ВЕСТНИК ТУРИНСКОГО ПОЛИТЕХНИЧЕСКОГО УНИВЕРСИТЕТА В ГОРОДЕ ТАШКЕНТЕ

ACTA OF TURIN POLYTECHNIC UNIVERSITY IN TASHKENT

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ACTA TTPU

Preface

Dear readers! I am pleased to announce a new edition of the journal of the Turin Polytechnic University ACTA TTPU. It is an № 1 issue to be published in 2022 year which includes selected articles submitted to the Editors. We observed an increase in the number of submissions to our journal during a year and I believe that the growth of the popularity of the journal is due to the excellent work of the Editorial Board as well. We will continue our efforts in increasing the quality, as well as requirements for the submissions and simplification of the selection procedures bringing the quality to higher standarts.

I appreciate very much our Editorial board for their contribution to improving the quality of our journal and all authors for presented papers. We are always open to any criticism and suggestions to improve the readability and content of the submitted papers published in our journal.

Editor in-chief
DSc. J.Sh.Inoyatkhodjaev

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ASSEMBLY SYSTEMS UNDER INDUSTRY 4.0 PARADIGM. SWOT ANALYSIS

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Abstract– The tendency of the manufacturing is currently moving from mass to customized production. With the rapid success of the digitalization in last decades, manufacturing is expected to be approaching the fourth industrial revolution, coined as Industry 4.0 (I4.0). This paradigm is boosted by technologies such as Internet of Things, Cloud Computing, Robotics, Big Data, and Augmented Reality, that will influence both products and processes, allowing efficiency and productivity improvements. There is much confidence that the future assembly systems will have unprecedented capabilities to satisfy complex customer demands under I4.0 era. Nevertheless, there is still doubts among academics and industry alike that how I4.0 offerings will be affected on assembly systems. Therefore, this paper presents a literature review identifying reoccurring themes and trends of assembly systems under I4.0 and their expected effect on future assembly systems. Central characteristics of focus are strengths, weaknesses, opportunities, and threats are identified and discussed. The findings of this paper can provide support in developing smart assembly systems endeavors for theory and practice. Moreover, industrial practitioners can use the strengths/opportunities offered by Assembly 4.0 to take strategic decisions to decrease the effect of the threats/weaknesses that come along with Assembly 4.0.

Key words– Industry 4.0, Assembly 4.0, SWOT analysis

I INTRODUCTION

When analyzing the concept of assembly systems under "Industry 4.0" era, as a growing area of research in the production engineering is "Assembly 4.0", the particular focus of the investigation on design and management of "Smart Assembly Stations" (1; 2).

Despite, that the terms "Assembly 4.0" and "Smart Assembly Stations" are novel and evolving concepts, which remains abstract phenomenon, (3) highlighted the advanced assembly technologies and systems and new trends of modularity and reconfigurable using a modular and reconfigurable assembly system. In this paper, they also concluded that integrated IT systems are a key element of design smart and digital manufacturing systems. Alternatively, (2) on their keynote paper, divided the main design principles of the efficient "Assembly System 4.0" into four layers, namely into connectivity, information, knowledge, and smart layers. In addition, this paper proposes a future state map of the assembly paradigms as an effect of the integration with the "Industry 4.0" principles. However, uses case are needed to quantify the different impacting variables for validating the proposed framework. The later on (1) developed a general framework of assembly system design in the "Industry 4.0" era using Assembly System (AS) design method. Beyond the main design principles like line balancing and scheduling, they also used material feeding, equipment selection, ergonomic risks and learning effects dimensions of this process. According to authors of this paper, the further research is required to support the proposed framework presenting case studies of real production systems.

Besides this advanced trends, today‘s assembly systems have to produce products in low cost, high quality in order to retain competitiveness and satisfy steadily increasing the customer requirements in a personal customized market era (4). Thus, more robust and responsive "Assembly 4.0" framework and strategies have to be developed to meet the dynamic requirements of customer and the shortened product lifecycle.

This paper presents the first original SWOT analysis which investigates the impact that I4.0 principles have on Assembly Systems. Aim of this paper is the conceptualize "Assembly 4.0" under "Industry 4.0" paradigm, giving roadmap developing smart assembly systems endeavors for theory and practice.

II THE METHODOLOGY

A snow balling approach was used as a tool to find the appropriate research papers to make SWOT analysis of Assembly systems under Industry 4.0 paradigm. To cover relevant publications in the fields of engineering from both academia and practice, we took advantage of three publication databases (Scopus, Science Direct and Google Scholar). Data collection was proceeded a deep learning of key input words of research fields within 2010 and 2020 years. Since Industry 4.0 concept is a novel approach and has emerged in the beginning of this decade, therefore we decided to look research papers published beyond 2010.

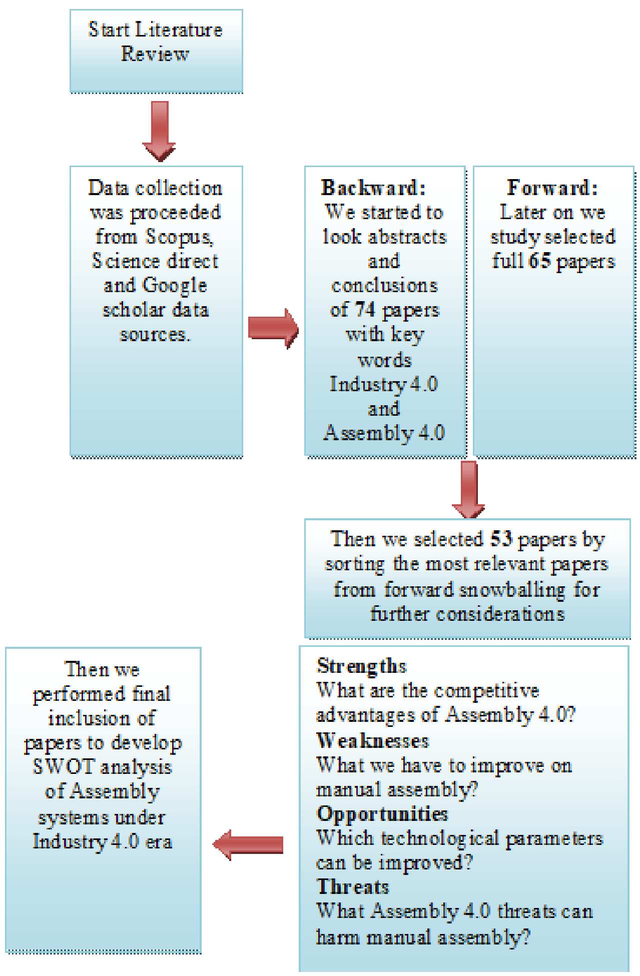

Fig. 1: Methodology

To conceptualize "Industry 4.0" and identify key terms, a preliminary digitalization technologies were reviewed, which will be fundamental role to design "Assembly 4.0".

After that, a search combining the keywords of "Industry 4.0" and "Assembly 4.0" was conducted, then the results were complemented by a backward and forward search. Of these results, only the publications which had a clear reference to "Industry 4.0" and "Assembly 4.0" in their title, abstract, or keywords were considered as relevant. This procedure led to 53 publications were selected for further consideration. Later, the results were aggregated and discussed in order to eliminate discrepancies. The keywords were then ranked according to relevance to design "Assembly 4.0", namely Internet of Things, Simulation, Operator Support Systems and Intelligent Support Systems were defined as a key elements to design smart assembly stations.

Then we performed final inclusion of papers to develop SWOT analysis of Assembly systems under Industry 4.0 era.

SWOT analysis stands for the short form of four words; Strength, Weaknesses, Opportunities, and Threats (see Fig. 2). SWOT analysis is a technique to identify the internal strengths and weaknesses and external opportunities and threats.

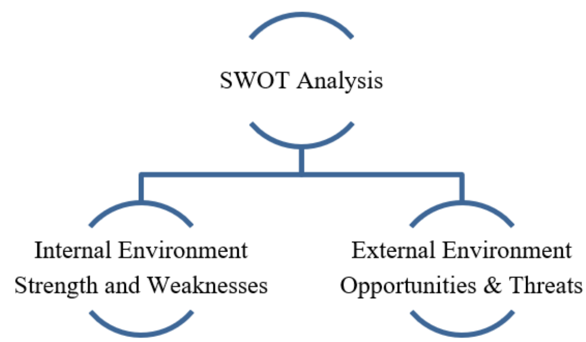

Fig. 2: SWOT analysis: internal and external environment

The internal analysis identifies resources, capabilities, core competencies, and competitive advantages inherent to the organization. The external analysis is used to identify market opportunities and threats by looking at competitors' resources, the industry environment, and the general environment. The main objective of the SWOT analysis is to use the knowledge an organization has about its internal and external environments and to formulate its strategy accordingly.

