TOSHKENT DAVLAT TRANSPORT UNIVERSITETI
Tashkent state transport university

International Journal Of Transport And Technological Machines

Tashkent 2023, issue 4, https://ijttm.uz/

TOSHKENT DAVLAT TRANSPORT UNIVERSITETI
Tashkent state transport university

Issue 4, 2023

INTERNATIONAL JOURNAL OF TRANSPORT AND TECHNOLOGICAL MACHINES

ISSN: 2249-9512

THE SCIENCE OF TODAY IS THE TECHNOLOGY OF TOMORROW

TOSHKENT DAVLAT TRANSPORT UNIVERSITETI
Tashkent state transport university
International Journal Of Transport And Technological Machines

Tashkent 2023, issue 4, https://ijttm.uz/

INTERNATIONAL JOURNAL OF TRANSPORT AND TECHNOLOGICAL MACHINES

Published since 2023

TASHKENT STATE TRANSPORT UNIVERSITY

Founder of the scientific and technical journal, “International Journal of Transport and Technological Machines” – Tashkent State Transport University (100167, Republic of Uzbekistan, Tashkent, Temiryulchilar str., house No. 1, office: 379, tel Tel.: +998 97 156 94 21 E-mail: k.j.rustamov82@gmail.com).

In the International Journal of Transport and Technological Machines publishes the most significant results of scientific and applied research carried out in universities of transport and information technology profile, other higher educational institutions, research institutes and centers of the Republic of Uzbekistan and foreign countries.

The journal is published 4 times a year and contains publications in the following main areas:

- Automotive engineering
- Civil Engineering
- Construction Engineering and Management
- Instrumentation technology
- Environmental Engineering
- Environmental Sciences
- Green production
- Industrial Safety
- Mechanical Engineering Technology
- Mining
- Mechatronics

CONTENTS

TOSHKENT DAVLAT TRANSPORT UNIVERSITETI
Tashkent state transport university

International Journal Of Transport And Technological Machines

Tashkent 2023, issue 4, https://ijttm.uz/

THE INFLUENCE OF ENERGY-INFORMATION IMPACT ON AN ELECTRIC VEHICLE.

Savluchinsky V.V.[1], Avliyokulov Zh.S.[2], Valiev J.F[2]

1Belarusian National Technical University, Belarus

2Tashkent State Transport University, Uzbekistan

Abstract. The main results of studying the energy-informational impact on the driver of an electric vehicle. The parameters of electrical and magnetic fields recorded in the vehicle exhibit fairly complex patterns. A significant influence on the level of electromagnetic radiation comes from the electronic devices for onboard diagnostics and control, passive and active noise and vibration protection means, navigation systems, immediate access to information, climate control devices, air purification, and security systems. Moreover, during the movement of the electric vehicle, there is a change in electromagnetic radiation due to the presence of external fields from power lines, telecommunication towers, radio transmitting stations, and others. The loads arising from the operation of an electric vehicle inevitably affect the elements of its structure, resulting in their alteration. Apart from regular operational faults, which are unavoidable, sudden malfunctions can always occur due to changes in the technical condition of the vehicle and road conditions, which are of an incidental nature.

Key words: electric vehicle, electromagnetic fields, comfort and safety system, resonance phenomena, driver reaction, emergency situation, national standard, STB, components of consciousness, biological effect of microwaves, fatigue mode**.**

Introduction. Comfort and safety systems can create conditions for emergency situations: all typical errors occurring during vehicle control are linked to the driver's reaction, which may depend on the comfort system installed in the vehicle; strong electromagnetic field effects are evident in electric vehicles where the battery pack is placed under the rear seat or in the trunk, and the current flows practically throughout the entire electric vehicle, turning the car into a charged circuit; the maximum electromagnetic field occurs in the area where the driver sits, the low-frequency field in an electric car changes thousands of times, and these changes have a harmful effect on the human body, potentially affecting the driver's reaction speed; during the operation of electrically powered vehicles, electromagnetic fields are generated that may disrupt electromagnetic safety - according to GOST R 54811-2011[1] "National Standard of the Russian Federation - ELECTRIC VEHICLES," trolleybuses, including trolleybuses, are not considered electric vehicles in this standard, although these vehicles' operation involves electrical equipment that needs assessment for the electromagnetic safety of drivers and passengers. In the Republic of Belarus, guidance is based on global technical regulations No. 20[2] and STB 2594-2021 [3].

Main part. In recent times, parameters characterizing the frequency spectrum of generated, amplified, or converted oscillations have gained increasing importance in high-frequency radio electronics. The output frequency spectrum contains not only the main oscillation but also side oscillations located outside the frequency band (undesirable oscillations). Currently, the frequency band is used by at least four services - broadcasting, radio navigation, etc. Satellite communication systems are combined with terrestrial radio relay lines, and the power of radio transmitting devices tends to increase, while the sensitivity of radio receiving devices steadily rises. Interference leads to errors in the operation of navigation equipment, disruption of telephone and telegraph communication, and harmful effects on the human body, which is also enclosed within a circuit represented by an electric vehicle [4].

