) $E[h(\xi)] = \frac{1}{2}(a+b)$,
where $E[h(\xi)]$ is the expectation of $h(\xi)$.

We formulate the main result of our work.

Theorem 1.2. Let $\mathbb{X}(h) := \{X_n(h),\ n \in \mathbb{Z}\}$ be the MA(1) process defined by (3). Then

(1) $\mathbb{X}(h)$ is strictly stationary random process;

(2) The density function of each $X_n(h)$ has the following form

(3) $$f_{\mathbb{X}}(t) := f_{X_n}(t) = \begin{cases} \frac{1-b}{a}t, \text{ if } t \in [0,a), \\ \frac{b}{1-a}t + \frac{1-a-b}{1-a}, \text{ if } t \in [a,1), \\ -\frac{1-b}{a}t + \frac{1+a-b}{a}, \text{ if } t \in [1,1+a), \\ \frac{b}{1-a}(2-t), \text{ if } t \in [1+a,2), \\ 0, \text{ otherwise;} \end{cases}$$

(4) For every $n \in \mathbb{Z}$ the expectation of X_n can be written as

$$E[X_n] = \frac{1}{2}(1+a+b);$$

(5) The variance of X_n can be written as

$$Var(X_n) = \frac{1}{12}\left(a^2 - 2ab - 3b^2 + 4b + 1\right);$$

(6) The autocorrelation function (ACF) of $\mathbb{X}$:

$$\rho(1) = \frac{-2ab + a + 4b^2 - 3b}{a^2 - 2ab - 3b^2 + 4b + 1},$$

and

$$\rho(m) = 0 \quad \text{for } m \geq 2.$$

II Proofs of the Theorems 1.1 and 1.2

Proof of Theorem 1. By definition of random process $\mathbb{X}(h) := \{X_n(h),\ n \in \mathbb{Z}\}$ it is easy to see that it ia strictly stationary process.

Note that the map h is invertible. Using this and the distribution function of uniformly distributed random variable ξ_0 we find the distribution of $h(\xi_0)$:

$$F(t) := P\left\{\xi_0 < h^{-1}(t)\right\} = \begin{cases} 0, & t < 0, \\ \frac{1-b}{a}t, & 0 \leq t < a, \\ \frac{b}{1-a}t + \frac{1-a-b}{1-a}, & a \leq t \leq 1, \\ 1, & t > 1, \end{cases}$$

Consequently, the probability density function of $h(\xi_0)$ is

$$f_{h(\xi)}(t) = F'_{h(\xi)}(t) = \begin{cases} \frac{1-b}{a}, & 0 \leq t < a, \\ \frac{b}{1-a}, & a \leq t \leq 1, \\ 0, & otherwise \end{cases}$$

Now we evaluate the expectation of $h(\xi_0)$:

$$E\left[h\left(\xi_n\right)\right] = \int_{-\infty}^{\infty} h\left(x\right) f_{\xi_n}\left(x\right) dx$$
$$= \int_0^b \left(a + \frac{1-a}{b}x\right) dx + \int_b^1 \frac{a}{1-b}\left(x-b\right) dx$$
$$= \frac{ab^2}{2} + \frac{\left(1-a\right)b^2}{3} + \frac{a}{1-b}\left(\frac{1}{3} - \frac{b}{2} - \frac{b^3}{3} + \frac{b^3}{2}\right)$$
$$= \frac{1}{2}\left(a+b\right)$$

TheoremI is completely proved. □

Proof of Theorem 2.

Since the sequence of random variables $\{\xi_n, n \geq 0\}$ is independent and identically distributed, using the definition of $\{X_k, k \geq 1\}$ we can decide that it is identically distributed also.

The density function of X_1 random variable can be found by the following formula (see [8])

$$f_{X_1}\left(t\right) = \int_{-\infty}^{\infty} f_{h(\xi_0)}\left(x\right) f_{\xi_1}\left(t-x\right) dx$$

Because $f_{\xi_1}(x)$ and $f_{h(\xi_0)}(x)$ functions are zero outside$[0,1]$ interval ,we get following double inequality $\begin{cases} 0 \leq x \leq 1 \\ t-1 \leq x \leq t \end{cases}$

Then

1) if $0 \leq t \leq a$ we have $0 \leq x \leq t$ and

$$f_{X_1}\left(t\right) = \int_0^t f_{h(\xi_0)}\left(x\right) f_{\xi_1}\left(t-x\right) dx = \int_0^t \frac{1-b}{a} dx = \frac{1-b}{a} t$$

2) if $a \leq t \leq 1$ we have $0 \leq x \leq t$ and

$$f_{X_1}\left(t\right) = \int_0^t f_{h(\xi_0)}\left(x\right) f_{\xi_1}\left(t-x\right) dx$$
$$= \int_0^a \frac{1-b}{a} dx + \int_a^t \frac{b}{1-a} dx$$
$$= \frac{1-b}{a} a + \frac{b}{1-a}\left(t-a\right) = \frac{b}{1-a} t + \frac{1-a-b}{1-a}$$

3) if $1 \leq t \leq 1+a$ we have $t-1 \leq x \leq 1$ and

$$f_{X_1}\left(t\right) = \int_{t-1}^1 f_{h(\xi_0)}\left(x\right) f_{\xi_1}\left(t-x\right) dx$$
$$= \int_{t-1}^a \frac{1-b}{a} dx + \int_a^1 \frac{b}{1-a} dx$$
$$= \frac{1-b}{a}\left(a-t+1\right) + \frac{b}{1-a}\left(1-a\right)$$
$$= -\frac{1-b}{a} t + \frac{1+a-b}{a}$$

4) if $1+a \leq t \leq 2$ we have $t-1 \leq x \leq 1$ and

$$f_{X_1}\left(t\right) = \int_{t-1}^1 f_{h(\xi_0)}\left(x\right) f_{\xi_1}\left(t-x\right) dx = \int_{t-1}^1 \frac{b}{1-a} dx$$
$$= \frac{b}{1-a}\left(2-t\right)$$

We have

$$f_{X_1}\left(t\right) = \begin{cases} \frac{1-b}{a} t, \; t \in [0,a), \\ \frac{b}{1-a} t + \frac{1-a-b}{1-a}, \; t \in [a,1), \\ -\frac{1-b}{a} t + \frac{1+a-b}{a}, \; t \in [1,1+a), \\ \frac{b}{1-a}\left(2-t\right), \; t \in [1+a,2), \\ 0, otherwise \end{cases}$$

We evaluate the expectation of X_1 :

$$E\left[X_1\right] = \int_{-\infty}^{\infty} x \cdot f_{X_1}\left(x\right) dx$$
$$= \int_0^a \frac{1-b}{a} x^2 dx + \int_a^1 \left(\frac{b}{1-a} x^2 + \frac{1-a-b}{1-a} x\right) dx$$
$$+ \int_1^{1+a} \left(\frac{b-1}{a} x^2 + \frac{1+a-b}{a} x\right) dx + \int_{1+a}^2 \frac{b}{1-a}\left(2x - x^2\right) dx$$
$$= \frac{1-b}{3a} a^3 + \frac{b}{3\left(1-a\right)}\left(1-a^3\right) + \frac{1-a-b}{2\left(1-a\right)}\left(1-a^2\right)$$
$$+ \frac{b-1}{3a}\left(\left(1+a\right)^3 - 1\right) + \frac{1+a-b}{2a}\left(\left(1+a\right)^2 - 1\right)$$
$$+ \frac{b}{1-a}\left(2^2 - \frac{2^3}{3} - \left(1+a\right)^2 + \frac{\left(1+a\right)^3}{3}\right)$$
$$= \frac{2a^2\left(1-b\right)}{6} + \frac{2a^2 b - 3a^2 - ab - b + 3}{6}$$
$$+ \frac{2a^2 b + a^2 + 3ab + 3a}{6} + \frac{2b\left(2 - a - a^2.\right)}{6}$$
$$= \frac{1}{2}\left(1+a+b\right)$$

We find the second moment of X_1 :

$$E\left[(X_1)^2\right] = \int_{-\infty}^{\infty} x\cdot f_{X_1}(x)\,dx$$
$$= \int_0^a \frac{1-b}{a}x^3dx + \int_a^1 \left(\frac{b}{1-a}x^3 + \frac{1-a-b}{1-a}x^2\right)dx$$
$$+\int_1^{1+a}\left(\frac{b-1}{a}x^3 + \frac{1+a-b}{a}x^2\right)dx$$
$$+\int_{1+a}^2 \frac{b}{1-a}\left(2x^2-x^3\right)dx = \frac{1-b}{4a}a^4$$
$$+\frac{b}{4(1-a)}\left(1-a^4\right) + \frac{1-a-b}{3(1-a)}\left(1-a^3\right)$$
$$+\frac{b-1}{4a}\left((1+a)^4-1\right) + \frac{1+a-b}{3a}\left((1+a)^3-1\right)$$
$$+\frac{b}{1-a}\left(\frac{2\cdot 2^3}{3} - \frac{2^4}{4} - \frac{2(1+a)^3}{3} + \frac{(1+a)^4}{4}\right)$$
$$= \frac{3a^3(1-b)}{12} + \frac{3a^3b-4a^3-a^2b-ab-b+4}{12}$$
$$+\frac{3a^3b+a^3+8a^2b+4a^2+6ab+6a}{12}$$
$$+\frac{-3a^3b-7a^2b-ab+11b}{12}$$
$$= \frac{1}{6}\left(2a^2+2ab+3a+5b+2\right)$$

Using the expectation and the second moment we evaluate its variance (see [7], [3]):

$$Var[X_1] = E\left[(X_1)^2\right] - (E[X_1])^2$$
$$= \frac{1}{6}\left(2a^2+2ab+3a+5b+2\right) - \left(\frac{1}{2}(1+a+b)\right)^2$$
$$= \frac{1}{12}\left(a^2-2ab-3b^2+4b+1\right)$$

We are interested in finding the autocovarience between $X_1$and X_2. First we will find some quantities needed to find autocovarience.

1)

$$E[\xi_0] = \int_{-\infty}^{\infty} x\cdot f_{\xi_n}(x)\,dx = \int_0^1 1dx = \frac{1}{2}$$

2)

$$E[\xi_0\cdot h(\xi_0)] = \int_{-\infty}^{\infty} x\cdot h(x)\,f_{\xi_0}(x)\,dx$$
$$= \int_0^b \left(a+\frac{1-a}{b}x\right)xdx + \int_b^1 \frac{a}{1-b}(x-b)\,xdx$$
$$= \frac{ab^2+2b^2}{6} + \frac{2a-ab-ab^2}{6}$$
$$= \frac{1}{6}\left(2b^2+2a-ab\right)$$

3)

$$E[X_2X_1] = E[(\xi_2+h(\xi_1))(\xi_1+h(\xi_0))]$$
$$= E[\xi_2]\cdot E[\xi_1] + E[\xi_2]\cdot E[h(\xi_0)]$$
$$+E[\xi_1\cdot h(\xi_1)] + E[h(\xi_1)]\cdot E[h(\xi_0)]$$
$$= \frac{1}{4} + \frac{a+b}{4} + \frac{2b^2+2a-ab}{6} + \left(\frac{a+b}{2}\right)^2$$
$$= \frac{1}{12}\left(3a^2+4ab+7a+7b^2+3b+3\right)$$

and its the autocovariance function $h=1$

$$\gamma(1) = Cov[X_2\cdot X_1] = E[(X_2-E[X_2])(X_1-E[X_1])]$$
$$= E[X_2X_1 - X_2E[X_1] - X_1E[X_2] + E[X_2]E[X_1]]$$
$$= E[X_2X_1] - (E[X_1])^2$$
$$= \frac{1}{12}\left(3a^2+4ab+7a+7b^2+3b+3\right) - \left(\frac{1+a+b}{2}\right)^2$$
$$= \frac{1}{12}\left(-2ab+a+4b^2-3b\right)$$

and its the autocorelation function(ACF) for $h=1$

$$\rho(1) = \frac{\gamma(1)}{\gamma(0)} = \frac{-2ab+a+4b^2-3b}{a^2-2ab-3b^2+4b+1}$$

□

We define a new random process on the unit circle:

$$Z_n = X_n \mod 1,\ n\geq 1.$$

The random process $\mathbb{Z} := \{Z_n\ n\geq 1\}$ is strictly stationary . We find the density function and the moments of $\mathbb{Z} := \{Z_n\ n\geq 1\}$.