III STATE OF ART

Since the first Industrial Revolution, successor revolutions have resulted in manufacturing from water and steam-powered machines to electrical and digital automated production that made manufacturing process more complex, autonomous and sustainable (5; 6).

Currently, the global manufacturing landscape has changed deeply in last few years due to successive technological developments in manufacturing environment and today trend is more and more intended towards mass customization rather mass production. In order to swap with this tendency, the new Industry 4.0 concept has emerged and becoming an increasingly important topic in the last decade (7). This term stands for fourth industrial revolution that is defines a new level of organization and control over entire value chain of the product lifecycle (8).

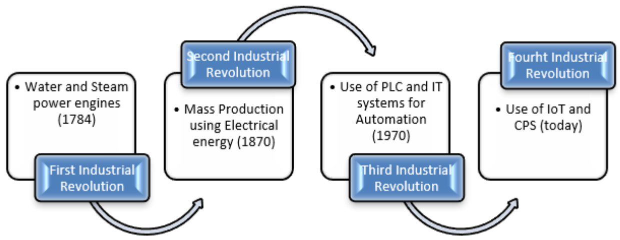

Fig. 3: Industrial Revolutions (5)

This paradigm is boosted by technologies such as Internet of Things, Cloud Computing, Robotics, Big Data, and Augmented Reality, that will influence both products and processes, allowing efficiency and productivity improvements among companies that will adopt such technologies (9). All of these, properly integrated, enable to develop a Cyber-Physical System (CPS), which is a virtual model of a physical entity capable to make decentralized decisions. CPS are able to communicate in real-time with the corresponding physical entity – to get input data and provide instructions as output (10; 11).

The term of "Industry 4.0" appeared for the first time in an article published in November 2011 by the German government that resulted from initiative regarding high-tech strategy for 2020 (7). In April 2013, the term "Industry 4.0" appeared in industrial fair in Hannover Germany and quickly rose as the German national initiative (12).

Then (1) developed a general framework of assembly system design in the "Industry 4.0" era using Assembly System (AS) design method (see Fig. 4).

Aided assembly improves the fastening and picking activities through several technologies reducing their duration and ensuring safe working conditions. As soon as a product reaches a workstation, assisted picking devices, as light picking, automatically show the components to pick from the workstation storage locations considering the final product to assembly and the optimal picking sequence that minimizes the worker effort.

Intelligent storage management system ensures significant economic savings. Sensorized workstation storage locations self-monitor their inventory level and automatically send refilling requests to the central warehouse.

Self-configured workstation layout autonomously adjust the rack, shelf and workbench dimensions considering the assembly product and the assigned worker. Sensors and actuators are embedded in the workstation structure which automatically adjust the shelves width and depth as well as the workbench height.

Fig. 4: Main characteristics of Assembly system 4.0 (1)

Sensorized and connected AS entities ensure a complete product and process traceability. Every assembly task is monitored to detect in real-time any possible error or non-compliance. Product quality is tremendously improved replacing statistical fault analysis with single item control.

Late customization of assembled products is one of the most relevant features of AS40. Accordingly, to the personalized production paradigm, the customer is involved since the design phase to tailor the product on its own needs. However, customer involvement is not limited to this phase. Late modifications of product specifications are allowed exploiting the company cloud database.

IV RESULTS AND DISCUSSION

Strength

What are the competitive advantages of Assembly 4.0?

During fastening activities under "Assembly 4.0" environment, the worker is aided through augmented realty devices, as head-worn displays, which suggest the sequence of activities to complete an assembly task considering the customer personalization. A further I40 technology assists the workers during assembly activities. Cobots automatically adjust their configuration in real-time to best fit with the worker physique and the fastening task features. Moreover, cobots provide to the worker an artificial force to perform hazardous activities reducing the ergonomic risk of strenuous tasks. Table 1 summarizes competitive advantages which can be achieved by Assembly 4.0 technologies.

TABLE 1: COMPETITIVE ADVANTAGES OF ASSEMBLY 4.0

	Capability Flexibility	**Capacity Flexibility**
Definition	Ability to react the system to changing product variant	Ability to react the system to changing product amount
Reason	Product Quality Product Variety	Production time Production volume
Possible solution	Human Dexterity Skills	Robotics and Flexible Automation, Aided systems
Type of assembly	Manual Assembly	Fixed Purpose automation
Integrated solution	Human Assisted Systems	

Weaknesses

What we have to improve on Assembly 4.0 environment?

Additional training. The operators of manual assembly process must be additionally trained when they work with assisted systems like augmented reality and cobots. Moreover, it requires high safety requirements when human and robot works collaboratively.

High investment. To design intelligent storage and self-configured workstations require high investment than compared to original systems. Because, sensorized workstation storage locations self-monitor their inventory level and automatically send refilling requests to the central warehouse.

Opportunities

Which technological parameters can be improved?

Today's assembly systems face four major problems from industrial point of view and we called them 4 "P" four pillar problems of the assembly system. First is product variability, since assembly systems have to manage hundreds of different product mix, distinguished by different assembly cycles, as well as thousands of different parts, hundred tools, equipment, and several workers qualifications (3). Second is production time reduction or time to market, the assembly processes experience several challenges, such as the growing complexity of their processes, supply networks and lead-time, and customization (9).Third, assembly systems need to become more decentralized to increase product quality. It is not acceptable, that a failure or stop of a single assembly station causes hours of down-time for the whole production line. Fourth, increase of demand for the production volume.

In general, "Ability to adapt to high production volumes, varying product variants, increase product quality and decrease production time to market", is the requirements for the assembly system of today (see Fig. 5).

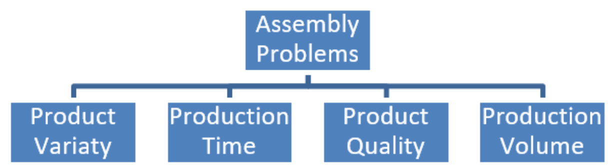

Fig. 5: 4 P Pillars problems of Assembly systems

Threats

What Assembly 4.0 threats can harm manual assembly?

BIG DATA: The enormous quantity of data collected from the assembly field represents the value-added information of the Assembly 4.0 those leading to problems with handling with data. A gap in technical skills: The needs required of the workforce all evolving. Only with the right workforce will business models be able to successfully implement new technology and maintain operations.

Fig. 6 summarizes the strengths and opportunities of Assembly 4.0 as well as its weaknesses and threats.

V CONCLUSION

Assembly 4.0 is established on the idea of the cyber-physical systems, which allows the connection between man and machine. In the cyber-physical systems, the information and data are generated by physical objects and flows to the cloud, the cloud then allows all the connected objects to use the available data or information. These stored data and information are later used for the continuous improvement and optimization of products, to do so Assembly 4.0 needs to have proper knowledge management and knowledge management system. Lack of proper platform and systems to manage data knowledge would act as a barrier to implementation and adoption of Assembly 4.0 and beside the proper

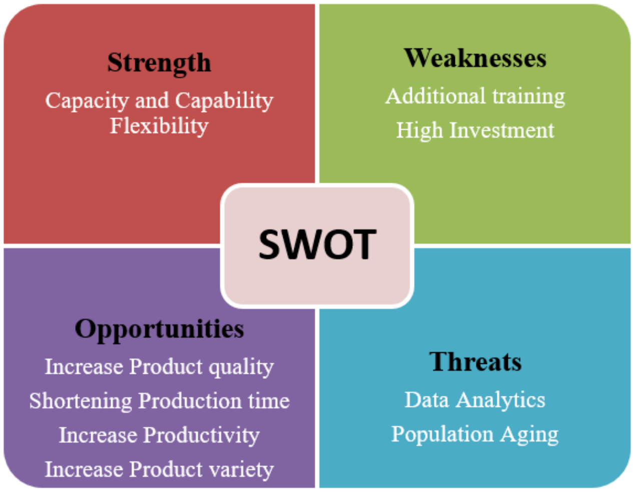

Fig. 6: Strength, weaknesses, opportunities and threats offered by Assembly 4.0

platform for knowledge.

Therefore, through the extant literature review, this study identified the factors of Assembly 4.0 in four categories. The SWOT analysis was applied to categorize the factors of Assembly 4.0 into strengths, weaknesses, opportunities, and threats. From the analysis, it is observed that Assembly 4.0 offers more advantages to the industry than its disadvantages. In this paper detailed analysis of Strengths, Weaknesses, Opportunities and Threats is used to formulate appropriate strategies that help in achieving the goal of Assembly 4.0.

Strengths-Opportunities Strategy: pursue opportunities that match the company's strengths. For example, strength like flexibility in production system help industries to get benefitted by opportunities like increased product quality, shortening production time, increase productivity and increase product variety.

Weaknesses-Opportunities Strategy: overcome weaknesses to make good use of opportunities. For example, weakness such as training of operator and equipping with new skills will cause initial investment but result in faster information flow as an opportunity that helps in better connectivity and shorter production times.