It is noted that different electromagnetic fields can alter the body's motor activity, change sensitivity to stimuli, disrupt the formation of conditioned reflexes, and suppress memory. Changes in motor activity have been observed under the influence of extremely high-frequency fields. An electromagnetic field initiates a braking process; this principle is employed in the technique of radio-harassment. Beam-like effects of the electromagnetic field have been proven.
The impact of extremely low-frequency fields does not immediately lead to pathological changes in biological systems but concludes at the second stage of adaptation. Extreme stimuli cause distress effects - depletion of the body's protective resources, damage to biological structures, and various forms of pathology. Extreme stress on regulatory-adaptive mechanisms may fail to maintain and support a stable, consistent state - homeostasis, leading to a lethal outcome.
Studies [5] have highlighted work on auditory effects resulting from exposure to pulsed electromagnetic radiation. Exposure of the head to rectangular pulses with a peak energy flux density of about 300 mW/cm^2, averaging about 0.1 mW/cm^2, caused auditory sensations in humans.

With the emergence of electric transport, the driver may be subjected to informational-psychological influence on all components of consciousness - mental processes (perception, memory, imagination, thinking, attention). As metrological values and sensations indicating an unfavorable information environment, reactions of the driver's organism to the influence of electromagnetic fields of radio frequency and microwave range can be highlighted.

Among the entire spectrum of physical fields of electromagnetic nature, electromagnetic fields of the microwave range stand out due to their highest biological significance and pronounced symptomatology. Sources of these fields in electric transport or an electric vehicle and in the scanned ether can be various radio-emitting means, broadcasting devices, household electrical appliances, sources of electromagnetic radiation for radio communications, such as Wi-Fi, wireless Wi-Max, LTE (long-term evolution), Bluetooth, which employ microwaves, some properties of the magnetic field used in electric motors, direct current generators, magnetrons [6].

Depending on the duration and intensity of electromagnetic field exposure, changes induced in the organism by radio frequency and microwaves are divided into alterations from acute thermogenic effects. Upon exposure, warmth is felt at the site of action, similar to the effect of sunlight; mild discomfort, headache, dizziness, nausea, vomiting, a sense of fear, thirst, slight weakness, limb pains, increased sweating are noted. Body temperature elevation, bouts of tachycardia, disruption of cardiac activity, hypertension are observed. Exposure of the head to rectangular pulses with peak energy flux densities of about 300 mW/cm² and averages of 0.1-0.4 mW/cm² causes auditory sensations [7].

The drowsy state of the driver, arising with a moderate degree of intoxication, may occur under the influence of pulsed magnetic fields, exhibiting symptoms similar to alcohol intake, affecting the central nervous system and the brain, sharply inhibiting its normal function. The influence of the magnetic field, when the car represents a closed circuit, especially with active comfort systems, can be likened to alcohol intoxication and classified into three degrees: mild, moderate, and severe. A comparison of states under the influence of alcohol and electromagnetic fields is presented in table [8].

Table - Comparison of states when exposed to alcohol and electromagnetic field.

Ethanol concentration in blood plasma and action phase, driver reaction. **Degree of intoxication.**	Clinical symptoms	Observed changes	Electromagnetic field intensity, mW/cm^2
0.5% (50 mg%) subclinical phase.	Without visible deviations in behavior and well-	Feeling of warmth. Vasodilation. With 0.5-1	100

Slight absentmindedness or appearance of aggression.	being, registered only with the help of special tests	h irradiation, the pressure increases by 20-300 mm Hg.	
1.5% (150% mg) euphoria. The driver's reaction time increases by one and a half times. There is a risk of hitting a pedestrian. Mild intoxication.	Increased sociability, talkativeness, increased self-esteem, decreased attention and judgment, impaired performance of test assessment tasks. Emotional instability, decreased criticism, memory impairment, decreased sensitivity, incoordination of movements.	Auditory effect when exposed to pulsed magnetic fields	0,4
		The biological effect of microwaves begins.	10
2.5% (250 mg%) excitation. The reaction worsens 6-9 times, and there is a high risk of falling asleep while driving. Moderate intoxication.	Emotional lability, decreased inhibitory behavior, loss of criticism, impaired memory and ability to concentrate, impaired perception and decreased reaction time, muscle incoordination. Disorientation, dizziness, confused speech, changes in emotional status (fear, sadness, anger), diplopia,	Decreased blood pressure, a tendency to increase heart rate, slight fluctuations in the blood volume of the heart.	1

	decreased pain sensitivity.		
4% (400 mg%) sopor. The driver has no control over himself. **Severe intoxication.**	Impairment of consciousness to the depth of stupor: marked decrease in response to stimuli, complete muscle incoordination, inability to stand, urination, defecation, convulsive syndrome. Apathy, inability to walk or stand, involuntary urination, defecation, sleep or superficial coma (stupor).	An increase in blood pressure followed by a decrease. The hypnotic effect begins, it is these higher cells that are inhibited and switched off	100
5% (500 mg%) coma. **Severe intoxication.**	Anesthesia, analgesia, decreased reflexes, hypothermia, respiratory and hemodynamic impairment, possible death.	Voice changes, motor agitation, pronounced vocal changes, convulsions, body temperature, pulse, respiratory movements (shortness of breath).	300
7% (700 mg%) and above	Death due to cerebral edema.	Pain during irradiation.	600

The table shows a correlation between clinical symptoms from the concentration of ethanol in the blood and observed changes in physical condition depending on the intensity of the electromagnetic field, mW/cm^2. A possible result is delayed inhibition.