Using the density function of X_1 we can write the density of Z_1 :

$$F_{Z_n}(z) = P(Z_1\leq z) = P(\{X_1\leq z\}\cup\{1<X_1\leq 1+z\})$$

1) In the case $0\leq z<a$, we have

$$F_{Z_1}(z) = \int_0^z \frac{1-b}{a}tdt + \int_1^{1+z}\left(\frac{b-1}{a}t + \frac{1+a-b}{a}\right)dt$$
$$= \frac{1-b}{a}\cdot\frac{z^2}{2} + \frac{b-1}{2a}\left((1+z)^2-1\right) - \frac{1+a-b}{a}z = z$$

2) If $a\leq z<1$, we have

$$\begin{aligned}
F_{Z_1}(z) &= \int_0^a \frac{1-b}{a} t\,dt + \int_a^z \left(\frac{b}{1-a}t + \frac{1-a-b}{1-a}\right)dt \\
&+ \int_1^{1+a}\left(\frac{b-1}{a}t + \frac{1+a-b}{a}\right)dt + \int_{1+a}^{1+z}\frac{b}{1-a}(2-t)\,dt \\
&= \frac{1-b}{a}\cdot\frac{a^2}{2} + \frac{b}{2(1-a)}\left(z^2-a^2\right) + \frac{1-a-b}{1-a}(z-a) \\
&+ \frac{b-1}{2a}\left((1+a)^2-1\right) - \frac{1+a-b}{a}(1+a-1) \\
&+ \frac{b}{1-a}\left(2(1+z)-2(1+a)\right) \\
&- \frac{b}{1-a}\left(\frac{(1+z)^2}{2} - \frac{(1+a)^2}{2}\right) = \frac{a-ab}{2} \\
&+ \frac{b}{1-a}\left(\frac{z^2}{2}-z\right) + z + \frac{2a^2-ab^2-2a+2ab}{2(1-a)} \\
&+ \frac{ab+a}{2} + \frac{b}{1-a}\left(-\frac{z^2}{2}+z\right) + \frac{ab^2-2ab}{2(1-a)} = z
\end{aligned}$$

Finally we have

$$F_{Z_1}(z) = \begin{cases} 0, z < 0; \\ z, 0 \le z \le 1; \\ 1, z > 1. \end{cases}$$

It is obvious that Z_1 is uniform distribution on interval $[0,1]$. We evaluate its expectation and variance :

$$1)E[Z_1] = \int_{-\infty}^{\infty} z\cdot f_{Z_1}(z)\,dz = \int_0^1 z dz = \frac{1}{2}$$

$$\begin{aligned}
Var[Z_1] &= \int_{-\infty}^{\infty}(z-E[Z_1])^2 f_{Z_1}(z)\,dz \\
&= \int_0^1\left(z-\frac{1}{2}\right)^2 dz = \frac{1}{12}.
\end{aligned}$$

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REQUIREMENTS FOR THE STRENGTH OF LOAD-BEARING STRUCTURES OF LOCOMOTIVES

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Abstract– This article presents a brief analysis of the requirements for the strength of load-bearing structures of locomotives according to the newly adopted international standard GOST 34939-2023 “Locomotives. Requirements for bearing structure strength and dynamic properties”. This standard was adopted by the Eurasian Standardization, Metrology and Certification Council on January 20, 2023 and was also implemented in the Republic of Uzbekistan. This normative-technical document regulates the requirements for strength and dynamic qualities of locomotives in the CIS countries.

Key words– load-bearing structure, body, frame structure, bogie frame, main frame, lifetime, assigned lifetime, residual lifetime, extended lifetime.

I INTRODUCTION

In transportation engineering, the load-bearing system is understood as a sequence of metal structures of the object united by kinematic connections and perceiving the gravity forces of all equipment and its own gravity forces balanced by reactions in the spots of contact interaction "wheel-rail". Thus, the entire sequence of force elements from the body (cab, main frame, bogie frames, support and return devices, leashes, springs and other elements) to the wheelset is a load-bearing system, and the constituent parts interacting on the force flow of weight loads are its elements [7].

The body and main frame of the locomotive are designed to provide working conditions for the locomotive crew, locating power and auxiliary equipment, locomotive control devices. Designs of the main frame and body are determined by the type of locomotive service, equipment layout, method of load perception and transfer, production and technical conditions of locomotive manufacture and operation. Therefore, high demands are placed on bodies and main frames in terms of stiffness, strength and reliability [7].

The lifetime of the locomotive as a whole is determined by the life of its basic parts (bogie frame, body frame, load-bearing body elements) [7, 23].

Upon expiration of the lifetime of the locomotive, established by the normative and technical documentation, its lifetime can be extended, which requires a number of works and scientific justification in accordance with the established normative documents [4-9, 13-18, 21-25]. These requirements also apply to industrial locomotives. To date, more than 70 units of traction units of PE2M, PE2U, MPE2U types are in operation at industrial enterprises of the Republic of Uzbekistan, and more than 50% of them have already worked out their lifetime, specified in the regulatory documentation, and require urgent measures to extend their useful life [2].

According to the technical documentation, the lifetime of traction units PE2M, PE2U and MPE2U is not less than 24 years [2, 3].

The residual lifetime is assessed by the strength of the frame structures, which are an integral part of the locomotive that determines its lifetime. The main supporting parts of the locomotive are its main frame and bogie frame [2-19, 21-25].

To assess the residual lifetime of locomotives, technical diagnostics of its load-bearing structures, assessment of mechanical properties of its material through laboratory tests and analysis of its stress-strain state are carried out. The stress-strain state can be analyzed by the strain measurement method or the finite element method (FEM) using modern software [20, 21, 23]. In this process, a 3D model of the frame structure is created, taking into account all features of the structure (material, geometric parameters). When analyzing the stress-strain state of the frame structure and during design work, static and dynamic forces acting in all modes throughout its use are taken into account.

II THE METHODOLOGY

1. Requirements for strength and stiffness of load-bearing structures

The tasks of ensuring strength and reliability, creation of more advanced rolling stock structures with minimum metal consumption and long operating lifetime require the choice of geometrical parameters and properties of materials of parts with their maximum adaptation to the operating conditions and loading of structures. At the same time, the accumulation of damage in the structural materials used must not lead to sudden failures causing damage to people, the environment and the products themselves. This largely depends on the perfection and completeness of the current regulatory requirements, which are realized by calculations and tests of structures during their design [7].

The load-bearing capacity of the structure is evaluated under the action of design loads according to permissible values:

- stresses;
- strains;
- fatigue reserve factors;
- stability margin factors.

The strength of the main frame when subjected to the standard longitudinal force applied along the coupling axes should be confirmed by impact testing, as well as by calculation or the results of bench static tests with double-sided compression and tensile tests. The strength conditions of the main frame are:

- under impact test: $\sigma \leq \sigma_{0,2}$;
- under static loading: $\sigma \leq 0,9\sigma_{0,2}$.

$\sigma_{0,2}$ — *yield strength;*
σ — *stress corresponding to the standard longitudinal force.*

Fatigue reserve factors of load-bearing structures shall be not less than:

- 2,0 — for steel structures;
- 2,2 — for structures of aluminium alloys.

The fulfilment of this requirement at the design stage is verified by calculation results, and if a prototype is available, it is confirmed by test results.

The fatigue resistance of bogie frames and intermediate frames of the second stage of spring suspension should be confirmed by the absence of fatigue cracks after 10 million cycles of loading on a vibration test bench.

The stability margin factor for body elements (main frame) must be at least 1.10 for design modes I and IV.

The maximum calculated value of the deflection of the lower chord of the body (main frame), referred to its full length, shall not exceed:

- from the vertical gross load: for the load-bearing body - 0.4 mm/m, for the load-bearing (main) frame - 0.6 mm/m;
- under simultaneous action of vertical gross load and calculated longitudinal force: for load-bearing body - 1.5 mm/m, for load-bearing frame - 2.2 mm/m.

2. Calculation of strength indicators

2.1 General requirements

After selecting materials when designing load-bearing structures of the underframe for the given loading parameters, the following is performed by calculation:

- selection of dimensions and structural shapes of load-bearing elements for given loading parameters;
- analyses of the stress-strain state in the most loaded zones for different design loads;
- estimation of strength and fatigue resistance;
- estimation of expected lifetime.

The strength calculations are subject to: body (main frame), bogie frames, intermediate frames of the second stage of spring suspension, elements of connection of the body (main frame) with bogies, spring suspension springs, axle box housings, equipment fastening units.

2.2 Calculation modes for strength assessment

Locomotive underframe elements are calculated for the most unfavourable possible combination of simultaneously acting load groups in accordance with the established calculation modes [8]. Calculation modes I–IV are used to evaluate strength by allowable stresses in relation to the yield strength of the material [1, 7].

Design mode III is used to evaluate fatigue resistance.

Mode I includes:

- mode *Ia* to account for maximum longitudinal quasi-static forces;
- mode *Ib* to account the maximum longitudinal impact forces on the coupling device (collisions).

Mode II includes:

- mode *IIa* to account for forces acting in curved sections of track with maximum permitted unmitigated acceleration;

- mode *IIb* to take into account the forces acting upon starting;
- mode *IIv* for emergency braking forces.

Mode III takes into account the forces acting at various speeds, up to design speeds, along a straight section of track.

Mode IV is designed to take into account the forces due to the repair technology and emergency recovery operations and arising:

- when lifting the body (main frame) on two diagonally placed jacks;
- when lifting the locomotive by the coupling unit;
- when rolling out the wheelset.

3. Strength assessment

3.1 General provisions

Strength assessments are carried out:

- during design;
- during prototype testing;
- when introducing design or technological changes affecting strength;
- when changing the load.

Strength assessment is carried out according to the following limit states:

- appearance of residual deformations under static loading resulting from exceeding the yield strength of the material;
- occurrence of macro-cracks under cyclic (high-cycle and low-cycle) loading;
- loss of stability (failure to preserve the original shape of a structure or its element due to its insufficient stiffness);
- inadmissible change of geometry and dimensions of parts due to accumulation of plastic deformations.

3.2 Methods of calculation and assessment of strength

Strength assessment methods are determined depending on the operating conditions of the element in question and the achievement of its limit state.

Bodies (main frames), bogie frames, intermediate frames of the second stage of spring suspension, spring suspension springs, connection assemblies and traction and braking force transmission assemblies are evaluated for both allowable stresses and fatigue resistance.