Strengths – Threats Strategy: To identify how to use advantages and strengths to minimize threats caused by the external environment. For instance, the implementation of Assembly 4.0 causes job loss due to high automation and digitization causes Big Data Analytics issues. To decrease these effects the industries can use the opportunity of new business models offered by industry 4.0 to create new opportunities.

More detailed strategies will be conducted in future research as a next step. The achieved result is useful to the industries and identifies the possible challenges and opportunities offered by Assembly 4.0. The analysis result shows the factors that should be considered during the implementation of the Assembly 4.0.

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THE PROCESSES IN SOFTWARE ENGINEERING

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Abstract– It is commonly mistaken that Software Engineering is about coding. However, the work of Software Engineering is beyond writing a code. It composes several important processes before starting producing executables, which is the main product produced by developers. The paper presents the development of any software and consecutive processes needed to accomplish to produce high standard software.

Key words– Software, software process, requirements engineering, design, implementation, integration, verification and validation, software management, software phases.

I Introduction

A well-organized set of actions that are necessary for the creation of a software system can be defined as the software process. Many software processes exist, yet they all perform the same tasks. The purpose of the software development process is to generate software with defined and predictable process and product attributes (cost, time, functionality, reliability, and others). The software process produces more than just code; it also produces documentation and data.[1]

II Activities of the software process

1 Production Activities

Executables, which are the end result of any software process, are very important in the creation of software. Developers construct the first intermediate product of the software process, the source code, rather than the executables directly. As a result, the coding phase is the initial activity of the software development process from the bottom up.

Source code is frequently huge, with many lines of code, and it must be structured into both physical and logical units (files, directories, and devices, functions, packages, subsystems, classes in object-oriented programming). The task of identifying and arranging the units of source code that must be created falls within the design phase of the software development process.

To understand exactly what software is built for and what it should perform (e.g., add numbers, count automobiles, forecast weather, operate mobile phones, help corporate administration...), it is necessary to examine the requirements.

1	Requirement Engineering	What the software should do
2	Architecture and Design	Which units, and how to organize them
3	Implementation	Write source code, integrate units

Table 1: Three steps of the production activities

Thus, the production activities are divided into three steps: gathering requirements and formalizing them (requirements engineering); identifying and organizing the units into which the software is divided (architecture and design); and writing source code, integrating different units, and obtaining executable code (programming and implementation correspondingly).

All of the production activities are logically dependent on the preceding ones: requirements must be decided in advance to build the software design; to implement the code, both design and requirements are required.

The production operations of the software process can be performed in order as a first, straightforward approach (Waterfall Model) [2]. However, each step may offer input to the preceding ones, allowing the process to repeat itself over previously completed phases.

The production operations generate a number of papers, particularly when it comes to the software system's requirements and design.

Figure 1 depicts all of a software process's production activities, as well as the intermediate products that are generated and transferred between them. The Requirements Engineering step creates requirement papers, which the Design phase uses. Design papers are prepared once the architecture and design have been specified. The first part of the implementation activity is to individually implement the software system's units, which is based on the subdivision in units produced during the Design phase and documented in the design document. The pieces are then combined to create the final software system.

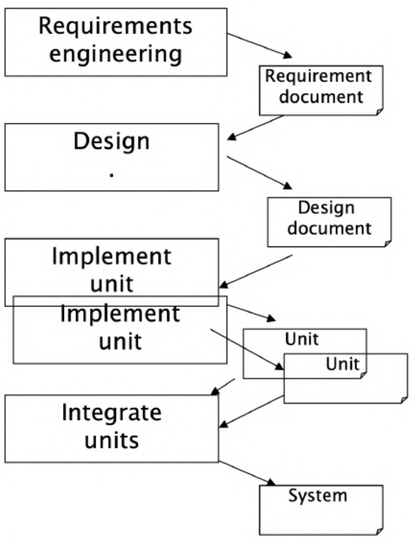

Fig. 1: The sequence of production activities

2 Verification and Validation Activities

Activities to validate the output of the production activities must be included in the software development process. Questions like the ones below should always be answered once the software units have been constructed [3].

- Does it work?
- Is it doing what it should do?
- Did we understand the requirements correctly?
- Did we implement the requirements correctly?

Verification and validation (V and V) activities must be completed after each phase. These are required for all phases, particularly the first ones. In reality, a mistake in the earliest stages of the software development process will have an impact on the rest of the process.

Verification and Validation indicates that the stages must be checked for correctness from both an external (whether they are consistent with prior phases or stakeholders' wishes) and an internal (if they are intrinsically accurate, e.g. if the coded units behave appropriately) perspective.

3 The management activities

The final point to consider in the construction of a software system is the individuals who will do the tasks and how the workforce will be organized.

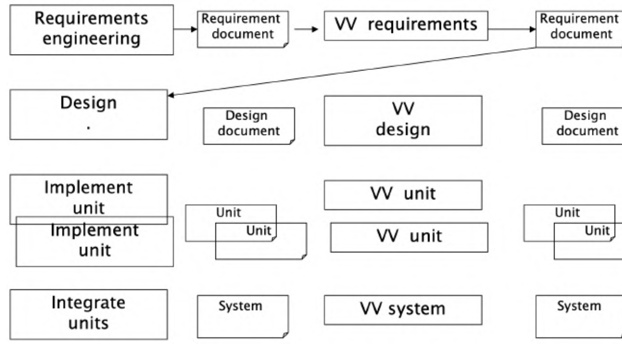

Fig. 2: Production + V and V activities

- Who does what, and when?
- Which resources will be used?
- How much will the project cost? When will it be finished?
- Where are the documents and units? Who can modify that?
- Are we doing it state of the art?

All those questions lead to the need for some management process.

Project management is a term that refers to the process of all operations linked to a software project, and its elements are organized in terms of assigning work to individuals and tracking their progress, as well as estimating and controlling the available budget.

Configuration Management is a term that refers to the process of managing Over time, software projects adapt and evolve. The practice of identifying and maintaining all papers and units relating to a software project, as well as keeping track of software versions and upgrades, is known as configuration management. Configuration control is another term for configuration management.

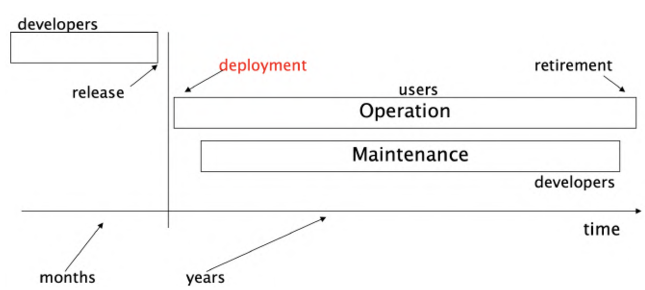

Fig. 3: Main phases of the software process

Quality assurance. The activity of verifying whether the specifications are met from the finished software. Measurable quality goals must be defined for the software project, and must be controlled (through V and V activities) once the project is delivered. Also how the work will be done is defined within this activity [3].

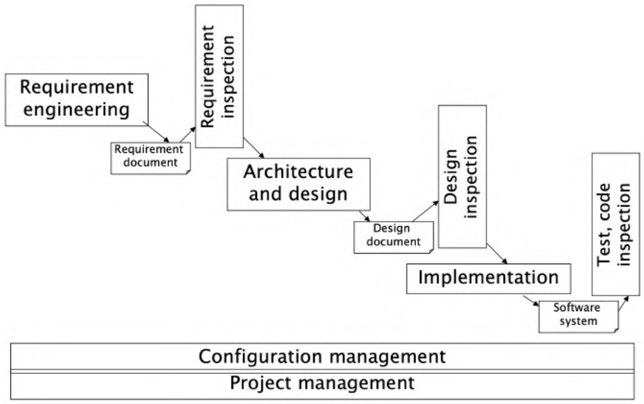

Fig. 4: The whole picture

III PHASES

Software development is only the initial step in the process. In truth, the software must first be deployed and made operational; then it must be maintained and changed in response to new demands; and lastly, when the program can no longer be maintained, it must be retired.

Operate the software	Deployment, Operation
Modify the software	Maintenance
End up	Retirement

TABLE 2: AIMS OF THE PHASES OF THE SOFTWARE PROCESS

The goal of the Maintenance phase is to enhance software quality (for example, in terms of performance or other qualities), satisfy changing customer demands, or remedy problems in deployed software. Maintenance may be thought of as a series of stages in the development process (dev1, dev2, ... devN, with dev0 being the initial Development phase; see Figure 5). The activities of development and maintenance are the same (requirements, architecture, design, coding). A software release is achieved at the end of each development phase.