Biochemical changes in the brain during a 10-minute exposure to a constant magnetic field of 50 mT lead to an increase in the tissue content of ammonia by 56%, glutamic acid by 62%, aspartic acid by 41.2%, with a simultaneous decrease in glutamine content by 71.3%. The content of gamma-aminobutyric acid, associated with inhibitory processes of the nervous system, increases by 60%. This results in the appearance of spindle-shaped structures, and predominance of delta waves in the electroencephalogram (EEG), characteristic of a sleep state and influencing the drowsiness of the driver affected by the comfort system of the car when assessing road conditions.

A method for diagnosing the driver's state during movement can involve registering shifts in the EEG rhythm distribution in the fatigued brain, displaying the driver's condition on the screen of the car's information system through sensors installed in the driver's seat. An example is presented in the figure.

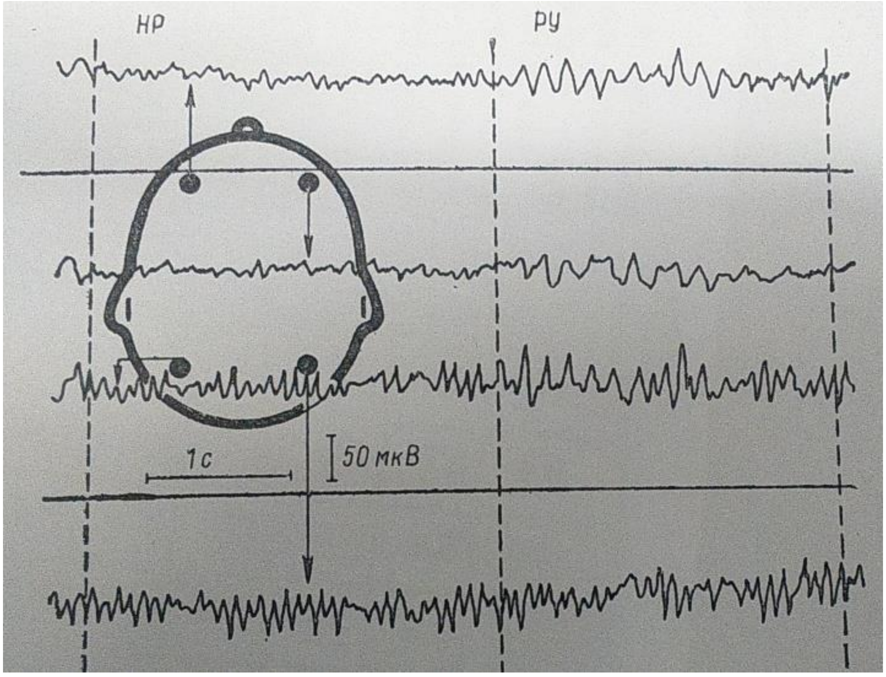


Figure - Shifts in the distribution of EEG rhythms in a tired brain: NR - normal mode; RU – fatigue mode.

From the figure, it is evident that the appearance of slow waves in the EEG indicates the driver's brain transitioning to a state of reduced functional mobility - slowing down, i.e., drowsiness. This reaction can be implemented as a warning indicator for the driver, signaling the brain's transition to a state characterized by decreased attention during movement [9].

A mobile phone held to the ear, as an emitter of waves in the decimetre range with significant penetration, can impact human brain structures. It is noted that different electromagnetic fields can alter the body's motor activity, change sensitivity to stimuli, disrupt the formation of conditioned reflexes, and suppress memory.

Therefore, it is advisable to have a device that signals the emergence of hazardous radiation modes within the vehicle, correlated with the effects of pulsed magnetic fields. Under the influence of these fields, symptoms akin to alcohol intake, affecting the central nervous system and the brain, sharply inhibiting normal function, are observed.

The comfort system, depending on its power level within the vehicle, exerts a negative impact on subtle mental functions: attention worsens, calculation accuracy diminishes, carelessness manifests, and reaction speed slows down. The most dangerous phenomenon for the driver is the slowing of reaction time depending on the level of excitement of the cerebral cortex during vehicle movement, especially in the case of an electric vehicle. This can lead to impaired coordination of movements.

Conclusion. The United Nations Economic Commission for Europe has developed norms for the permissible efficiency of braking characteristics in mechanical vehicles. The primary assessment parameter adopted is the value of the minimum braking distance required to stop a given vehicle moving at a specified speed close to the maximum. Therefore, the energy-informational impact on the driver of an electric vehicle will influence their reaction during braking, leading to an increase in reaction time.

The influence of a magnetic field, especially when the car constitutes a closed circuit, particularly with active comfort systems, can be compared to alcohol intoxication and categorized into three levels: mild, moderate, and severe. Accordingly, the reaction time to the appearance of an obstacle necessitating braking increases from 1.5 to 9 times.