Strength assessment by allowable stresses is carried out for cases of the most unfavourable possible combination of simultaneously acting normative loads in accordance with design modes.

The total stresses obtained as a result of the calculation must not exceed the permissible values set out in table 1 for the relevant design modes.

<table>
<tr><th colspan="2" rowspan="2">Calculation mode</th><th colspan="2">Permissible stress for elements</th></tr>
<tr><th>body (main frame)</th><th>bogie</th></tr>
<tr><td rowspan="2">Mode I</td><td>Ia</td><td colspan="2">$0,9\sigma_{0,2}$</td></tr>
<tr><td>Ib</td><td>$0,9\sigma_{0,2}$*</td><td>$0,9\sigma_{0,2}$</td></tr>
<tr><td colspan="2">Mode II</td><td colspan="2" rowspan="2">$0,6\sigma_{0,2}$</td></tr>
<tr><td colspan="2">Mode III</td></tr>
<tr><td colspan="2">Mode IV</td><td colspan="2">$0,9\sigma_{0,2}$</td></tr>
<tr><td colspan="4">* The value of $\sigma_{0,2}$ is used in the tests</td></tr>
</table>

TABLE 1: PERMISSIBLE STRESSES FOR BODY ELEMENTS (MAIN FRAME) AND BOGIES.

III CONCLUSION

These requirements are considered to be a basic and mandatory condition for ensuring the safety and reliability of passenger and freight traffic when using locomotives. Compliance with these requirements is required from the locomotive design process, through modifications during modernisation, operation and lifetime extension.

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STUDY OF METHODS FOR MODELING ELECTRIC VEHICLE OSCILLATORY RESPONSES TO LOCAL ROAD SURFACES OF UZBEKISTAN.

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Abstract– The growing penetration of electric vehicles (EVs) into the automobile market presents an imperative to understand their dynamic responses to various road conditions. The study examines and enhances methodologies for modeling the oscillatory responses of EVs, particularly focusing on the unique and locally prevalent road surfaces of Uzbekistan. This geographic specificity is seldom addressed in current research, yet carries immense practical implications for the effective utilization of EVs in the region. Traditional computational models, developed predominantly for conventional vehicles, struggle to capture the distinctive dynamics of EVs arising from their unique weight distribution, torque delivery, and drivetrain configurations. Our research introduces an advanced simulation model, employing multi-body dynamics and non-linear damping, and tailored specifically to EVs' peculiarities. The model is further refined to represent the intricacies of Uzbekistan's local road conditions, encompassing the diverse terrains and weather-induced variations. Extensive real-world data collected across the country is used for model validation, enabling more reliable and region-specific predictability. Findings reveal an appreciable enhancement in the accuracy and reliability of EV behavior prediction on diverse local surfaces compared to standard models. These advances offer significant potential for the improved design of EV suspension systems and the development of region-specific predictive control strategies. Our work contributes to the safer, more efficient deployment of EVs in Uzbekistan and serves as a model for other regionally tailored EV dynamic response studies.

Key words–

I INTRODUCTION

Electric vehicles (EVs) represent the future of the automotive industry, bringing a multitude of benefits, including environmental sustainability, energy efficiency, and reduced operating costs. However, their adoption brings forth a unique set of challenges, one of which is effectively understanding and managing their oscillatory behavior when traversing varied road surfaces. Current computational models used to predict the oscillatory responses of traditional vehicles often fall short when applied to EVs due to differences in weight distribution, torque characteristics, and drivetrain configurations. It's crucial to develop improved methodologies that accurately reflect the real-world dynamic responses of EVs on diverse terrains. This paper introduces an enhanced simulation method specifically tailored for EVs, taking into account their unique characteristics and the complexities presented by a range of road conditions. By leveraging advanced multi-body dynamics and non-linear damping, we aim to augment existing models to provide better insights into the performance of EVs under varying conditions. Our goal is to contribute to the ongoing efforts to improve the safety, performance, and comfort of electric vehicles, ultimately facilitating their wider acceptance and adoption.

The increasing adoption of electric vehicles (EVs) worldwide necessitates a comprehensive understanding of their dynamic responses to diverse road conditions. Particularly, in Uzbekistan, where the local road surfaces present unique challenges, the need for precise modeling of EV oscillatory responses is pronounced. Traditional computational models, primarily designed for conventional internal combustion engine vehicles, often fall short in capturing the distinctive dynamics of EVs, including their unique weight distribution, torque delivery, and drivetrain configurations. These models' limited capability hinders the accurate prediction of EVs' performance and safety on Uzbekistan's local road surfaces, which range from urban asphalt to rural gravel and exhibit weather-induced variations. Consequently, this lack of precise modeling and prediction poses potential risks to vehicle safety, performance, and passenger comfort, restrict-

Fig. 1

ing the efficient utilization of EVs in the region. Despite the clear need, current research scarcely addresses the specific challenges associated with modeling EV behavior on Uzbekistan's road conditions. This research paper aims to address this crucial gap in the field by developing an advanced, region-specific simulation model for predicting the oscillatory responses of EVs on various road surfaces prevalent in Uzbekistan. (Figure-1)

II THE BACKGROUND

1 *Traditional Computational Models.*

The computational modeling of vehicles has historically been rooted in the dynamics of Internal Combustion Engine (ICE) vehicles. Traditional computational models are primarily established based on the mechanical attributes of these vehicles. As we traverse this section, it becomes evident that while these models have been sufficient for ICE vehicles, they fall short when applied to EVs. Linear Oscillatory Models: The majority of traditional modeling begins with a simple linear oscillatory system. Here, the vehicle is considered as a sprung mass, with the suspension system acting as a damper and spring in series. Such models are ideal for simple road conditions and constant speeds but don't account for complexities arising from abrupt accelerations, decelerations, or terrains with varying undulations. Integrate remote sensing technology to gather more detailed surface data, such as material density, temperature, or moisture content. Such data can influence the road-vehicle interaction model.

Tyre-road Interaction: In traditional models, the interaction between the tyre and road is often represented using basic friction models. While this approach provides a fair representation for normal driving conditions, it fails to capture the intricate dynamics when the tyre interacts with rough or slippery surfaces, especially pertinent in electric vehicles due to their distinct weight distribution. Improving Model Accuracy using satellite data archives to understand long-term changes in road conditions and their impact on vehicle dynamics. This historical data can enhance the accuracy and predictive capabilities of simulation models. When an EV's navigation system is charting a route, it could leverage the simulation model. With satellite data on road surfaces, the vehicle could predict which routes would provide smoother rides, or how different routes might affect battery consumption due to oscillatory behavior.

Drivetrain Dynamics: Classical models often incorporate the drivetrain as a fixed component, distributing power evenly to the wheels. This static representation misses out on the variable torque distribution and its implications on vehicle dynamics, a feature that's more accentuated in electric vehicles with their rapid torque application. Dynamic Road Condition Update using Satellite Communication (SatCom), EVs can be updated in real-time regarding changing road conditions ahead. This can aid in preparing the vehicle's adaptive suspension systems or alerting the driver.

2 *Differences from Traditional Vehicles.*

Weight Distribution: The weight distribution in electric vehicles (EVs) is not just different from traditional internal combustion engine (ICE) vehicles; it's a transformative design choice that redefines vehicle dynamics. This revolutionary change stems from the strategic placement and substantial weight of the battery pack. In EVs, batteries are intentionally positioned at the lowest point of the vehicle, integrated seamlessly into the chassis. This ingenious design decision confers a lower center of gravity, a feature that is not just beneficial but pivotal for advanced vehicle handling and stability.

Imagine a vehicle that corners with unprecedented precision, offers enhanced stability even at high speeds, and provides a level of control that traditional vehicles simply can-

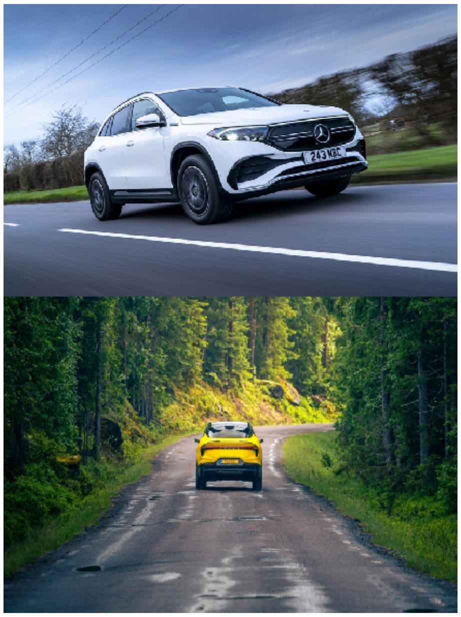

Fig. 2

not match. This is the reality of EVs, thanks to their optimal weight distribution. In stark contrast, ICE vehicles exhibit a more conventional weight spread between the front and rear, primarily due to their engine and transmission layout. While functional, this older design cannot compete with the balance and poise offered by the EV's low-set battery placement.

The implications are clear: the weight distribution in electric vehicles isn't just a technical detail; it's a cornerstone of their superior performance. It redefines the relationship between vehicle and road, creating a driving experience that is safer, more responsive, and unequivocally more attuned to the demands of modern driving. As we move towards a future where road safety and vehicle efficiency are paramount, the advanced weight distribution of EVs doesn't just set a new standard – it revolutionizes what we expect from vehicle dynamics.

Battery Placement and Vehicle Dynamics: The placement of the battery pack in EVs not only influences the overall weight distribution but also impacts the vehicle's response to road surfaces. The lower center of gravity in EVs can lead to reduced body roll and potentially better handling on curved roads. However, the added weight from batteries can also result in increased stress on suspension components, affecting the vehicle's response to bumps and irregularities in road surfaces. Impact on Vehicle Response to Road Surfaces: The unique weight characteristics of EVs demand different considerations in simulation models. For instance, the oscillatory response of an EV to various road surfaces can be distinctly different from that of ICE vehicles. This is due to the combined effect of weight distribution, suspension system design, and the rigidity introduced by the battery structure. These factors must be accurately represented in simulations to ensure the reliability and safety of EVs in diverse road conditions.

III CURRENT SIMULATION TECHNIQUES IN VEHICLE DYNAMICS

1 The realm of vehicle dynamics has seen a plethora of simulation models and techniques, each contributing uniquely to the understanding and enhancement of vehicle performance.

A review of these existing models and techniques reveals a diverse and sophisticated landscape:

1. Multi-Body Dynamics (MBD) Simulations:

- MBD simulations are at the forefront of vehicle dynamics modeling;
- These models treat the vehicle as a system of interconnected rigid or flexible bodies, allowing for the detailed analysis of movement and forces;
- Applications include the analysis of suspension response, ride comfort, and handling characteristics under various conditions.

2. Finite Element Analysis (FEA):

- FEA is crucial for structural analysis, helping to predict and visualize how components behave under stress, vibration, and other physical effects;
- It's particularly useful in understanding chassis and body deformations, as well as in designing components for optimal strength and weight.

3. Computational Fluid Dynamics (CFD):

- While primarily associated with aerodynamics, CFD is also employed in vehicle dynamics for thermal management and to analyze the effect of air flow on vehicle stability;
- CFD simulations assist in optimizing vehicle shapes for reduced drag and improved fuel efficiency.

4. Empirical and Data-Driven Models:

- These models rely on real-world data and testing results to simulate vehicle behavior;
- They are often used for calibrating other simulation models or when detailed physical modeling is impractical.