The initial maintenance is generally the most time-consuming, while the subsequent ones are bound by the prior ones. Requirements are created from scratch in dev0, giving you complete control over the requirements for the initial development_0 phase. Only requirements are used in design and implementation. The requirements1 for the following development_0 phase, dev1, are generated from requirements, design, and implementation. Similarly, all prior development_0 phases requirements, design, and implementation, from dev0 to dev(N-1), will influence the requirements, design, and implementation of devN.

For example, if Java is chosen as the programming language in the dev0 phase, Java must be used in all subsequent development stages. Similarly, if the client/server approach is established for the program under dev0, all future advancements must follow suit.

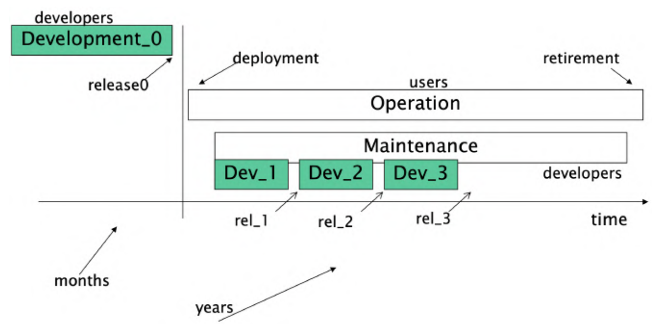

Fig. 5: Maintenance as a series of development phases

After years of use, the limits imposed by prior maintenances grow too big, and changing the software becomes nearly impossible. Maintenance is frequently the most expensive part of the software development process: for example, in commercial software, maintenance expenditures can account for up to 60 percent of total costs.

IV SOFTWARE ENGINEERING APPROACHES AND RECENT TRENDS

The term "software engineering" refers to a variety of methods to the software development process. In general, the activities required for the creation of any program do not vary significantly, with the normal phases of production, verification and validation, and management being constant. Information and choices must be produced, shared, and managed in any software development process, which is often done through the usage of documents.

Software engineering codifies the methods in which software information and choices are recorded and exchanged (including formal languages that may be used to write documents) and provides strategies and models to assist all development activities and the process as a whole (e.g., **CMM**,**CMM-I** , **Iso 900-3** and so on).

1 Main approaches to software development

Despite the fact that there are several techniques of bringing all of the activities of a software process together, there are at least three essential approaches that can be identified, in addition to basic solo programming.

Cowboy programming is a term used to describe a type of programming that is Cowboy coding focuses solely on code, with the belief that every other activity is a waste of time and should not be performed by genuine programmers [5]. It is a completely unrestrained method to software development in which programmers have entire influence over the development process.

Cowboy code focuses solely on rapid development and bug fixes, with the goal of completing a project as quickly as possible. There is no systematic procedure for requirements elicitation and testing, which increases the risk of mistakes and problems after deployment. Cowboy-programmed software is difficult to combine with other software and maintain over time because to the lack of clearly defined requirements and design.

This kind of programming is still used, especially when resources are limited or project deadlines are pressing.

UML, document-based, semiformal. Documents are written using a semiformal language (UML). Humans are in charge of transformation and control, not machines.

This strategy is generally used by established organizations and domains that have to handle huge projects in normal industrial practice.

Model-based / formal. All documentation and specifications for the program to be built are written in formal languages. The installed software's controls and transformations are performed automatically rather than by people.

In important domains, this method has a low acceptance rate. It is often utilized for tiny parts of projects that are later merged, rather than for full projects; it does not scale up to huge industrial projects.

Agile[6]. The agile methodology focuses on code and testing while attempting to restrict the usage of documents: it is a light-weight technique that supports quick project iterations.

It is the most recent method to be described (the Agile Manifesto was published in 2001), and there is still disagreement over its benefits and drawbacks. Agile methodology use is still restricted, but it is growing.

2 Recent trends in software engineering

Component-based [2]. Software engineering based on components. Component-based development assesses the feasibility of purchasing and then integrating commercial or open source components, i.e. off-the-shelf components, rather than focusing only on constructing the elements of the system to create. The method promotes component reuse while also emphasizing the software architecture definition step. The technique's main motivations are to save time and money while developing complicated systems, as well as to increase the quality of the final product by integrating dependable and verified components.

Offshoring. The process of relocating software development and maintenance to a new country for cost and time savings or to take advantage of various talents. Offshoring ensures greater cost and time efficiency at the cost of probably inferior quality and security of the development's consequences.

3 Business models for software

In addition to the classic plan of selling licenses for unrestricted use of software, there are a variety of business models available for firms to monetise the software they build [2].

Traditional. A one-time licensing price, i.e. the right to use the program, is paid for the product. Additional costs for support and maintenance may be requested. Open source. The term "open source" refers to software that is free, and only support and maintenance are paid to the user.

ASP. ASP stands for Active Server Pages (pay per use). Software is installed on the provider's equipment and accessed by users over a network, most commonly the internet. Rather of purchasing the program, users pay to use it (e.g., mySAP.com).

Freeware and premium versions. There are both freeware and paid versions. A lite version of the program is provided to the user at no cost. There is a fee for the professional version.

Shareware. To allow for a trial use, the program is supplied for free. If users elect to keep and utilize it, they must pay for it (e.g., WinRar).

Adware. The program is available for free. The interface displays internet-refreshed marketing ads (e.g., Eudora).

V Conclusion

To sum up, the paper presented the procedures of creating a software. Software is not produced like in industrial disciplines, it is developed, and some basic essential processes are needed to fulfill all the procedures mentioned in the paper.

It is true that software engineering is quite young discipline with respect to conventional engineering: although traditional engineering techniques have been used for hundreds of years, software engineering has only been around for around 50. As a result of this reality, customer and management maturity, which is guaranteed in conventional engineering, is extremely changeable in software engineering.

Furthermore, classic engineering theories are based on a variety of hard sciences, such as physics, law, mathematical models, and so on. Software engineering, on the other hand, is based on a restricted set of ideas and laws, and may be regarded more of a social science to some extent.

Even if Software engineering is quite a young discipline in the engineering world, it already gain big popularity among people, also its products nowadays have huge impact not only on society or environment, but also other branches of engineering. It is hard to imagine any engineering disciplines which could ignore the effect of Software engineering on it. However, developing a good software requires some tasks to be completed. In high level this paper tried to cover them.

The software process is not a new concept for software development; rather, it is just the application of the engineering technique to software development.

The engineering process for traditional manufacturing follows the same phases as software development: a preliminary phase in which requirements are defined; an architecture and design phase in which the elements of the final output of the production process are specified; an implementation and integration phase in which the individual elements are created and then put together; and, finally, a validation and verification phase.

Because the nature of software changes, so does the nature of the process that underpins it. A software process, for example, can build stand-alone software; but, the creation of embedded software, which is intimately tied to the hardware on which it is placed, necessitates the execution of a System Process.

The steps of a System Process are similar to those of a typical software process at first, with a first System Requirements Engineering phase for gathering requirements for the entire system and a System Design phase for defining the entire system's design.

The procedure then splits into two distinct processes: hardware development and usual software development. Both processes are full-stack, with their own requirements, design, implementation, and testing phases. The hardware and software components of the system are the result of the two processes, which are then combined and tested together in the final System Integration step to form the system. Hence, based on all these knowledges it is possible to develop a software, as well as software systems.

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APPLICATION OF MATHEMATICAL METHODS EXPERIMENTAL PLANNING IN DETERMINING THE DEFECTIVE PARAMETERS OF BREAK-IN OIL

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Abstract– This article discusses mathematical methods for planning an experiment to determine the rejection parameters of running oils. When new engines are released and after repairs, internal combustion engines of transport equipment undergo cold and hot running-in. During the break-in process, special break-in oils are used. Break-in oils do not have a specific change schedule, this requires the determination of rejection parameters, the article provides the results of planning an experiment to determine the rejection parameters of the test oil.

Key words– engine, diesel, oils, motor, temperature

I Introduction

In world practice, the issue of ensuring the reliability of internal combustion engines is an urgent complex task solved in different directions. Important, among them are the operating conditions, the type of fuel used and a number of other indicators. Internal combustion engines of tractors and cars are subject to running-in during release. The manufacturer carries out running-in at test stations. Engine break-in is divided into cold and hot break-in.

II Materials and methods

The material for the study was the change in the defective parameters of OM-2 break-in oil. At the stage of cold running in order to obtain a good running-in of parts, a number of technologies are used.

Low-viscosity oils are used, for example MG-10-B2; special break-in oil OM-2 is used, additive DK-8 is added to the oil, etc. At the same time, the running-in time is reduced by 1.5-2 times, the removal of metal from the surfaces of parts is reduced [1].