At an electromagnetic field intensity of 10 mW/cm², biological effects of microwaves begin. The reaction time of a driver under the influence of alcohol or pulsed magnetic fields increases by 1.5-9 times; thus the reaction time of the driver can range from 2.1 to 18 seconds, and correspondingly, the braking distance will be 70 meters or more.

There is no direct correlation between changes in a biological entity and the frequency, intensity, and duration of exposure to extremely low frequencies concerning the manifested biological effect. The only existing explanation is that under certain narrow frequency spectra and amplitudes, energy fields occur, which affect biological entities, especially in specific cases, affecting the driver and passengers of an electric vehicle.

Literature:

1. GOST R 54811-2011 "National Standard of the Russian Federation - ELECTRIC VEHICLES."
2. State Standard of the Republic of Belarus. Global Technical Rules No. 20 concerning the safety of electric vehicles. State Standardization Committee of Minsk. Introduced into effect by the decree of the State Committee for Standardization of the Republic of

Belarus on April 10, 2020, No. 19, as the state standard of the Republic of Belarus from July 1, 2020.

3. STB 2594-2021 "Low-voltage electrical installations" - power installations for the external connection of electric vehicles or hybrid vehicles. Practical Guide. Approved and put into effect by the decree of the State Committee for Standardization of the Republic of Belarus on May 4, 2021, No. 51.
4. O.V. Betsky, K.I. Palatov, M.B. Tseytlin, Yu.D. Ilyin. Side Oscillations in Microwave Electronic Devices. / O.V. Betsky, K.I. Palatov, M.B. Tseytlin, Yu.D. Ilyin, edited by M.B. Tseytlin - Moscow: Radio and Communication, 1984, 152 p.
5. V.A. Banny. Assessment of the level of electromagnetic background and methods of protection against microwave radiation: teaching-methodical manual for first-year students of all faculties of medical universities / V.A. Banny - Gomel: Gomel State University, 2015. - 64 p.
6. O.V. Boyko, A.O. Lantushenko, G.A. Lukyanchuk, V.V. Salamatin, Yu.G. Shkorbato. Influence of microwave radiation at mobile communication frequencies and in the WiMAX network on the chromatin state of human buccal epithelium cells. / O.V. Boyko, A.O. Lantushenko, G.A. Lukyanchuk, V.V. Salamatin, Yu.G. Shkorbato - Scientific Notes of the National Technical University named after Vernadsky, series "Biology, Chemistry", vol. 23(62), No. 4, - 2010 p. 56-65.
7. Yu.B. Kudryashov. Radiation Biophysics: (ionizing radiation). / Yu.B. Kudryashov, edited by V.K. Mazurik, M.F. Lomanov. - Moscow: FIZMATLIT, 2004. - 448 p.
8. V.V. Savluchinsky, M.I. Kapkovich, S.A. Savik, A.V. Zyrjanov. Physiological fundamentals of informational-psychological influence. Teaching aid. / V.V. Savluchinsky, M.I. Kapkovich, S.A. Savik, A.V. Zyrjanov - Minsk: Belarusian National Technical University, 2022, 86 p.
9. G.M. Parkhomenko. Physiological foundations of occupational radiation hygiene. / G.M. Parkhomenko. - Moscow: Atomizdat, 1977 - 76 p.
10. Riskulov A.A., Sidikova T.D., Khakimov R.M., Avliyokulov J.S. (2023) The effect comparative evaluation of energy-saving additives on the bitumen properties. E3S Web of Conferences 401, 05028. https://doi.org/10.1051/e3sconf/202340105028
11. Riskulov A.A., Nurmetov Kh.I, Avliyokulov J.S. (2023) Material selection for vehicle brake chamber case with using computer methods of analysis. E3S Web of Conferences 401, 02061. https://doi.org/10.1051/e3sconf/202340102061

TOSHKENT DAVLAT TRANSPORT UNIVERSITETI
Tashkent state transport university

International Journal Of Transport And Technological Machines

Tashkent 2023, issue 4, https://ijttm.uz/

ADDITIVE TECHNOLOGIES AND REVERSE-ENGINEERING IN ROAD-CONSTRUCTION AND TRANSPORT MECHANICAL ENGINEERING

Zorin V.A. [1], **Baurova N.** [2] , **Nefelov I.S.** [3], **Konoplin A.U.** [4]

Moscow Automobile and road construction state technical university, 64, Leningradskiy avenue, 125319, Moscow, Russia