2 *Vehicle Modeling and Multi-body Dynamics Integration*

The methodology employed in this research paper begins with the development of a comprehensive vehicle model. This model incorporates advanced multi-body dynamics to accurately represent the complex interactions between the vehicle's components, including the chassis, suspension, tires, and electric drivetrain. Our methodology is centered on augmenting existing simulation models with advanced multi-body dynamics and non-linear damping characteristics specifically tailored to electric vehicles. We pay particular attention to the effects of electric drivetrains, which include weight distribution and torque delivery.

These elements significantly influence the oscillatory behavior of the vehicle. By accounting for these intricacies, we aim to create a simulation model that more accurately represents the real-world behavior of electric vehicles. The intricacies associated with electric vehicles, including their weight distribution, power delivery methods, and electronic control systems, necessitate a comprehensive approach to understanding their dynamic behavior. Multi-body dynamics (MBD) offers a versatile and robust framework to capture these complexities, particularly when investigating the oscillatory responses of EVs on varying road surfaces. This section delves into the integration of MBD into our simulation model, elucidating its advantages and its role in enhancing the accuracy of our findings.

Fundamentals of Multi-body Dynamics: At its core, MBD deals with the study of interconnected rigid and flexible bodies, considering their mutual interactions and external forces. In the context of EVs, MBD facilitates the representation of the entire vehicle as an assemblage of interconnected bodies – the chassis, battery packs, wheels, suspension components, and more.

(Figure-3) These components are connected through various joints, allowing relative motion, and are acted upon by forces, including gravitational, damping, and external road forces.

Fig. 3

Handling Non-linearity: Road surfaces, by nature, introduce non-linear forces due to their irregularities. When an EV traverses these terrains, the responses are non-linear and sometimes unpredictable. The strength of MBD lies in its inherent capability to model and analyze such non-linear systems. By incorporating non-linear damping characteristics and detailed tire-road interaction models, the proposed simulation framework can capture the actual responses with high fidelity.

Validation through Real-world Data: To ensure the reliability and applicability of the integrated MBD model, real-world data sets have been employed. By comparing the simulated results with actual vehicle response data on diverse road conditions, the model's accuracy and predictive capability have been ascertained. (Figure-4)

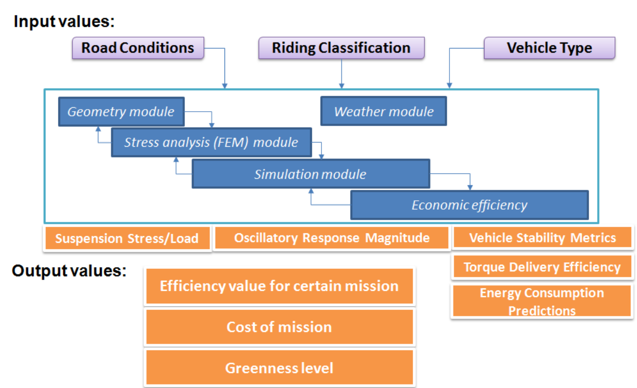

Fig. 4

In summary, the integration of multi-body dynamics into our simulation methodology offers a sophisticated approach to understanding the oscillatory behaviors of EVs. It captures the complexities and unique attributes of electric vehicles, ensuring that the model is not just theoretically sound but also practically relevant.

IV CHALLENGES IN SIMULATING OSCILLATORY RESPONSES

1 *Detail the specific challenges in simulating oscillatory responses of EVs to diverse road conditions.*

Simulating the oscillatory responses of electric vehicles (EVs) to diverse road conditions presents several specific challenges, each requiring careful consideration and advanced technological approaches:

1. Accurate Representation of Battery Dynamics:

- EVs have large, heavy batteries, which significantly influence their vibrational characteristics;
- Simulating how these batteries interact dynamically with the rest of the vehicle, especially under varying

road conditions, is complex. The challenge lies in accurately modeling the battery's mass, its distribution, and how it affects the vehicle's overall center of gravity and inertial properties.

2. Complex Suspension Systems:

- EVs often employ advanced suspension systems to cope with the additional weight of the batteries and to enhance ride comfort;
- Accurately simulating these systems is challenging due to their complexity and the need to model their response to a wide range of oscillatory inputs, from minor road irregularities to major undulations.

3. Variability of Road Surfaces:

- Roads vary greatly in texture, incline, and condition. Simulating every possible scenario an EV might encounter is a daunting task;
- The challenge is to develop models that can realistically mimic a broad spectrum of road conditions, including potholes, speed bumps, gravel, wet surfaces, and more.

4. Integration of Vehicle Control Systems:

- Modern EVs are equipped with sophisticated control systems for stability, braking, and power management;
- Simulating how these systems interact with the mechanical components during oscillatory responses requires a multi-disciplinary approach, combining aspects of mechanical, electrical, and software engineering.

5. Impact on Passenger Comfort and Battery Safety:

- Understanding how oscillatory movements affect passenger comfort and battery integrity is crucial;
- This requires simulations to not only focus on the mechanical aspects but also to consider human factors and the safety aspects of battery structures under various stress conditions.

6. High-Fidelity Modeling Requirements:

- To accurately predict oscillatory responses, high-fidelity models are needed, which are computationally intensive;
- Balancing the need for detailed, accurate modeling with computational efficiency is a significant challenge, especially when aiming for real-time simulation capabilities.

7. Data Collection and Validation:

- Collecting real-world data for model validation is challenging but essential;
- This involves extensive testing with a variety of EVs on numerous road types and conditions, which can be resource-intensive.

Addressing these challenges requires a concerted effort in research and development, combining advanced modeling techniques, extensive experimentation, and continual refinement of simulation tools. As EV technology and simulation methodologies evolve, these challenges present opportunities for innovation and advancements in vehicle design and safety.

2 *Discuss the complexity of accurately modeling battery dynamics.*

Accurately modeling the complexity of battery dynamics in electric vehicles (EVs) presents a multidimensional challenge that is critical for realistic and effective vehicle simulation. Each of these components has its own set of intricacies:

Weight and Distribution: The weight and placement of the battery pack significantly affect the vehicle's center of gravity and inertia. Modeling how this influences the vehicle's overall dynamics is critical.

Vibration Impact: Batteries are sensitive to vibrations and shocks. Simulating how road vibrations affect the battery's structural integrity and performance is complex and requires detailed material and structural analysis.

Thermal Behavior: Batteries also exhibit complex thermal behavior, which can be influenced by external conditions, including road surface and ambient temperature. Accurately modeling this thermal response is vital for predicting battery performance and safety.

In conclusion, the accurate simulation of battery dynamics in EVs involves a highly detailed and interdisciplinary approach. It requires integrating mechanical engineering principles with advanced computational models and real-world data. The complexity lies not only in modeling these elements individually but also in accurately simulating their interactions under a wide range of conditions. As technology progresses, the development of more sophisticated simulation tools and techniques becomes imperative to address these complexities and to advance the design and safety of electric vehicles.

V RECENT ADVANCES IN SIMULATION TECHNOLOGIES

1 *Recent advancements in simulation technologies have significantly enhanced the accuracy of modeling electric vehicle (EV) responses. These developments represent a convergence of various fields, including computational mechanics, software engineering, and data analytics. Some of the key advancements are:*

1. Machine Learning and AI Integration:

- Machine learning algorithms are being integrated into simulation software to predict and analyze complex vehicle behaviors more accurately.

- AI can process vast amounts of data from real-world driving conditions, allowing for more accurate and adaptive models of vehicle dynamics, battery performance, and road surface interaction.

2. Advanced Multi-Physics Simulation Tools:

- Modern simulation tools now combine multiple physical domains (mechanical, electrical, thermal) in a single environment.

- This holistic approach is crucial for EVs as it allows for simultaneous analysis of mechanical stress, battery temperature, and electrical performance under various conditions.

3. High-Fidelity Battery Modeling:

- The development of detailed battery models that accurately represent thermal behavior, degradation over time, and response to external stresses has been a significant focus.

- These models are essential for understanding and optimizing battery life and performance in EVs.

4. Improved Tire and Road Surface Modeling:

- Recent technologies enable more detailed modeling of tire-road interactions, considering factors like tire wear, surface texture, and weather conditions.

- This allows for more accurate predictions of vehicle handling, stability, and energy efficiency on various road types.

5. Real-Time Simulation Capabilities:

- There's an increasing emphasis on developing real-time simulation tools that can provide immediate feedback during the design and testing phases.

- These tools are invaluable for rapid prototyping and iterative design processes in EV development.

6. Hardware-in-the-Loop (HiL) and Software-in-the-Loop (SiL) Enhancements:

- HiL and SiL technologies have become more sophisticated, allowing for the integration of actual vehicle components or control systems into the simulation environment.

- This enables more realistic testing scenarios and helps in fine-tuning vehicle control systems and battery management strategies.

7. Cloud Computing and Scalability:

- The use of cloud computing has enabled more scalable and flexible simulation environments.

- Engineers can now access powerful computing resources on demand, allowing for larger, more complex simulations without the need for extensive in-house hardware.

8. Virtual Reality (VR) and Augmented Reality (AR):

- VR and AR technologies are being used to create immersive simulation environments.

- These tools are particularly useful for ergonomic studies, driver experience analysis, and in the visualization of complex vehicle dynamics.

In summary, these technological advancements are driving a new era in EV design and testing. They are not only enhancing the accuracy of simulations but are also making them more comprehensive, efficient, and adaptable to the rapidly evolving requirements of electric vehicle technology. Including examples of cutting-edge software, algorithms, or methodologies highlights the practical applications of the advancements in simulation technologies for electric vehicles (EVs). Here are some notable examples: ANSYS Software Suite, Simulink and CarSim, Dassault Systèmes' SIMULIA, Machine Learning Algorithms for Predictive Analysis, Real-Time Simulation with RT-LAB, Virtual Reality (VR) Tools. These tools and methodologies represent the cutting edge in EV simulation technology, offering comprehensive and versatile solutions to the complex challenges of EV design and testing. Their application facilitates a deeper understanding and optimization of EV performance, safety, and reliability.

2 *Case Studies and Applications.*

Describing specific case studies helps to illustrate the real-world application and effectiveness of enhanced simulation techniques in electric vehicle (EV) development. Here are some examples: Tesla's Use of Simulation for Vehicle Design and Testing, a notable case is the development of the Tesla Model S, where simulations were used to optimize the aerodynamics, battery pack design, and thermal management systems. The simulations helped in reducing drag, improving battery efficiency, and ensuring optimal cooling, which contributed to the car's extended range and performance; BMW utilized advanced simulation techniques in developing its i3 and i8 models. The company implemented multi-physics simulations to test and refine the vehicle's lightweight carbon fiber-reinforced plastic (CFRP) structure. This not only ensured the safety and durability of the vehicle but also significantly reduced the development time and costs; General Motors (GM) used Computer-Aided Engineering (CAE) extensively in the development of the Chevrolet Bolt. The simulations included crash simulations, battery performance under various environmental conditions, and the optimization of the electric motor. This comprehensive use of simulation not only improved vehicle safety but also maximized range and efficiency; in developing the Nissan Leaf, Nissan used advanced Computational Fluid Dynamics (CFD) simulations to enhance the vehicle's aerodynamics. The simulations helped in designing a car body that significantly reduced air resistance, thus improving the vehicle's range and energy consumption; Volvo used Virtual Reality (VR) simulations in the development of its autonomous vehicle technologies. The simulations enabled engineers to test and refine the vehicle's sensing and navigation systems in a wide range of virtual environments and scenarios, ensuring the safety and reliability of the autonomous systems before real-world testing.