It has been established that in agricultural production, when carrying out post-repair running-in of tractor engines, M-10G2 engine oil is most often used instead of special running-in oils, which reduces the service life of repaired machines by 20-30%. A method for deep cleaning of used oils is proposed, which allows removing 97-99% of all types of contaminants from the oil for its further use as a base for break-in oil. The composition of the break-in oil is substantiated, consisting of 98% of purified oil, 1.5% of oleic acid, 0.03% of graphenes, 0.5% of carbamide. As a result of research, it was found that the introduction of carbamide into the oil increases the antiwear properties of the break-in oil composition by 1.3-1.5 times. The addition of 0.5-1.5% oleic acid provides the Rebinder effect on the friction surface and helps to remove post-repair microroughnesses from the friction surface. It has been determined that the introduction of graphenes into the composition of the break-in oil makes it possible to increase the heat capacity of the oil by 10-20% and to increase the anti-wear properties of the break-in oil by more than 15% [2].

In a flow- circulation lubrication system at test stations of engine-building plants, large amounts of oil are used for a long time, as a result of which its performance properties deteriorate. In break-in oils, this process is very intensive due to the increased metal removal from the friction surfaces during running-in, the washing out of technological contaminants and the operation of the compositions of special additives introduced into such oils.

Establishing the rejection parameters of the oil will allow it to be maintained in an optimal condition for engine running-in and to determine the maximum possible terms of its use. To obtain the optimal composition of products in various fields of science, mathematical methods are increasingly used, in particular, mathematical planning of experiments and modeling of research objects [1, 5, 6]. This allows you to significantly reduce the number of experiments, to obtain mathematical relationships that reflect the mutual influence of components.

In this case, the optimum can be achieved for several indicators. The paper presents work on determining the rejection parameters of OM-2 oil, which is used when running in D-243 engines. To determine the rejection criteria of the lubricating medium, the idea of simplex planning was used [1].

III RESULTS

The research methodology included the following works:

- choice of optimization parameters for w factors;
- selection of limits of change in the value of factors;
- selection of variation intervals and the order of the mathematical model (linear, quadratic);
- compilation of a matrix (determination of the composition and number of samples);
- preparation of prototypes; conducting research on the planned set of laboratory methods;
- processing of research results (calculation of regression coefficients, checking the significance of coefficients, checking the adequacy of mathematical models);
- use of mathematical models with the required properties.

Such an experimental design assumes that the values of the factors are related to each other by the ratio:

$$X_1 + X_2 + ... + X_i = m$$

where:
X_i — concentration of components.

Let's designate the main factors affecting the operational properties of the break-in oil OM-2: X_i - base oil concentration $DC - 8 + 0.003\% PMS - 200A$; X_2 - the concentration of the diproxide additive; X_3 — concentration of detergent components $TSIATM - 339 + PMS$; X_4 — concentration of insoluble sediment in oil;

The ratio of the concentration of additives in the factor X_s in the experiments was kept equal to 1:1. The ratio between the amount of mechanical impurities of organic and inorganic origin in all cases was taken equal 1.35. This value was obtained as a result of statistical processing of the results of analyzes of a large number of samples of working oil OM-2.

It makes no sense to test some components in their pure form, the area under study can be localized by pseudo-coordinates, which will accordingly have values:

$$0 < Z_i < 1$$

The values of the factors will be related by the ratio:

$$Z_1 + Z_2 + Z_3 + Z_4 = i$$

The limiting values of the factors X in true coordinates were taken as follows in% (the values of the factors in pseudo-coordinates are indicated in brackets)

X_1	from	92	(0)	to	100	(1)
X_2	from	0	(0)	to	4	(1)
X_3	from	0	(0)	to	8	(1)
X_4	from	0	(0)	to	0,8	(1)

When the values of all factors change at three levels, mathematical planning allows, after examining 10 prototypes, to obtain quadratic mathematical models that are built for all estimated oil quality parameters. When conducting a traditional one-factor experiment with a four-factor system at three levels of the value of each factor, it would be necessary to examine 81 samples. The parameters characterizing the performance of the oil were selected:

$$\frac{dM_{tp}}{d\tau}$$

running-in speed, wear, anti-scratch properties. After carrying out the experiment on the studied parameters, regression mathematical models were built. The models were tested for adequacy, and the regression coefficients were tested for significance - by the methods of mathematical statistics. The compositions of the samples were determined according to the rules of the regression index - by the methods of mathematical statistics for significance. The compositions of the samples were determined according to the rules for constructing the planning matrix (Table.1).

In the case of a four-factor problem, a simplex is a spatial figure, the image and use of which is difficult. Such a simplex can be replaced with a flat one, for which it is necessary to lower the order of the factor space by excluding the insignificant influence of the base oil from consideration, which was carried out by substitution:

$$Z_i = 1 - Z_2 - Z_3 - Z_4$$

The model of the dependence of the running-in speed on the quantitative ratios of the components in this case has the form:

$$Y = 0.19 + 0.29Z_2 - 0.09Z_3 + 0.07Z_4 +$$
$$+ 0.36Z_2Z_3 + 0.12Z_2Z_4 + 0.6Z_3Z_4^2$$

Sample number	Factor values								Estimated parameters		
	pseudo-coordinates				true coordinates				Break-in speed	wear, g	carbon formation assessment, points
	Z_1	Z_2	Z_3	Z_4	X_1	X_2	X_3	X_4			
1	1	0	0	0	100	0	0	0	0.190	0.1326	3
2	0	1	0	0	96	4	0	0	0.480	0.6233	5
3	0	0	1	0	92	0	8	0	0.100	0.0764	0.5
4	0	0	0	1	99.2	0	0	0.8	0.260	0.1512	4
5	0.5	0.5	0	0	98	2	2	2	0.340	0.1340	4
6	0.5	0	0.5	0	96	0	4	0	0.130	0.0346	1.5
7	0.5	0	0	0.5	99.6	0	0	0.4	0.230	0.1508	3.5
8	0	0.5	0.5	0	94	2	4	0	0.380	0.0,0313	3.5
9	0	0.5	0	0.5	97.6	2	0	0.4	0.400	0.0290	5
10	0	0	0.5	0.5	95.6	0	4	0.4	0.330	0.0260	-

TABLE 1: EXPERIMENT PLANNING MATRIX

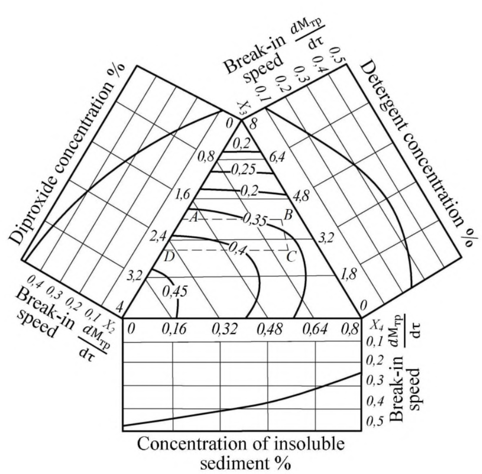

Fig. 1: Dependence of the running-in speed on the oil composition $\frac{dM_{tp}}{d\tau}$

The model of the dependence of wear on the quantitative ratios of oil components was expressed by the formula:

$$Y_2 = 0.1326 - 0.8829Z_2 - 0.358Z_3 + 0.0542Z_4 + 0.36788Z_2Z_3 -$$
$$-0.0952Z_2Z_4 + 0.1072Z_3Z_4 + 1.3738Z_2^2 + 0.2796Z_3^2 + 0.0356Z_4^2$$

The dependence of the intensity of varnish deposits on the quantitative ratios of the components was expressed by a model that has the following form:

$$Y_3 = 3 + 2Z_2 - 3.5Z_3 + Z_4 + 4Z_2Z_4 + 2Z_2Z_4 + Z_3^2 + 4Z_3Z_4$$

The indicated models were used to build graphical dependencies in the form of simplexes. In this case, the coordinates are converted to true. In Figure 1 shows such a construction for the dependence of the running-in rate on the oil composition

$$\frac{dM_{tp}}{d\tau}$$

IV ANALYSIS

As can be seen from Figure 1, the graph has the form of a triangle, at the vertices of which there are concentration maxima: X_2 - diproxide; X_3 – detergents $TSIATM - 399 + PMS$; X_4 - mechanical impurities formed in the oil (insoluble sediment). The concentrations of the components decrease along the simplex in a clockwise direction. The parameter values are determined by the constant level lines on the triangle.

Based on the comparison of these lines on three simplexes (running-in rate, wear, lacquer deposits), the AVSD trapezoid is constructed, shown in Figure 1, which determines the rejection parameters.

The AB limit is due to the content of detergents in the fresh oil, BC boundary - the need to maintain high running-in properties; the border of the SD ensures that the used oil retains sufficient detergent properties.

V CONCLUSION

From the results of the experiments, based on the analysis of data on simplices, it can be concluded that in order to ensure the optimal operational properties of OM-2 oil, $\frac{dM_{tp}}{d\tau}$ the wear rate with minimal wear and varnishes should be at least 0.35, which is ensured by the concentration of diproxide 0.6- 0.7%. Limit content of mechanical impurities 0.5%, detergents not less 3%. When the running-in oil reaches the specified parameters, it must be replaced.