Abstract: Additive technologies have high priority in development of modern mechanical engineering. Development and application of the methods reverse engineering providing possibility of development 3-D models of the detail which failed in use allows to manufacture the spare part by methods 3-D printing at the operational enterprise, considerably having reduced the simple machines waiting for receipt of the original spare part. The main stages a reverse engineering are considered. On the example of a real detail – an excavator loader window fixer – the sequence of actions for scanning of the damaged detail is shown, to formation polygonal, and then solid-state 3-D models with the subsequent production of the spare part by means of 3-D printers. Results of strength tests of a detail proved its compliance to requirements of reliability and safety. Application of reverse engineering methods and additive manufacturing techniques of various structural elements of machines showed a practical opportunity and economic feasibility of the offered approach. It is shown that introduction of the offered methods in the modern road-construction industry will allow to increase considerably performance in the sphere of production and repair of road machines. Experience of the works which are carried out to Moscow Automobile and Road Construction State Technical University on formation and application of reverse engineering methods and additive technologies is described at production of spare parts of details of road-construction machines. The possibility of replacement in process a reverse engineering of traditional metal structural materials on new, polymeric composite materials, providing necessary strength and operational properties of details is described. It allows to reduce material consumption, duration and cost of repair of road machines. Besides, increase in a share of the machines details manufactured of polymeric materials instead of metal provides significant decrease in an environmental pressure from operation of the construction equipment.

Keywords. Road- construction machines; additive technologies; reverse engineering; 3D - scanning; 3D printing; polymeric composite material

The main characteristics road-construction and transport technological machines are the big nomenclature of types (more than 1500), complexity of a design, rather small outputs in comparison with cars, a large number of manufacturers of the machines located worldwide, long terms of operation. As a result, elimination of refusals and malfunctions of machines in the course of use is connected with long idle times waiting for spare parts and also essential expenses on their acquisition and delivery. The existing network of the dealer centers of maintenance and repair of machines does not provide a possibility of elimination of the listed shortcomings.

Modern design methods, the latest structural materials and processing equipment for production of machines details allow not only to reduce duration of idle times of machines under repair, but also provide a possibility of improvement of quality of repair due to use of new structural materials, improvement of a design of details and technological methods of their production. Especially broad prospects in this area are offered polymeric structural materials and additive manufacturing techniques of machines spare parts [1,2,3].

At operation of road machines often there is a damage of details. Defects can result from accidents, influence of chemicals, thermal influence, etc. Especially external body machines details suffer from it.

In modern transport, municipal and road machines a large number of structural elements is made of polymeric materials. They are applied to details of an exterior and an interior, protection covers, elements of various systems of the equipment and various small-sized details. Purpose of similar details can be various from decorative to functional. So, for example, facing panels of bumpers serve not only for creation of an esthetic image of the machine, but also are a part of a system of the passive safety absorbing energy of blow in case of the road accident. Polymeric materials use for simplification of the machines, decrease in noise level, increase in service life of products, reduction of labor input of production and also in cases when materials with special mechanical characteristics are required. For example, in a design of the modern KamAZ truck depending on a complete set about 250 - 380 kg of various polymeric materials (fig. 1) are applied [3].

Recovery of the road-construction machines having damages of details from polymeric materials is carried out by replacement by spare parts, pasting or welding by hot air now.

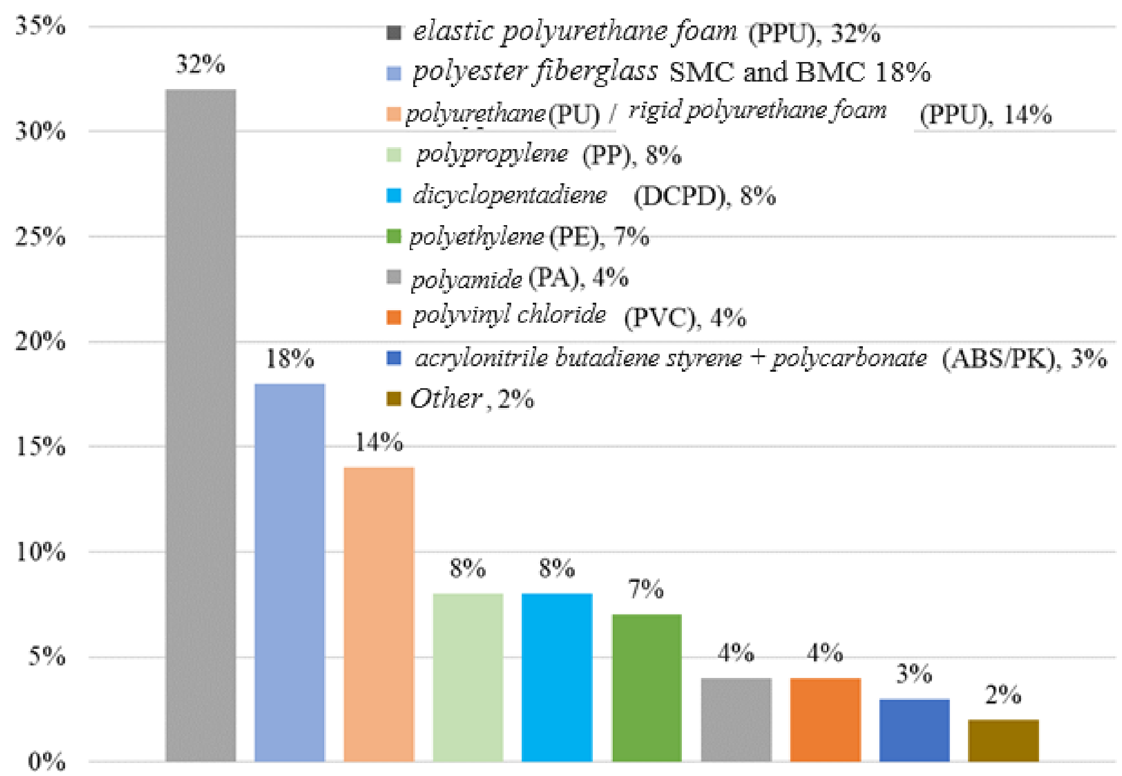


Fig. 1 – Distribution of the polymeric materials used for assembly of the KAMAZ cars on the weight, %