Each of these case studies demonstrates how enhanced simulation techniques can significantly contribute to various aspects of EV development, from design optimization and performance enhancement to safety improvements and cost reduction. These examples highlight the growing importance of simulation in the rapidly evolving field of electric vehicle technology.

VI FUTURE DIRECTIONS AND RESEARCH OPPORTUNITIES.

The study of Electric Vehicle (EV) oscillatory responses to local road surfaces, particularly in the context of Uzbekistan, opens several avenues for future research. Advancements in this field are not only pivotal for enhancing EV performance but also for aligning with global standards of vehicular technology. Here are potential future research directions:

- Future research should focus on developing high-fidelity local simulation models that specifically cater to the unique road conditions of Uzbekistan. Example: "Innovative models incorporating detailed topographical data of Uzbek roads can provide more accurate predictions of EV performance, leading to better-informed design and engineering choices tailored to local needs."
- Collaborating with international research bodies and industries can bring in global perspectives, advanced methodologies, and shared knowledge. Example: "Through international collaboration, Uzbek researchers can integrate global advancements in EV technology with local expertise, fostering a more holistic approach to EV road response research."
- Investigating new materials for both road surfaces and EV tires can provide insights into reducing wear and tear and improving energy efficiency. Example: "Exploring materials that are both durable and efficient for Uzbekistan's diverse terrains could lead to significant improvements in EV performance and longevity."
- Studying how EVs respond to extreme weather conditions prevalent in different regions of Uzbekistan can be crucial, especially given the impact of temperature on battery performance. Example: "Research focused on adapting EVs to the hot summers and cold winters of Uzbekistan will be critical in ensuring their reliability and efficiency year-round."
- Differentiating between urban and rural driving conditions in simulations can lead to more targeted vehicle designs and infrastructure planning. Example: "Creating separate models for urban centers like Tashkent and rural areas can help in designing EVs that are versatile and adaptable to varying driving environments across the country."
- Future research can also emphasize developing eco-friendly and sustainable EV technologies, aligning with global environmental concerns. Example: "Emphasizing research on sustainable battery technologies and environmentally friendly materials can position Uzbekistan as a leader in green EV technology."

VII CONCLUSION

The exploration of methods for modeling the oscillatory responses of electric vehicles (EVs) to Uzbekistan's local road surfaces yields several key findings with significant implications for the development and use of EVs in the region:

- Adaptation to Local Road Conditions: The research underscores the necessity of developing EV models that are specifically adapted to the varied and unique road conditions of Uzbekistan, from urban streets to rural pathways. Implication: Tailoring EV design and performance to local conditions ensures better handling, safety, and reliability, making

EVs more appealing and practical for Uzbek consumers.

- Advancements in Simulation Techniques: The studies highlight the advancement of simulation techniques, which are crucial for accurately predicting and enhancing EV performance on diverse terrains. Implication: Improved simulations lead to better-engineered vehicles that are equipped to handle the specific challenges posed by Uzbek roads, potentially increasing consumer trust and adoption rates.

- Collaboration and Knowledge Exchange: The importance of international collaboration in research is evident, combining global technological advancements with local expertise. Implication: Such collaborations can accelerate the development of EV technology in Uzbekistan, placing it at par with global standards and fostering innovation within the local automotive sector.

- Sustainability and Environmental Impact: The focus on sustainable and eco-friendly solutions in EV research aligns with global environmental concerns, emphasizing the need for green technologies in the automotive industry. Implication: This approach not only addresses environmental issues but also enhances the marketability of Uzbek EVs as eco-friendly alternatives, both domestically and internationally.

- Economic and Infrastructural Development: The adaptation and advancement of EV technology have the potential to drive economic growth and infrastructural development, especially in the automotive and energy sectors. Implication: The rise in EV usage could lead to increased demand for supporting infrastructure, such as charging stations, stimulating economic growth and job creation.

In conclusion, the study of EV oscillatory response modeling in relation to Uzbekistan's road conditions is more than a technical endeavor, it is a step towards aligning the nation's automotive sector with global trends while addressing local needs. These findings not only pave the way for the development of EVs that are well-suited to the Uzbek environment but also open doors to economic growth, sustainable development, and enhanced international collaboration. As Uzbekistan continues to embrace and invest in EV technology, these insights will be instrumental in shaping a future where mobility is efficient, safe, and environmentally responsible.

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APPLICATION OF RHEOLOGICAL MODELS IN THE STUDY OF COMPENSATION OF ROAD STRUCTURE SOILS WITH CABLES.

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Abstract– In the article, the types of rheological models used to reveal the essence of the working process of the interaction between the working body of the rollers and the soil in the densification of the soil of the road structure and the analysis of their use are mentioned. At the same time, it is explained that the indicators of the technological operation mode of the rollers in providing the soil compaction coefficient of the road structure layers are evaluated through these models.

Key words– working body, soil, interaction, vibration, rheological model, elastic, plastic, viscous, Maxwell's model, Newton's element, operating mode, efficiency.

I INTRODUCTION

In recent years, a lot of attention has been paid to the design, construction and use of modern highways in our country. We know that the highway structure belongs to one of the types of complex artificial structures, and there are technical regulations that must be followed during their construction, as well as standard requirements that regulate the physical and mechanical properties of the soils used in the structure [1]. Taking into account these aspects, several technological operations are carried out during the construction of the road structure with the participation of earth digging and road construction machines, but in all layers of the road structure (road structure base, road base, road pavement base, pavement) one important process is the compaction of structural soil. technological processes are carried out using rollers and tamping machines [2].

Many scientists and researchers are conducting scientific research on the process of soil interaction with the working bodies of the compacting machine and the wide application of the obtained results to production practice. In this direction, the world's leading scientists, including foreign researchers, Michael Leonard, Paulwan Susante, Guiyan Xing, K. Terzaghi, W.A. Lewis, Mooney, Michael A. Robert W. Rinehart, CIS scientists V.I. Balovnev, V.V. Badalov, M.A. Zavyalov, N.N. Zaitsev, A.V. Zakharenko, N.N. Ivanov, S.I. Ivanchenko, G.V. Kustarev, M.P. Kostelov, E.N. Kuzin, D.K. Lomanov, Yu.M. Lvovich, A.G. Maslov, V.V. Mikheev, S.V. Nosov, I.A. Nedorezov, V.B. Permyakov, S.V. Savelev, V.A. Smolentseva, N. Ya. Kharkhuta, AM Kholodov, A. Hall and Uzbek scientists A.D., Kayumov, T.Q., Hankelov, R.M. Khudaikulov, D.A. Makhmudova and other scientists.

The densification process involves complex technological operations, in which different types of cages are used [3]. On the other hand, the working bodies of the compacting machines are of different types, depending on the physico-mechanical properties of the soil layers of the road structure, indicators and technological processes, static, vibrational and combined compaction methods are used.

In this case, various types of models are used to study the laws of the process of interaction between the working body and the soil and the physical and technological essence of the work operation, as well as to illuminate the complete work cycle performed in each layer. evaluation of the technological process using differential equations allows obtaining positive results in research.

II THE MAIN PART

Many types of models are used in scientific research including mathematical, simulation, probabilistic and rheological models. The system of equations modeling the process of interaction of the machine's working body with the environment is determined from the the properties of the environment and the characteristic movement of the working body. The mechanical characteristics of the medium in rheological models (RM) are determined from the following main properties: elastic; plastic; viscous.

Other mechanical properties are derived from the underlying invariants, i.e. constants. Simple types of RMs are used in studying and researching the general laws of the process of interaction of working bodies with the environment. The types and views of these models are shown in Figure 1 [4].

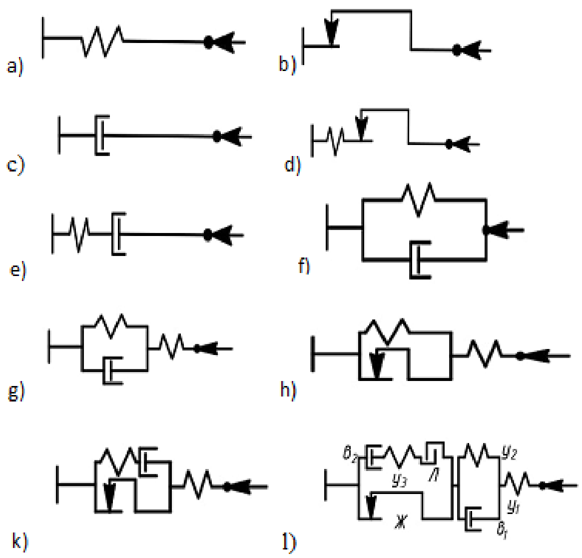

Fig. 1: Types of rheological models.
a) Hook; b) You are Vena; c) Newton; d) Prandtl; e) Muswell; f) Voigt; g) Kelvin; h) Bingham; k) Shvedov; l) Combined Kelvin and Shvedov model.

The specified types of rheological models are used to reveal the essence of the interaction process between the working bodies of compacting machines and soils, as well as to study the mechanical regularity in the organic continuation of the technological operation in compaction. In this respect, by placing the rheological models in parallel and in series with each other, it provides an opportunity to analyze the required criteria by introducing various quantities, including deformation, stress, uniformity and excitation force indicators into differential equations.

III APPLICATION OF RHEOLOGICAL MODELS IN THE PROCESS OF DENSIFICATION.

Various types of rheological models are used based on the nature of the research, as well as the physical-mechanical properties of the layer elements in the road structure. In particular, the researcher, A.A. Shestopalov, V.S. Serebrennikov, used the rheological model shown in Figure 2 to reflect the situation in the process of compaction of asphalt concrete pavements with vibrating rollers [5].

The first differential equations related to this rheological model is described by the following expression :

$$\dot{m}_1 \cdot \ddot{x}_1 + b \cdot (\dot{x}_1 - \dot{x}_2) + c \cdot (x_1 - x_2) = m_1 \cdot g$$

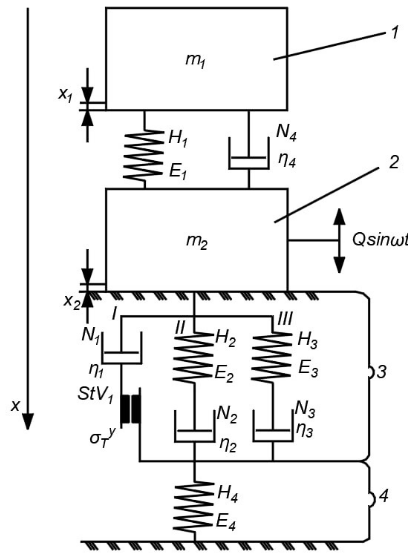

Fig. 2: Rheological model of asphalt concrete pavement.
1-loading; 2-valets; 3-asphalt concrete mixture; 4-base.

$$\dot{m}_2 \cdot \ddot{x}_2 - b \cdot (\dot{x}_1 - \dot{x}_2) - c \cdot (x_1 - x_2) = Q \cdot \sin \omega \cdot t + m_2 \cdot g - P(t)$$

Researcher V. V. Mikheev [6] in his research proposed a single and multi-mass model in order to study and analyze the process of interaction of the roadbed with the deformable soil environment. According to it, a multi-mass model of rheologically non-equivalent bodies was considered, which allows to connect the distribution of normal stresses caused by the action of road rollers over the thickness of the compacting soil (Fig. 3).