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NEURAL NETWORKS PERFORMANCE IMPROVEMENT USING PINK NOISE AUGMENTATION.

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Abstract– Data augmentation techniques artificially generate different versions of a real dataset to increase its size. Many practices have shown an increase in the accuracy of machine learning models after applying them. When training a machine learning model, it functions as a regularizer and helps to reduce overfitting. This work will discuss the improved neural network performance with the pink noise data augmentation in order to model system drifts.

Key words– Pink Noise, Neural Networks, Data Augmentation Techniques, System Drifts

I Objective

The ability of neural network models to generalize what they've learnt to new data can be improved by training them on more data. Augmentation approaches can supply different datasets to fit models, which can help them generalize what they've learnt to new data. In this paper, we will apply data augmentation strategies to improve the generalization resilience of model inference when training neural networks.

II Introduction

Data augmentation is a set of techniques to artificially increase the amount of data by generating new data points from existing data. This includes making small changes to data like introducing random variations and disturbances, ensuring that the data is not destroyed.[1] Our purpose is to boost the model generalizability using data augmentation. We discuss the generation of augmented sets with the addition of pink noise to original data. We are exploring human indoor localization in a restricted area because it is trendy in the fields like energy management, health monitoring, and security. The purpose is to explore cheap but efficient techniques for indoor localization because for outdoors person tracking, there exists GPS technology that can quickly determine a person location through the wearable tag or cell phone. At home or inside a room, a person is not always carrying a phone; that is why we should search approaches for tagless localization. Four sets of experimental data are collected in a 3x3 meter room for a short period. A 4x4 pixel Omron D6T-44L-06 thermopile infrared sensor is installed on the ceiling of a room, and the person reference location is collected with an ultrasound-based tag of the Marvelmind Starter Set HW v4.9. [2] Each tuple of experimental data has 18 elements: 16 pixels of the infrared sensor (IR) plus the X and Y coordinates of the person representing the label.

III Main part

The first set of experimental data is used for the model training in a 60/20/20 ratio representing training/validation/test sets. The other three sets are used only for inference because our purpose is to improve the model generalization, which refers to model performance for unseen data. Since the amount of training data is small, we generate synthetic data by adding pink noise. Pink noise (1/f noise), is used to generate augmented data for emulating long-term drifts in the system. It represents a frequency spectrum where the power spectral density (power per frequency interval) is inversely proportional to the signal frequency.[3] Each octave interval in pink noise delivers the same amount of noise energy. The power spectral density of pink noise is represented as follows:

$$S(f) \propto \frac{1}{f} \tag{1}$$

We use the same techniques that we have used in our previous work to decide on the amplitude of the pink noise. First, we create a baseline from which we may track the generalization improvement. The baseline is obtained by training the model without augmented data. Our goal in creating augmented sets is to achieve better generalization of the model. The first intuition on noise parameter is related to the signal variance between a person detection and without detection. The signal deviation is derived using the maximum and minimum sensor one-pixel output variance values.

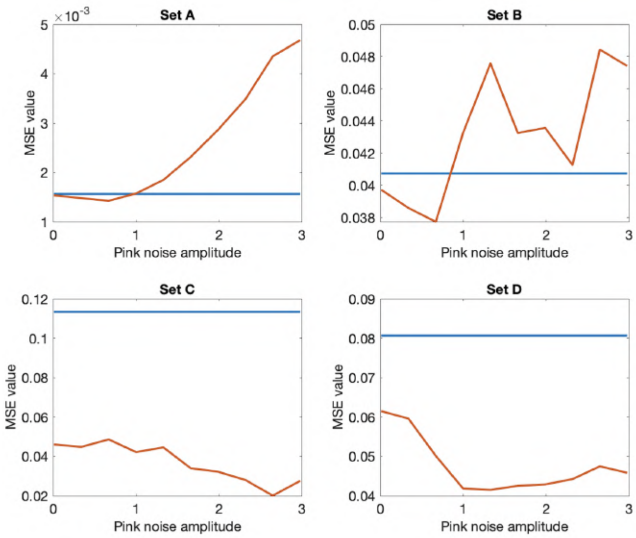

Fig. 1: Model output MSE values(red line) with augmented data generated in pink noise amplitude range [0; 3], for data sets A, B, C and D. Blue line represents the model MSE baseline obtained without augmented data.

Noise Amplitude	MSE_A	MSE_B	MSE_C	MSE_D
Baseline	0.001565	0.040742	0.113454	0.080686
0.01	0.001538	0.039735	0.046079	0.061516
0.34	0.001481	0.038605	0.04483	0.059618
0.67	0.001427	0.037736	0.048638	0.050147
1.00	0.001577	0.043275	0.042183	0.04185
1.33	0.00185	0.047579	0.044584	0.041498
1.66	0.002317	0.043262	0.033977	0.042545
1.99	0.002867	0.043579	0.032207	0.042899
2.32	0.003487	0.041271	0.02802	0.044242
2.65	0.004355	0.048448	0.020107	0.047483
2.98	0.004683	0.047419	0.027579	0.045834

TABLE 1: RESULT OF THE MODEL TRAININGS AT DIFFERENT PINK NOISE AMPLITUDES. FOR EACH NOISE PARAMETER CORRESPONDING MSE METRICS FOR SETS A, B, C, D AND BEST TRAINING ARE SHOWN.

All 16 pixels of the IR sensor are transformed into temperature inside the sensor. We look at how the model behaves when the noise amplitude is up to 50% of the signal level because the power of the pink noise decreases with the frequency. Thus, we use noise amplitudes in range [0; 3]. Since we have four sets of experimental data collected under different conditions with different environments and ambient temperatures, to evaluate the model overall generalization quality we calculate the sum of errors. We analyze the model behavior trained with augmented sets generated based on pink noise amplitude in this range: {0.01 0.34 0.67 1.00 1.33 1.66 1.99 2.32 2.65 2.98}. For every noise amplitude in the range, the model is trained 30 times and based on the minimum MSE sum of all sets, the best model is chosen. Table 1 reports the best results of trainings, shown in Figure 1 and Figure 2. For set A, model behavior shows a monotonic increase as the noise amount increases. In an interval [0;1], MSE is below the baseline, which means the model can obtain better results with augmented data. Noise values greater than one seem to reduce the original data quality so that the model output is increasing very high above the baseline. Considering pink noise, set B has more improved characteristics. The model output is below the baseline until the noise amplitude one and starts to fluctuate with higher MSE values above the baseline. The plots of sets C and D have almost similar behavior. Both of them are below the corresponding baselines in full range, even showing better generalizations for higher noise amplitudes.

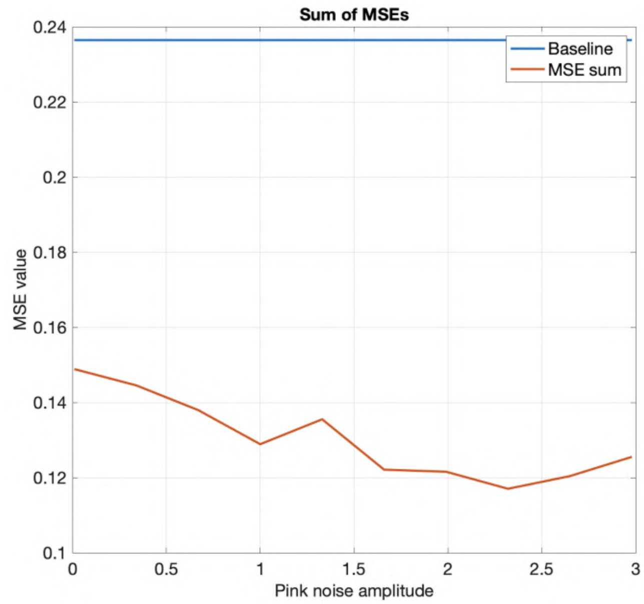

Fig. 2: The model overall inference generalization obtained by pink noise augmentation.