The range of the nonmetallic materials applied in mechanical engineering includes thermoplastic polymeric materials, thermoreactive polymeric materials, elastomers, hydrogels, functional polymers, polymeric mixes, composite materials.

The most popular nonmetallic materials applied by production of details of road machines are thermoplastic polymers (ABS, PLA, PETG, HIPS, Nylon, PPSU), thermoelastoplastics (FLEX, eLastic, Rubber), the thermoplastic filled polymers (BFBronze, Carbon).

Design of machines details from polymeric composite materials represents the embodiment of trinity of material, a design and technology:

- formation of structure of polymeric composite material;
- justification of types and fillers concentration;
- justification of need of application and type of heat treatment of material;
- shaping of a detail;
- research of indicators of mechanical and operational properties of new material of a detail.

The present stage of development of mechanical engineering is characterized by continuous accumulation of volumes of additive technologies use. Their application in the field of mechanical engineering provides ampler opportunities for designers not only from a position of costs reduction for materials and the subsequent machining of the received preparations, but also utilization and the recycling which fulfilled details "life cycle". Use of 3D printers by production and especially at repair of details has not only serious design and technological advantages, but also economic priorities.

Additive technologies are widely applied in various industries, but by production and repair of road-construction machines now they are applied seldom.

The analysis of conditions and expediency of application of 3D printing by production and repair of details of transport, municipal and road-construction machines shows broad potential prospects in this area (see fig. 2).

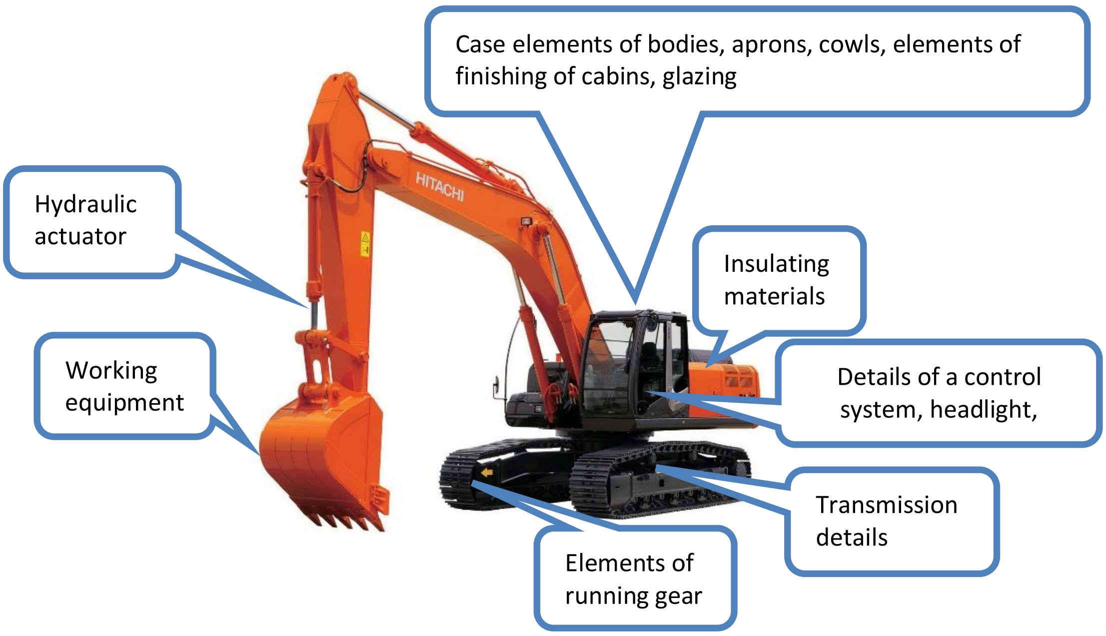


Fig. 2. - Main applications of polymeric materials and additive technologies by production of caterpillar ladle excavators

In this regard, issues of development of repair details technology of road-construction machines from polymeric materials with use of methods of 3D printing are topical and modern. Such orientation is proved by certain operational properties of the details made of polymeric composite materials: the high corrosion resistance, decrease in mass of the same details, to use of more technological equipment based on the principles of additive technologies do not require machining for providing spatial and linear geometry of details and ensuring quality of working surfaces. The most important, polymeric composite materials have wider range of opportunities of change of mechanical and operational properties due to addition of various types of fillers depending on requirements imposed to concrete types of details.