A one-mass model is in the form of Lagrange's equation, which is modeled by an elastic viscoplastic body and takes into account the possibility of a section mass change in the distribution of layer characteristics during densification, and the initial expression is as follows:

$$m(\sigma_1,\sigma_0)\ddot{z} + \frac{\partial m(\sigma_1,\sigma_0)}{\partial t}\dot{z} = -(c_{def}((\sigma_1,\sigma_0)(1-\theta(\sigma_1-\sigma_{fl}))z -$$

$$-b(\sigma_2,\sigma_1)\dot{z} - \frac{\dot{z}}{|\dot{z}|}\theta(\sigma_1-\sigma_{fl})S_{cont}(\sigma_1)\sigma_{fl} + F_{out}(t)$$

$$\rightarrow \theta(x) = \begin{Bmatrix} 1, x \succ 0 \\ 0, x \leq \end{Bmatrix}$$

Researcher E. A. Shishkinn [7] proposed a rheological model for densification of asphalt concrete mixture.

As a result of the scientific research, the researcher proposed this rheological model shown in Figure 4 under the conditions of densification of asphalt concrete mixture with smooth valets.

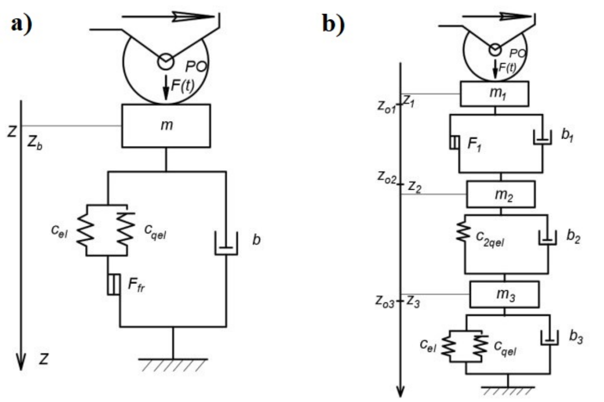

Fig. 3: One- and multi-mass model for the study and analysis of the interaction process of the roadbed with the deformable soil environment.
a) One mass. b) Multi-mass.

This model consists of the following elements : Hook elements 1 and 2, characterized by elastic modulus b and c, respectively; μ Newton's element 3, which describes viscosity; De Saint - Venan element describing the conditional yield strength σ_t. Element 4 in the rheological model serves to account for the accumulation of plastic deformation when the asphalt concrete mixture is loaded, which in this case is equal to the residual deformation for the model. According to this rheological model, the total deformation consists of the deformation of Hooke's elements (1 and 2) and is determined by the following expression:

$$h = h_b + h_c = h_b + h_\mu$$

where h_b - the deformation of the elastic element of model 1, cm; $h_c = h_\mu$- fit respectively elastic 2 and viscous deformation of model elements, cm.

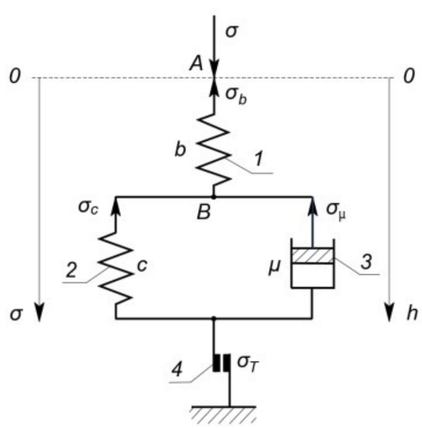

Fig. 4: Rheological model of asphalt concrete mixture taking into account elastic, viscous and plastic properties.

After some substitutions, we have the following expression:

$$\frac{d\sigma}{dt} + \frac{b+c}{\mu} \cdot \sigma = b \cdot \frac{dh}{dt} + \frac{bc}{\mu} h$$

Researcher K. V. Belyaev [8] also proposed a rheological model related to the densification of asphalt concrete mixtures. According to this, the densification mode provides such a state of deformation stress of the mixture that as a result of such an effect residual deformation is formed and the maximum increases, which is considered effective. In this case, the efficiency of thickening agents increases, and the energy capacity of the process decreases.

A rheological model was developed in order to explain the state of deformation stress in the process of densification of the asphalt-concrete mixture. The formula of the model view is $\mathbf{StV_1} - ((\mathbf{N_1}||\mathbf{StV_2} - (\mathbf{H}||\mathbf{N_2})))$ and its mechanical analogue is presented in Figure 6. This model explains the densification of the asphalt-concrete mixture in two stages - the initial and the main stage.

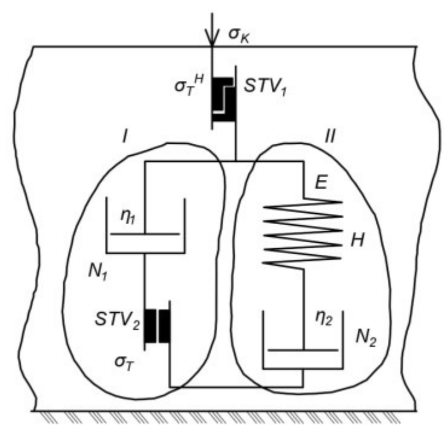

Fig. 5: Rheological model in the process of densification of asphalt concrete mixture.

In this case, the viscoelastic deformation in the thickening layer coating is expressed by an equation of this form:

$$\frac{d\sigma}{dt} + \frac{\sigma_k}{\theta} = \eta \frac{d^2\varepsilon}{dt^2} + E_d(1 + \frac{\eta 1}{\eta 2}) \frac{d\varepsilon}{dt}$$

where $\eta_1 = \eta_2 = \frac{1}{2}\eta$ is the viscosity of the mixture, Pa s.

The rheological model of the asphalt concrete mixture proposed by V.B. Permyakov [9] was taken as a basis for modeling the processes occurring in the compacted layer without taking into account the basis of the road surface.

In order to apply the given rheological model in the development of densification technology at the initial stage, it is necessary to exclude the viscosity from the considered calculation scheme, using the known legal relationship between the deformation modulus and the relaxation time.

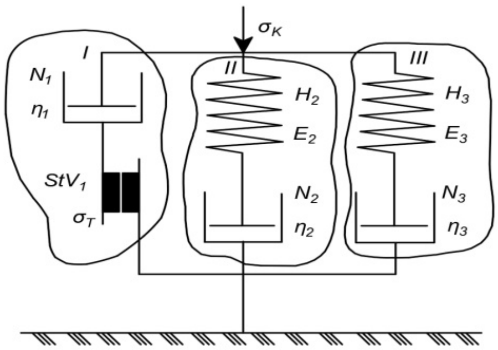

Fig. 6: Rheological model in the process of densification of asphalt-concrete mixture without taking into account the base.

According to the developed rheological model, the expression of bonds is in the form of the following equation:

$$(n+m)\cdot E_m(t)\cdot\theta_2\cdot\theta_3\cdot\frac{d^2\varepsilon}{dt^2}+\frac{(n+m)^2\cdot E_m(t)\cdot\theta_2\cdot\theta_3}{n\cdot\theta_3+m\cdot\theta_2}\frac{d\varepsilon}{dt}=$$

$$\theta_2\cdot\theta_3\cdot n\cdot m\cdot\frac{d^2\sigma}{dt^2}+(\sigma_k-\sigma_F)+(n\cdot\theta_2+m\cdot\theta_3)\cdot\frac{d\sigma_k}{dt}$$

IV CONCLUSION

A number of scientists V.B. Developed by Permyakov, K.V.Belyaev, E.A.Shishkin. These rheological models can be used to study the laws of soil compaction. The main reason for this is that the elasticity, viscosity and plasticity characteristics of asphalt concrete are fully manifested in soil, but in developing the rheological model of the soil compaction process, it is necessary to take into account the conditions that show the soil's unique properties. These are the determination of the laws of change of elasticity, viscosity or plasticity with time and their numerical values.

The developed rheological models, in turn, connect the value of the stress that appears in the soil during the compaction of the soil to such parameters as the value of the load applied to the soil, the vibration frequency and amplitude of the working body, and allow to control the condition of not exceeding the value of the strength limit of the soil and to justify the basic structural and technological parameters of the compacting machine. It should be noted that during the analysis of the models considered above, other types of soils of the road structure layer can be used in the research of the interaction process with the working bodies of the road. For this purpose, it is appropriate to take into account the specific characteristics of the soils used as construction materials on the roads under construction.

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THE NEED TO FORM A READING CULTURE IN A NEW SPIRITUAL SPACE.

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Abstract– The scientific article examines the concept of a new spiritual space and the formation of an enlightened society in it, their mutual influence, the manifestation of the spiritual image of the new Uzbekistan, the place and role of the formation of a reading culture in It, family, neighborhood, education along with the library and information service in the formation of the system reading cultures, trade unions, government, political parties, public organizations, the media and other institutions of civil society are important factors, in addition, the Formation of an enlightened society in New Uzbekistan through reading - from a deep study of the rich history, scientific and cultural heritage of our people , national and religious values. Issues such as its composition are explained.

Key words– new spiritual space, reading culture, national and religious values, “enlightenment against ignorance”, public culture, reading leadership, reading activity, reading process, need for reading, educational worldview.

I INTRODUCTION

In the process of creating the foundations of the Third Renaissance in New Uzbekistan, the issue of forming a modern and innovative spiritual space that can meet the requirements of the current stage of development of the society is of urgent importance.

What is the new spiritual space? This question was answered in the work "Development Strategy of New Uzbekistan" by the President of the Republic of Uzbekistan Sh.M. Mirziyoev: "In my opinion, it is an enlightened society that clearly reflects the spiritual image of the New Uzbekistan that we dream of, where our people aspire and where our country lives happily" [1, p.266].

In order to create a new spiritual space, first of all, in the current globalization process, it is necessary to pay special attention to spirituality and enlightenment, moral education and education of young people.

Secondly, in order to fight against various threats that are entering in the form of "mass culture", it is required to act based on our national traditions formed over the centuries and the rich spiritual heritage of our ancestors.

For this, it is necessary to develop strategic directions for the organization of continuous spiritual-educational education, promotion-campaign work in society based on the idea of "enlightenment against ignorance" [1, p.266] and methods of their practical application.

II RESEARCH METHODS

In the creation of a new spiritual space, in the implementation of the idea of "enlightenment against ignorance", among many cultural and educational institutions, library and information institutions, including school libraries, perform a special social task.

Because the formation of reading culture among users requires an approach taking into account their age characteristics and the uniqueness of different socio-demographic groups. It is a prerequisite and an integral part of the work with users in the process of library information service, and provides feedback in the process of reading management, in addition to creating a basis for evaluating the effectiveness of the library information service.

To divide users into certain groups is to group them according to the characteristics that have a strong influence on the formation of the psychology of users.

When grouping users, attention is also paid to demographic, social professional, social psychological characteristics.

Library-information service provision is carried out through the satisfaction of users’ interests and needs, guidance to reading, provision of information, bibliographic and information retrieval support, and it can be defined as a system of organizational forms of service to users. Libraries occupy a special place in the system of educational institutions. However, "in these institutions, only the presence of employees with special knowledge and skills in working with readers can ensure the success of the formation of reading culture" [5.B.75].