After analyzing all sets independently, overall model generalization quality is evaluated based on Figure 2. General behavior describes decreasing output which is always below the baseline showing total improvement of the model. We should exclude from this range the pink noise amplitude intervals in which one or two sets of improvement overcomes other sets MSEs that are above the baseline. Going back to Figure 1 it becomes clear that in a range [0;1], the model has the most improved area with all individual sets improvements. Only the set A results at the beginning of the noise interval could be a bit confusing. We can clarify it with a

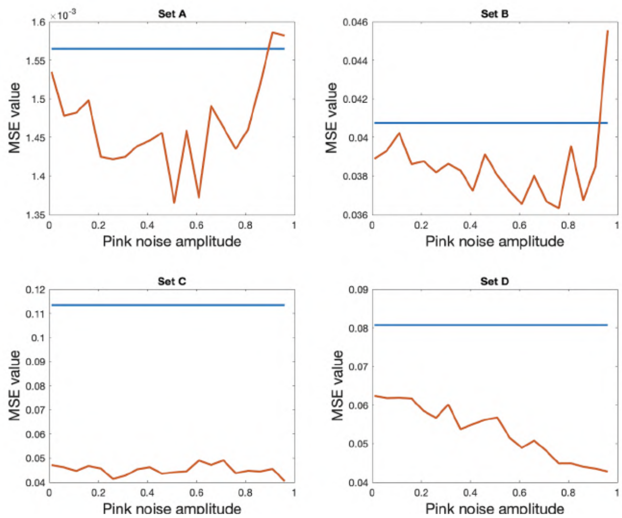

Fig. 3: Model output MSE values(red line) with augmented data generated in pink noise amplitude range [0; 1], for data sets A, B, C and D. Blue line represents the model MSE baseline obtained without augmented data.

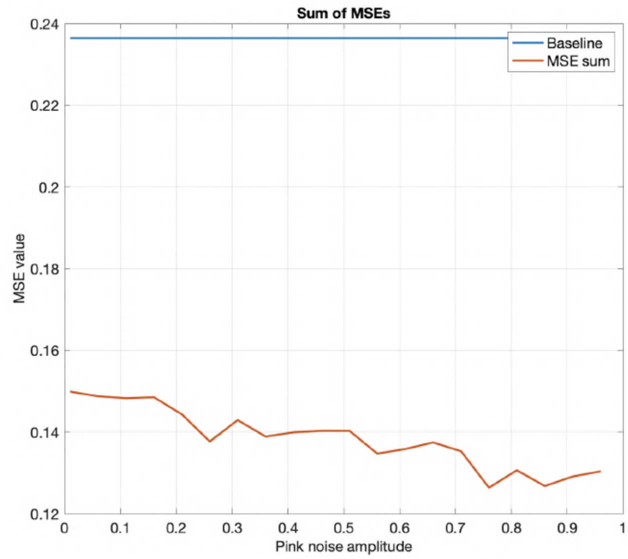

Fig. 4: The model overall inference generalization obtained by pink noise augmentation.

further experiment in which the range [0; 1] is explored with high resolution obtained by dividing the range into several intervals. Pink noise amplitudes greater than 1 show the model improvement for sets C and D, which overcome the terrible results of sets A and B. However, it does not satisfy the stated criteria for good generalization. We performed one more experiment to check the model behavior for the pink noise amplitude range in [0; 1] to double-check our previous results. Figure 3 and Figure 4 represents the plots, and we prove that the interval [0; 1] is indeed a range giving the model the best generalization quality. After determining the reasonable intervals of pink noise amplitudes, we can further continue our trainings to explore the model characteristics with the combination of white and pink noise amplitudes in future experiments.

IV CONCLUSION

Data augmentation is a technique for increasing the size of a training dataset artificially by producing modified versions of the original dataset. The ability of Neural Network models to generalize what they have learned to new data can be improved by training neural network models on more data, and the augmentation techniques can create variations of the datasets that can improve the ability of the fit models to generalize what they have learned to new unseen data. We have seen that by modeling the system drifts as pink noise, and using it to generate augmented sets helps the model to learn better giving improved inference results.

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Synergetic properties of the interaction of the vehicle with the element of road infrastructure in urban driving modes

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Abstract– This paper analyzed the synergistic properties of intelligent transportation systems in local conditions based on a Chevrolet Nexia. Vehicle to the infrastructure of the intelligent transport system has experimented on the example of the "Intelligent start-stop system" in urban driving modes. We analyzed the vehicle's driving modes and opted for the idle mode to save fuel. The synergy of the vehicle with the traffic light depends on many factors and has been studied on the example of the information model of the "Intelligent start-stop system". A vehicle with an "intelligent start-stop system" was saved 8.25% of fuel during 100 km in urban conditions. In addition, emissions of harmful gases into the environment have been minimized. It was found that an average of 132 liters of fuel was saved when one vehicle traveled 20,000 km per year. Moreover, the idling time of the vehicle's engine was characterized by a reduction of 28 - 32% in 100 km of the total test distance. Also included are the concepts of order parameter and flexible parameter on the principles of synergetic by using intelligent transport systems in the local condition.

Key words– intelligent transport system, intelligent start-stop system, infrastructure, traffic light, mode, synergetic, order and flexible parameters.

I Introduction

In exploition, the driving of vehicles consists of a complex dynamic variables, which are provided in accordance with the principles of synergetics in the system "Vehicle - Driver - Road - Pedestrian – Environment". In the system "V-D-R-P-E" mechanic – "Vehicle – road", biomechanic – "Driver – vehicle", "Driver – road", "Pedestrian – vehicler" and "Pedestrian – road", biological – "Driver – pedestrain" systems can be distinguished [1]. In addition, they are integrated into the vehicle's mechatronic systems in intelligent transport systems. Under synergetic principles, the system is characterized by the presence of an open, dynamic unbalance and a nonlinear connection between the parts. The level of data retrieval from infrastructure while driving is limited for the driver.

Every developing society must constantly increase the volume of transport communications, enhance its reliability, safety, and quality. To achieve this, it is important to ensure the interoperability of vehicles and transport infrastructure, as well as the use of intelligent technologies in the field. Because, intelligent transport systems (ITS) and intelligent technologies (IT) are not only the collection of data through automotive mechatronic systems but also the automation of analysis, modeling the processes in real-time, minimizing the "human factor". It is also based on a specific methodological framework that allows for further correction, making it easier to propose or make clear management decisions.

Improvements to modern vehicle design and control of parts with mechatronic systems are aimed at solving various problems in this field. If we consider the vehicle as a complex unified system, then the system, according to the principles of synergetics, adapts to the standards, taking into account internal and external factors through self-regulation. This intelligent approach is based on many parameters. This intellectual approach is based on several factors.

ITS is divided into subsystems consisting of vehicle and infrastructure elements. According to the principles of synergetics, the complex elements of the system are divided into several hierarchical layers, depending on the rate of their change relative to the others. The intellectual elements of a vehicle are a fast-changing group and the intellectual infrastructure elements are a relatively slow-changing group.

II THE METHODOLOGY

As we know, the movement of vehicles in urban conditions depends on many factors. In such a case, it brings to the increased complexity of movement. In these complexities, we think it is necessary to increase the fuel economy of vehicles and improve environmental performance.

In Boris Kerner's "Three-phase traffic theory", which can be observed during the movement of vehicles under certain operating conditions, the function $q = f(\rho)$ of the flow of vehicles as a function of its density is analyzed [2]. We observe the theoretical hypothesis of the currents **F-"free flow"**, **S-"synchronized flow"** and **J-"traffic in congestion"** shown in Figure 1 in today's real conditions. This means that the level of development of transport infrastructure is important in the regulation of traffic on roads, the elimination of congestion, and other processes.

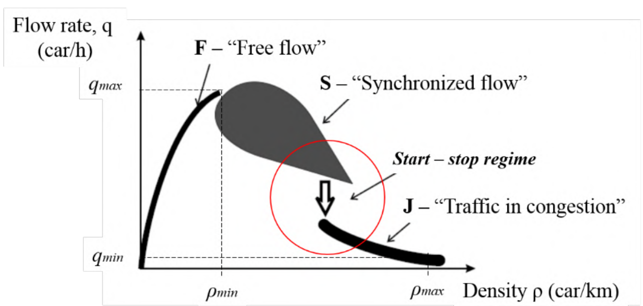


Fig. 1: Kerner's "Three-phase traffic theory" hypothesis

The development of transport infrastructure is the construction of highways, repairing highways, and equipping all elements of traffic safety with modern technologies. Today, they are not fully covered in terms of integration or synergy with the vehicle. As a result, there is a gap between vehicles and infrastructure, and energy consumption, environmental problems, road traffic accidents, and also their consequences are deteriorating. It is necessary to use ITS parts in solving the above problems. Major researchers in the field of traffic management, energy and resource-saving, optimization of automotive electronic control systems in the processes of interaction of the components of ITS with various objects, including B.McQueen, G.Nowacki, T.Hasegawa, S.Shaheen, R.Finson, Research work was carried out by I.Kabashkin, O.Katerna, N.Sembaev, N.Stavrova, V.Debelov, D.Morozov and others [3-11].

In addition, the research conducted by R.Nilesh and L.Robert in assessing the impact of ITS is aimed at ensuring road safety in the future [12-13].

M.Sumit, Sh.Khorinov, M.Vanderschuren, N.Parmar and H.Zhang have been used ITS technologies such as GPS, Wi-Fi, and Camera for monitoring traffic. They focused that, assess the traffic conditions of vehicles, prevent congestions and save energy resourcesusing of ITS technologies in their theoretical and practical research [14-18].