Nevertheless, despite wide circulation of technologies of 3D printing and constant improvement of 3D printers, there is very relevant a question of details quality. In general the details quality is affected by a huge number of factors, but it is possible to distinguish two main: the applied materials and parameters of the modes of the press. For this reason it is necessary to carry out more detailed study of these aspects of 3D printing.

Development of the 3D methods of design of road-construction machines details (spare parts) with use of new composite materials (including polymeric) and also technological processes of details production from these materials is one of the most important directions of scientific research of staff of "Production and Repairs of Car and Road-construction machines" department (PRADM) of MADI. Realization of these methods will allow to increase considerably a share of machine details from polymeric composite materials that fuel-lubricants and in general an environmental pressure from operation of road-construction machines will lead to decrease in metal consumption, weight, energy consumption.

The main problem arising at 3D printing introduction is formation of an exact 3D model of a detail [4,5,6,7]. Modern means of mechanization of the construction organizations are substantially presented by products of various manufacturers of the leading countries of the world. Access to design documentation of details and structural elements of machines is impossible. In this regard, for reproduction and modernization of the failed details technologies a reverse engineering – creations of computer model of a product on the available real detail can be used. For this purpose the scanning method by means of 3D - the scanner is widely used. By results of scanning of a detail in the Compass program are formed polygonal, and then solid-state model which can be exported in the STL format supported by the majority of modern 3D printers (fig. 3).

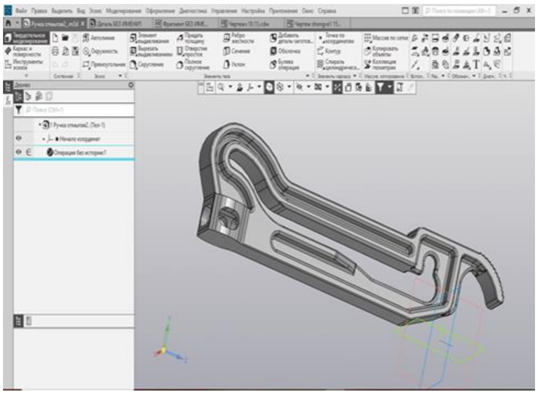


Fig. 3 – Formation of a 3D model of excavator-loaders fixer of window by results of scanning

In fig. 4 results reverse engineering and production of the excavator-loaders fixer of window are shown by 3D printing method. Original fixers are made of fragile materials and often fail. Expectation of delivery of the spare part from manufacturer makes up to 2-3 months. In this regard production of the spare part at the operational enterprise is method of 3D printing economically feasible.

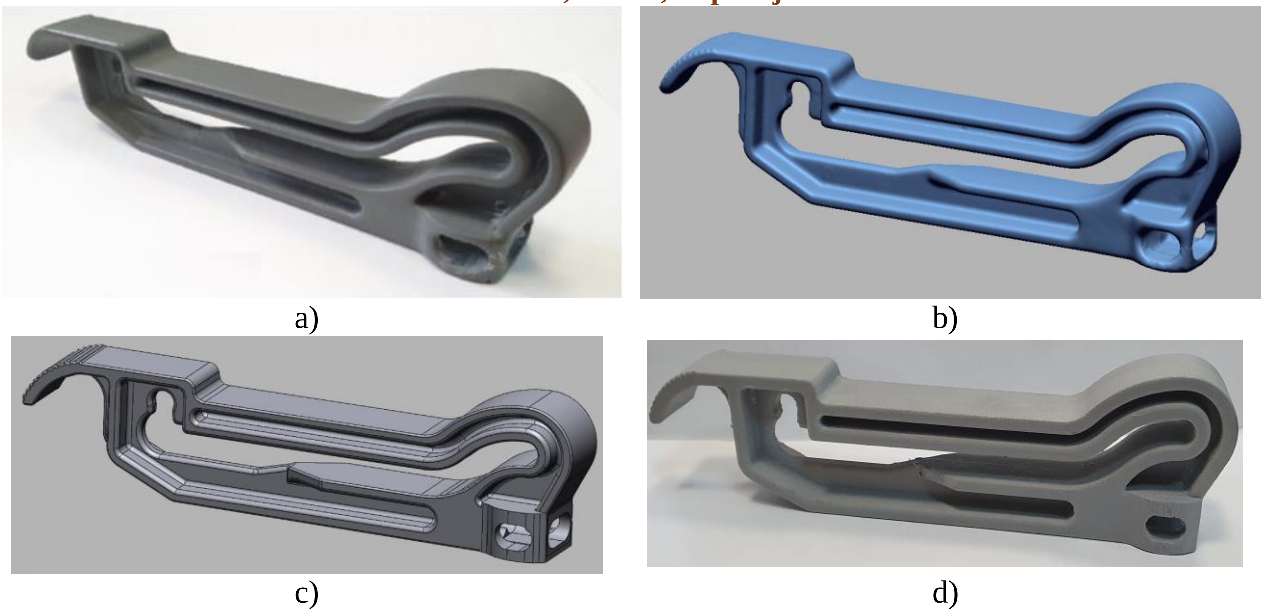


Fig. 4 – Stages of reverse engineering: a) the original damaged detail; b) polygonal 3D model; c) solid-state 3D model; d) the new detail made by 3D printing method.