Since the formation of the reading culture is related to the reader's activity, it is necessary for the employee of the library and information institution to use his opportunities as a pedagogue in order to improve the skills of his striving for the goal, his will, responsibility, and the ability to control himself. can be applied. Library and information institutions should be able to offer new forms of service utilizing new information delivery technologies, expand the collection of electronic resources and the use of remote resources along with the promotion of traditional books.

Library and information institutions should pay attention to the following situations in order to form a culture of reading, combining the forms and methods of traditional librarianship with the positive results of the wide use of new technologies:

- wide use of new forms and methods of attracting users to Library and information institutions;
- active participation in the implementation of programs related to reading and reading culture implemented in our country;
- forming the ability of users to independently use the library's information and bibliographic apparatus;
- development of methods to optimize the scientific-theoretical possibilities of the reading process;
- formation of skills and culture of using the Internet;
- constantly improving the skills of library and information institution employees.

III RESEARCH RESULTS

Since the formation of spirituality is closely related to the way people, especially young people, read books, the activity of the library staff is of particular importance in the formation of reading culture. Because the user does not have the opportunity to read all the books in the fund, but it is not necessary to read them all.

While the book is considered the highest spiritual wealth, the books that are placed on the bookshelf, but not read, and not recommended for reading to others, have no value. The value of the books that make a person think, guide a person along the way of life, change his outlook and philosophy of life, and help to direct activities towards the goal based on reaching a certain conclusion is incomparable.

Because a person should read the book in order to understand the purpose of living, the meaning and content of his life. A good book teaches thinking, improves speech, broadens and enriches thinking. Therefore, selecting and recommending the best books should be one of the most important directions in working with users of the library and information institution.

If a user who does not know which book to read gets his hands on some of these selected books and gets a proper understanding of their content and purpose, it is considered one of the most effective methods of reading books. "A reader who has read the best books begins to observe the world with a special gaze, unlike other people around him, expands his ideas about the character and needs of others, worldview, goes beyond his ego, and generalizes his life conclusions" [8.B.18]. Faith is formed in the person who reads the best books continuously, consistently and systematically. Faith, in general, is the firm, sincere belief and verbal affirmation that there is a perfecting will in all things past, present, and future. Anyone who has this faith and belief becomes a participant in the process of perfection and perfection. A person who is capable of observing beauty and virtue and has a sense of morality, strives for beauty in life, feels desire for it, and acts in accordance with the norm. Reading the book inspires a person to make his dreams come true, to new dreams and aspirations based on the achieved level.

In order to achieve new goals, the need to study, research, and regularly work on oneself forms the desire. This is how the desire to read is created. Today's level of development of human society requires constant reading. Optimizing this continuous process serves as a moral basis for the socio-economic, cultural development of the society, as well as for the transition to new qualitative stages.

Today, with the expansion of the modern information flow and the possibilities of the Internet, the role and importance of the book in the life of a person and society is decreasing.

But according to the researches and surveys conducted at the international level, according to the growth of Internet users, book buying and reading are also growing. If we take into account what is happening in the Western countries, it is evident that nothing can replace the book in spiritual growth. In addition, according to the results of the comparative analysis of experts in various fields, electronic books are convenient and fast to carry, but the feeling of boredom is strong, and they do not evoke human feelings like love, excitement, anticipation, and wide observation like a regular book. Recently, it is possible to observe that the culture of buying and reading books is growing significantly in our country. Because for many years no one had seen people waiting in line in front of bookstores to buy some books. This situation is a sign that people are turning towards spirituality and reading books.

So, no matter how much the flow of information increases, despite the abundance of information on the Internet, nothing can replace a book. The best way to promote book reading today is to recommend selected books. Because as a result of the expansion of publishing opportunities, books of different levels and contents are being published, it is necessary to be able to direct the reading of books that enrich human thinking and influence the formation of positive qualities.

Because only people who have formed an enlightened worldview and think on a global scale can contribute to the development of society. It is an invariable fact that success can be achieved in all spheres of life only through knowledge.

It is of particular importance to determine the place of reading among different layers of users, to know the main sources of information, to determine the reason for the decrease in the level of reading, and to show ways to improve the formation of reading culture, thereby:

1. in the formation of reading culture, to fully preserve the principles, forms and methods of traditional reading, to be able to use and improve new forms and methods, taking into account the characteristics of our time;

2. formation of the culture of reading on the basis of the ability to fully use modern electronic and technical tools, and the ability to analyze them to the extent that they can meet the requirements of the time.

3. a broad explanation that the increase in electronic resources in the information society is not the marginalization of the book, but the further expansion and improvement of the range of library-information services.

4. "Information culture", "Reading culture" are not separate concepts, in fact, information culture is also a concept that is part of reading culture, like "library-bibliography literacy", "computer literacy", "information literacy". some conflicts will be resolved.

Formation of reading culture in the process of library information service serves to turn libraries into institutions that provide spiritual, scientific, technological, and general cultural development of society. Libraries as a spiritual and educational institution perform the following tasks on the basis of harmonizing the development of society:

- provision of library information service according to the needs and requirements of each user;

- involving all groups of users in the process of socialization through the library-information service;

- formation of reading culture through the library and information service,

In terms of the location of the library and information institution:

1. to study, promote and protect, taking into account the specific characteristics of the local environment, based on local studies;

2. studying the culture of other nations, forming inter-religious and inter-national tolerance, along with the preservation of national talents;

3. it is to ensure active participation in the social democratic processes implemented in the life of society.

In addition, the following tasks are performed through the library-information service:

- establishing communication between users;

- organizing discussions with users in addition to individual work;

- improvement of "User-librarian", "User-resource", "user-user" relations serving the individual development of each user;

- to create an opportunity for each user to receive information and information in accordance with their requirements and needs;

- to develop and promote methods of creating opportunities for active participation in social changes taking place in the society by increasing users' socio-political economic, legal knowledge;

- providing scientific-practical and methodological support for students of secondary, secondary special, vocational educational institutions, students of higher educational institutions;

- should consist of providing special services to disabled users, housewives, unorganized youth, elderly, temporarily unemployed, deprived of freedom and other social demographic groups.

In addition to the above-mentioned tasks, it would be appropriate to develop separate programs to show the importance of reading as an intellectual factor of socio-cultural development of the society.

Including:

1. Programs that promote the importance of direct reading processes for the development of the individual and the development of society;

2. Programs that show the practical importance of reading in adaptation for population groups that do not participate in the sphere of social production, in order to fulfill a profession or interest in any socially useful activity, or in-depth study of another profession in accordance with the demand of the time;

3. Programs related to the alignment of the library and information service with the directions of implementation of tasks related to development promoted by the state and society;

4. Programs aimed at the implementation of tasks related to reading to ensure the normative balance and harmony of public interests and personal interests;

The library-information service consists of the processes of providing recommendations by conducting experiments, guiding, observing, assisting in the implementation of the task of ensuring the participation of each user in the social development. The formation of reading culture in every user through the library-information service, ensuring their transition from passive activity (reception of information and information) to active activity (reception of information and information, processing and analysis, creation of new information and knowledge by understanding its essence) serves the development of the whole society.

Since reading as a complex social phenomenon consists of components, one of its main elements is the psychology of reading.

In the psychology of reading, the social activity of a person has a special importance, it is manifested as an activity aimed at changing social conditions, socialization of a person.

In the system of reading culture, the conscious and purposeful activity of users occupies a central place, and the analysis of the activity of users in reading processes gives an opportunity to study their psychology, personality, and interaction to a certain extent.

Reading is a complex form of psychological activity, and it is a process of acquiring appropriate knowledge by assimilating and processing the text. The motivation and interest of the user's activity is formed as a result of his socio-demographic affiliation and social psychological thinking.

Any activity is aimed at achieving a goal because it depends on one or another result, and the system of psychological states and processes reflected in this activity is formed by the "motive-goal" relationship.

The final result of the user's activity depends on the knowledge level, speech and skills of the authors, emotional will, psychological aspects of reading, the opportunities and conditions created for reading, the level of attention of users, and others.

In addition to user activity, psychology of reading includes such concepts as "mastery", "explanation", "result of reading", "reading effectiveness". Comprehension and assimilation of the read sources is considered a complex mental activity of the user.

Comprehension of the source text constitutes effective reading. And efficiency is the result, the generalized process of understanding and acceptance, which describes the whole activity of the user. The result of the user's activity is an indicator of his achieved skill. One of the main forms of creation of the need for reading is the reading motive.

Motive means "motivate" in Latin, "motivation" in French. It is an inclination and volition that encourages a person to perform mental, practical action and behavior, and is inextricably linked to the satisfaction of certain needs. The main function of motives is to motivate human action and internal motivations.

Any activity arises under the influence of certain motives and takes place only when sufficient conditions are created. Therefore, in the process of working with users, in order to ensure the implementation of learning and mastering of resources, reading motives should be formed in them. Based on the study of specific sources and information, users are directed to decide on the purpose of knowing the motives, acquiring knowledge and skills.

Motives are of two types, external and internal motives, and external motives can be manifested in the absence of internal awareness of reading, blindly following others.

The group of internal motives includes motives that have a unique characteristic: they appear on the basis of an internal feeling in the user's personality that achieves a special goal in relation to communication. For example, the emergence of interest in knowledge is the illumination of aspirations in the user to increase his spiritual level.

Under the influence of similar motives, conflicting situations (situations) do not arise in the process of working with users.

Of course, despite the emergence of motives belonging to this category, some difficulties are likely to arise, because it is necessary to make a willful effort to acquire knowledge. Volitional efforts with such properties are aimed at reducing the power and possibility of destructive external stimuli.

When approaching this process from the point of view of pedagogy and psychology, only the perfect situation is called rational (optimal).

Creating such a situation in the process of working with users is considered an important task of the librarian, and his activity is aimed at forming internal motives, the personality of users, being able to correctly define the purpose in them, arouse interest and create ideals.

When working with librarian users, it is appropriate to approach the science of psychology today, dividing the motives into the following categories based on the achievements:

1. Negative motives associated with the user's worldview.

2. Political motives reflecting the attitude towards domestic and foreign policy.

3. Moral motives based on moral rules, principles, lifestyle, ethno-psychological features of the society.
4. Motives based on the feeling of beauty in relation to the reality, related to the refined (aesthetic) feeling.
5. Comprehensive social motives (patriotic, selfless, altruistic).
6. Stimulating motives aimed at evaluating the result of the activity and achieving the goal.
7. Motives showing professional training and skills
8. Motives related to study, knowledge, creativity.
9. Short-term, transient motives.
10. Motives associated with long-term, non-time-limited, calm behavior.

So, a motive is a factor that awakens a person's character and helps to satisfy his spiritual needs. From the point of view of reading need, reading motivation is an internal feeling that causes a voluntary desire, based on the content of the source and all other qualities that correspond to the user's need. For example, in the imagination of each user, the motives for choosing a book are the form of images (the desire to have information and imagination about a book that is torn and torn, that is, the fact that the book is torn and torn indicates that this book is of interest to many readers and is in the hands), thoughts, other books compared to this book, it is possible to reflect on the high uniqueness of the narrative and interesting style of this book, to have interest (having a plot that attracts attention), desire (for example, to read all the works of Tahir Malik) and aspiration.

Ultimately, for the user, it is not the forms of manifestation of reading motives, but the problems that interest him, i.e., what kind of answer he expects from the selected book, its content, and how well it meets his needs.