This process is very labor-consuming, however allows to receive 3D model suitable for further work in CAD systems and 3D printing. Depending on detail configuration the formation of 3D model by results of scanning demands from several hours to several days of continuous work. Production of detail on the 3D printer is also made within several hours, depending on complexity, dimensions of detail and performance of the printer.

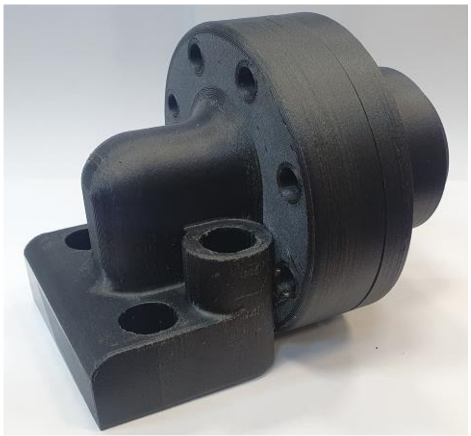
Thus, production of detail (spare part) of the road-construction machines by method reverse engineering includes the following main stages:

- 3D - scanning of the original detail damaged and demanding replacement;
- formation of a polygonal 3D model by means of the Compass program;
- formation of a solid-state 3D model taking into account design features of detail and new material mechanical properties;
- assessment of compliance to the projected detail to requirements of durability finite element method and editing model in case of need;
- production of a prototype of detail by 3D printing method;
- carrying out natural tests of detail;
- making decision on production of necessary number of spare parts.

To prove optimum composition of material and also the necessary technological modes of production of details, carry out mechanical and climatic tests, including in the conditions of extreme values of temperature, humidity, loading and so forth.

The conducted researches showed considerable reduction of idle times of the machines waiting for replacement to the damaged detail of difficult configuration with application of methods reverse engineering and 3D printing: since 2-3 months (delivery time of detail the manufacturer) up to 3-7 days.

In the course of carrying out researches for justification of opportunities of replacement traditional metal on polymeric composite materials and implementation of additive technologies in road-construction mechanical engineering various functional models of structural elements of machines (fig. 5) were made. The carried-out complex of tests for durability and durability proved a practical possibility and expediency of new structural materials use and technological methods of spare parts of road-construction machines production.

a) b)

Fig. 5 – Examples of structural elements of the road machines manufactured with application of reverse engineering methods and 3D printing:

a) one-stage reducer; b) the case of hydrohammers hydroaccumulator

Additive technologies allows to increase technological efficiency of repair and reliability of details from polymeric composite materials and also to reduce material consumption, duration and cost of road-construction machines repair. Besides, increase in share of the machines details manufactured of polymeric materials instead of metal provides significant decrease in an environmental pressure from operation of the construction equipment [8,9,10].

References

1. Kosenko, E.A., Baurova, N.I., Zorin**,** V.A**.** Naturelike Materials and Structures in Mechanical Engineering // Polymer Science - Series D, 2021, 14(1), pp. 69–72
2. Nefelov I.S., Baurova N.I. Simulation of optimal 3D-printing parameters // Polymer Science. Series D. 2023. Vol. 16. №1. pp. 173-177.
3. Nefelov I.S., Baurova N.I. The research of the influence of the parameters of 3D printing on the strength characteristics of plastic products // Polymer Science. Series D. 2022. Vol. 15. №4. pp. 663-666.
4. Anderson, I. Mechanical Properties of Specimens 3D Printed with Virgin and Recycled Polylactic Acid / I. Anderson // 3D Printing and Additive Manufacturing. – 2017. – Vol. 4. – № 2. – P. 110-115.
5. Cano-Vicent, A. Fused deposition modelling: Current status, methodology, applications and future prospects / A. Cano-Vicent [et al.] // Additive Manufacturing. – 2021. – Vol. 47. – P. 102378.
6. McIlroy, C. Disentanglement effects on welding behaviour of polymer melts during the fused-filament-fabrication method for additive manufacturing / C. McIlroy, P.D. Olmsted // Polymer. – 2017. – Vol. 123. – pp. 376-391.
7. Perez, D.B. Investigation of Interlayer Interface Strength and Print Morphology Effects in Fused Deposition Modeling 3D-Printed PLA / D.B. Perez, E. Celik, R.L. Karkkainen // 3D Printing and Additive Manufacturing. – 2021. – Vol. 8. – № 1. – pp. 23-32.
8. Ravi, A.K. An in-process laser localized pre-deposition heating approach to inter-layer bond strengthening in extrusion based polymer additive manufacturing / A.K. Ravi, A. Deshpande, K.H. Hsu // Journal of Manufacturing Processes. – 2016. – Vol. 24. – pp. 179-185.

9. Tao, Y. A review on voids of 3D printed parts by fused filament fabrication / Y. Tao [et al.] // Journal of Materials Research and Technology. – 2021. – Vol. 15. – pp. 4860-4879.
10. Wang, J. Coupled thermomechanical analysis of fused deposition using the finite element method / J. Wang, P. Papadopoulos // Finite Elements in Analysis and Design. – 2021. – Vol. 197. – P. 103607.