As mentioned above, reading is a voluntary activity in its essence, and the need for it is a social subject (individual, socio-demographic group, society) who has a caring attitude towards reading as a continuous, vital, necessary activity.

Reading can develop as an independent need only if it becomes a regular activity that meets the spiritual needs and interests of each user.

From the need to read comes the need to choose sources.

Most importantly, it is important to move from the level of obligation, sometimes due to interest, to the level of always due to interest in reading motivation.

In order to continuously and regularly continue working with users in the process of library-information service, it is necessary to study the interest of users. Therefore, the main goal of studying users in the library is to study their interest.

The user's interest is a factor that directs him to the activity, it affects the selection of sources, i.e. print products, information, their analytical absorption and evaluation. The user's interest develops in relation to his other intellectual interests and reading needs.

User interest is characterized by the level of dominance of reading motives, desire, aspiration, that is, enjoyment of acquiring knowledge, development of thinking.

However, direct interest in a specific resource cannot be interpreted as a stable interest of the user.

In such a situation, the librarian's main task is to help the user's interest in a specific source to be brought to an analytical direction, that is, to be brought to a generalized and stable direction through selected sources.

IV CONCLUSIONS

Therefore, in order to study the regularities of the formation of users' interest, it is necessary to consider their specific needs for reading, the level of understanding of reading expectations, the manifestation of reading goals and motives as an internal desire, and the characteristics of regular and continuous reading.

This allows us to determine whether users' interest is stable or unstable, strong or weak, active or passive, broad or narrow, extensive or superficial.

As mentioned above, users' interests are interrelated with their other interests, and according to their content, they are directed to reading resources of a professional, educational and scientific nature.

The age and education level of users can influence the direction of development in addition to determining the content of their interests.

Age difference in the content of reading processes, especially children. According to the specific characteristics of adolescents, the library staff should pay special attention to it. In addition, in the process of working with users individually, it is necessary to study the interaction between the depth of their interest and their abilities. Because, taking into account that the user's ability has a special effect on the development of his interest, the librarian can help to develop his ability further by shaping his interest and directing him to regular reading. The concept of reading culture includes the concepts of "love of books", "interest in reading", "feeling and understanding of reading", "creative reading", "library-bibliographic literacy" in addition to finding a way to the world of various printed publications, information and information. In particular, library-bibliographic literacy is considered a minimum level of skills and competencies necessary for a competent user to use information services.

Library-bibliographic literacy is formed at the first stage by learning how to use library catalogs, card files, bibliographic manuals, sources, and making a list of literature used in term papers, diploma theses, and dissertations.

Reading culture does not form and develop by itself. For this purpose, a culture of reading is being formed based on the needs of the state and society in terms of language, history, religion, independence, freedom, and interest of the nation.

Along with the library and information service, the family, neighborhood, education system, labor unions, state power, political parties, public organizations, mass media and other institutions of civil society are important factors in the formation of reading culture. In addition, the formation of an enlightened society in New Uzbekistan through reading:

- deep study of our nation's rich history, scientific and cultural heritage, national-religious values;
- understanding the essence of large-scale reforms, the importance of state programs;
- love for the motherland helps students to strengthen their sense of involvement in its destiny.

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ENGLISH AS A KEY COMPONENT OF EDUCATION IN TECHNICAL UNIVERSITIES

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Abstract– In modern era of globalization and world economic integration in many spheres of human activity, the question of the need to have a single language code for specialists in different professions has become of great importance. This need is especially acute in the field of engineering, since it is engineers who are primarily involved in scientific and technological progress and changes in technological structures. The current situation in teaching a foreign (English) language in technical universities helped us formulate the goal of this study, namely, to develop a holistic and continuous content of a foreign language training program for engineers, regardless of their nationality, that fully takes into account the specifics of engineering activity and develops strong foreign language communication skills in professionally oriented environment. In the final stages of foreign language learning within the ESP approach, students are introduced to the basics of English for technical purposes, its key technical terminology and some registers of technical sphere communication.

Key words– global workforce, cognitive abilities, English for specific purposes, predominant language, collaborative learning environments, communication skills, technical curricula.

I Introduction

In an era marked by globalization and rapid technological advancement, the significance of English as a medium of instruction and communication in technical universities has grown immensely. English is not merely a language; it serves as a bridge connecting students to a world of knowledge, professional opportunities, and international collaboration. This article delves into the integral role of English in technical education, examining its impact on students' learning experiences, employability, and the broader implications for the global workforce.

II Main Part

1. The Global Relevance of English in Technical Fields

1.1. The Dominance of English in Academia

English is the predominant language in academic publishing, especially in the fields of science, technology, engineering, and mathematics (STEM). A vast majority of influential research articles, journals, and conference proceedings are published in English. For students pursuing technical degrees, proficiency in English enables access to cutting-edge research, best practices, and new methodologies that are essential for their academic and professional development.

1.2. The Role of English in Industry

Technical industries are increasingly globalized, with companies operating across borders and employing a diverse workforce. English has emerged as the lingua franca in many organizations, facilitating communication among employees from various countries. Employers often prioritize candidates who possess strong English language skills, as these individuals are better equipped to engage in international collaborations, navigate technical documentation, and contribute to cross-cultural teams. Thus, integrating English into the curriculum of technical universities not only enhances students' academic learning but also significantly boosts their employability.

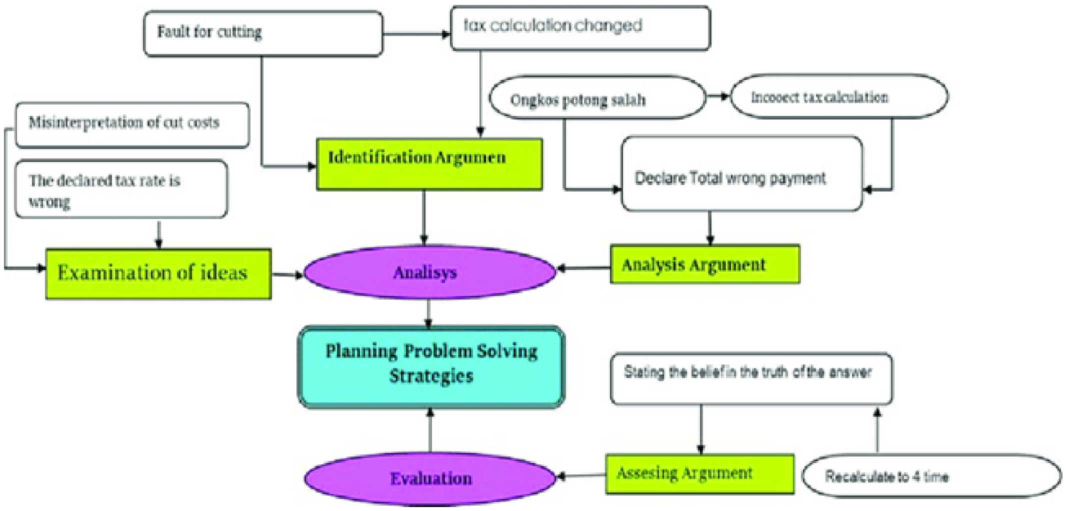
2. Educational Benefits of English Integration

2.1. Improved Communication Skills

Effective communication is a cornerstone of success in any technical field. By incorporating English language training into the technical curriculum, universities can help students develop critical communication skills necessary for their future careers. This includes technical writing, presentation skills, and the ability to engage in discussions and negotiations in English.

2.2. Enhanced Critical Thinking and Problem Solving

Learning a second language like English can enhance cognitive abilities, including critical thinking and problem-solving skills. As students learn to articulate complex ideas



and concepts in English, they engage in deeper analysis and reasoning. This cognitive engagement is particularly valuable in technical disciplines, where problem-solving is a daily requirement (Figure 1).

2.3. Exposure to Diverse Perspectives

English serves as a gateway to a plethora of knowledge and perspectives from around the world. Through English-language resources, students can engage with diverse viewpoints and approaches to problem-solving that enrich their understanding of their field. This exposure fosters a more inclusive and innovative learning environment, preparing students to think critically and creatively in their careers.

3. Strategies for Effective Integration of English

3.1. English for Specific Purposes (ESP)

One effective approach to integrating English into technical education is through English for Specific Purposes (ESP) programs. These courses focus on the language skills required in specific fields, such as engineering, information technology, or biotechnology. By tailoring English instruction to the needs of technical students, universities can ensure that learners acquire relevant vocabulary, communication skills, and cultural awareness essential for their professional success.

3.2. Bilingual Instruction and Resources

Offering bilingual instruction in technical courses can significantly benefit students. By allowing students to first learn complex concepts in their native language and then transitioning to English, educators can help reduce the cognitive load and anxiety often associated with learning in a second language. Additionally, providing resources such as bilingual textbooks and online materials can further facilitate this transition.

3.3. Collaborative Learning Environments

Promoting collaborative learning environments where students work together on projects can enhance their English language skills. Group assignments that require presentations, reports, and discussions in English encourage students to practice their language skills in a real-world context. Collaborative projects also foster teamwork, an essential skill in the workplace (Figure 2).

3.4. Language Support Services

Technical universities should provide robust language support services, including workshops, tutoring, and writing centers focused on technical English. These resources can assist students in overcoming language barriers and refining their communication skills. By offering targeted support, universities can help students navigate the challenges of technical writing and presentation.

4. Challenges and Considerations

4.1. Diverse Language Proficiency Levels

CALS domain	Skills measured
Unpacking dense information	The ability to comprehend and use complex words and sentences that contain concise information (e.g. nominalisations, embedded clauses, expanded noun phrases)
Connecting ideas logically	The ability to use 'connectives' common in academic texts (e.g. *consequently*, *on the one hand*, etc.)
Tracking participants and ideas	The ability to identify and produce the terms or phrases used to refer to the same participants or themes throughout a text (e.g. *Water evaporates at 100 degrees Celsius. This process* ...)
Organising analytic texts	The ability to organise analytic texts (including argumentative texts and paragraph-level structures) according to conventional academic text structures
Understanding metalinguistic vocabulary	The ability to understand precise meanings, particularly the use of language to make thinking as reasoning visible (e.g. *hypothesis*, *generalisation*, *argument*)
Understanding a writer's viewpoint	The ability to understand or use markers that signal a writer's viewpoint, especially markers that show a writer's degree of certainty in relation to a claim (e.g. *certainly*; *it is likely that*)
Recognising academic language	The ability to recognise academic language when compared with more colloquial language in communicative contexts where academic language use is expected.

One of the primary challenges in integrating English into technical education is the diverse language proficiency levels among students. While some students may be fluent in English, others may struggle with basic communication. Educators must implement differentiated instruction strategies to address these varying levels and ensure that all students can benefit from English integration.

4.2. Balancing Technical and Language Skills

Another challenge is striking a balance between technical and language skills within the curriculum. Educators must ensure that the focus on English does not detract from the core technical competencies that students need to develop. A well-structured curriculum that intertwines technical training with English language instruction is essential for achieving this balance (Figure 3).

III CONCLUSION

As the landscape of education and the workforce continues to evolve, the role of English in technical universities has never been more crucial. By integrating English into technical curricula, universities not only enhance their students' academic experiences but also equip them with the skills necessary for success in a globalized world. Through innovative teaching strategies and robust language support, technical universities can prepare their graduates to excel in their fields, fostering a generation of professionals who are not only technically proficient but also skilled communicators capable of navigating the complexities of the modern workforce. Embracing English as a core component of technical education is not merely an option; it is an imperative for future success.

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