The research work of I.Razi, A.Stevens, E.Dahlman and K.Chai have been learned the communication of vehicle to infrastructure. In this approach the information about oncoming road signs, dengerous turns, railway crossings, etc transmitted to vehicles through short-distance wireless technologies, which have been found to help prevent road accidents in the exploitation conditions [19-22].

Uzbek scientists A.A. Mukhitdinov, A.A. Shermukhamedov, E.Z. Fayzullaev, K.A. Sharipov, J.Sh. Inoyatkhodjaev and others have been achieved significantly positive results such as optimizing mechatronic systems and production processes in the field of exploitation characteristics of vehicles, road parameters, improving energy performance and environmental performance [23-24]. However, the problems of the synergy between vehicle traffic modes with transport infrastructure using ITS capabilities have not been sufficiently addressed. Also, the fact that the level of implementation of these technologies in our conditions remains low, indicates the availability of resources in the field to solve the problem of fuel economy, environmental performance and other issues.

There are several methods to save fuel. One of these methods is to use the "Intelligent start-stop system (ISSS)" in the component of "vehicle- to- infrastructure" of the ITS in the idling mode of the vehicle. Because saving fuel in this mode has not been researched in our country.

There are different aspects in the coverage of this article. In particular, there is no research on the effect on the engine parts, battery, starter, alternators in the process of turning off the vehicle engine at a red traffic light and restarting it at a yellow or green light in the ISSS. In general, the resource of the related parts can be reduced when the engine is started and turned off several times. However, due to the high level of quality and reliability in the production of mechanical and electronic parts of modern vehicles many violations of them are not observed during the exploitation of vehicles.

The object of the research was a vehicle with a 1,5-liter engine produced by UzAuto Motors. The main objective was to test the vehicle's fuel economy using ISST on the basis of the Chevrolet Nexia engine.

It was analyzed that vehicles equipped with an "auto start-stop system" can save 5-10% fuel when driving in urban conditions and reduce CO_2 emissions by approximately the same [25]. ISSS was tested in the auto polygon, and preliminary fuel savings are estimated to have improved by 7% in the new European cycle and 5% in the Tashkent drive cycle.

The efficiency of the ISSS is determined by saving fuel consumed during that time by turning off the vehicle engine more than 10 seconds before the red light of traffic light switches off and restarting it after a certain time. In addition, this system reduces the idling time of the engine and increases its efficiency and resource.

The difference in use of this system compared to others is that it enables mechatronic systems in the vehicle to ensure interoperability with traffic lights on the principles of synergetics. As a result of research and analysis, the system has been divided into two groups: constructive and synergistic approaches.

In constructive approach, in the “A-D-R-P-E” system, the process is based only on the driver’s observation, assessment of the situation and information from reality, stopping the vehicle at red lights of traffic light, traffic jams and other places. In these cases, according to the system conditions, the engine automatically shuts down within 3-5 seconds and after a certain time it is automatically restarted when the driver performs several operations (Figure 2, a).

In synergistic approach, the vehicle stops also of the above situations. ISSS activates in the designated area. According to the system requirements, several parameters are received and controlled from the vehicle and the infrastructure elements (traffic lights) to decide whether the engine should be shut down or not and restarted after a certain time (Fig. 2, b).

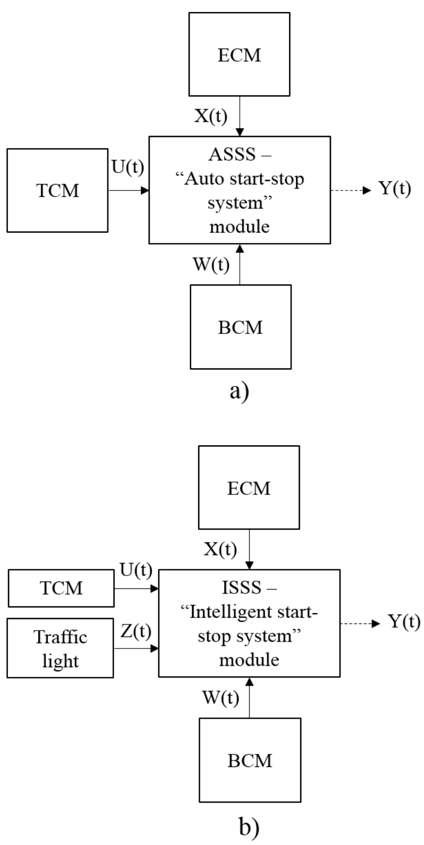


Fig. 2: a) constructive approach, b) synergetic approach. Information model of the system

The ISSS is based on a mechatronic system, such as mechanical system, a control unit, input signals (sensors) and actuators (actors).

Input parameters from the vehicle:

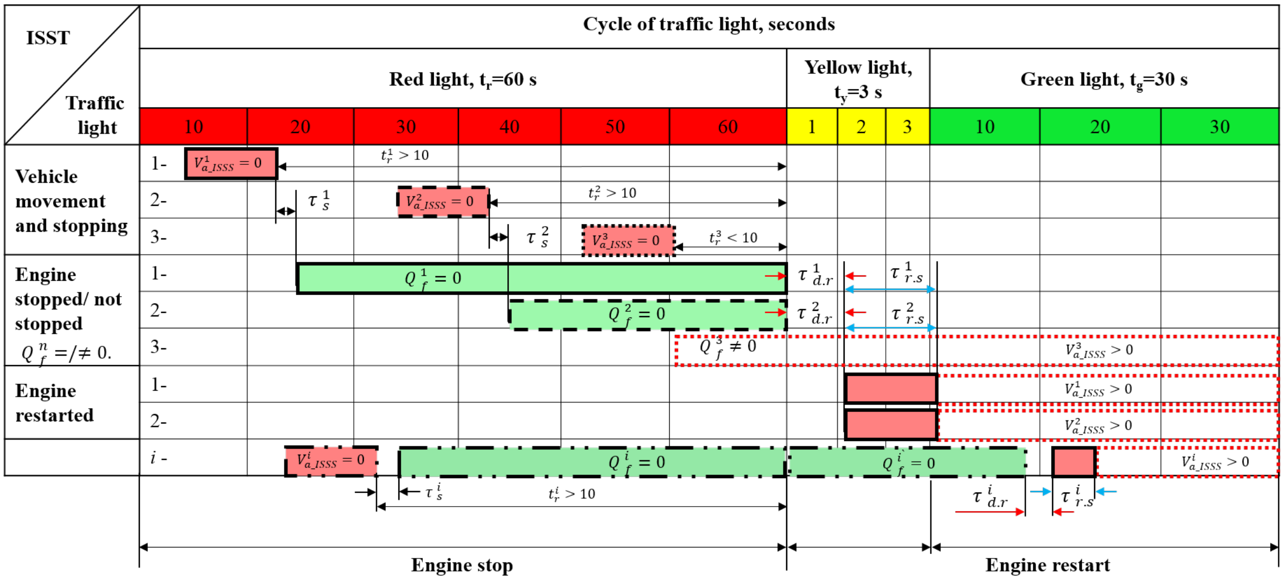
- Input X(t) parameters from the ECM (Engine Control Module);
- Input U(t) parameters from the TCM (Transmission Control Module);
- Input W(t) parameters from the BCM (Body Control Module);
- Input Z(t) parameters from the infrastructure elements to the system.
- Output Y(t) parameters from the system.

When the vehicle stops at a red traffic light, the engine is set for idle. In this mode, engine shutdown by ISSS is dependent on the traffic light that is active and continuous. If the green light is active, according to the system requirements the engine does not shut down. If the red light is active and its duration is more than $t_r > 10$ seconds, the system will shut down the engine when other input parameters are ok. The data required by the system program to shut down the engine is analyzed within 2 to 3 seconds. If $t_r < 10$ seconds, the system will not shut down the engine. In this prosess traffic lights should equipped with microcontrollers so that the vehicle can receive the necessary information from the traffic lights. The microcontroller in one traffic light acts as a “server”, the second traffic light and the microcontroller which is in the vehicle ISSS act as a “client”. In the traffic light area, vehicles can receive traffic light signals time continuously each second. Analyzes have shown that in such cases, it is effective to shut down the engine for at least 10 seconds before the vehicle moves in order to use the system.

All parameters included in the model from the vehicle’s ECM, TCM and BCM were taken as the $X(t)$ set of the vehicle’s construction. The parameters of the set $X(t)$ were determined during the experiment and their correlation values were calculated. As the function of ISSS depends on many parameters, strong connections have been taken. The boundary values of these parameters were determined using measurements (Figure 3).

As with auxiliary systems in modern vehicles, the driver can use the on-off function of ISSS. If the system is active and the engine is switched off at the red light of traffic light, in case of emergency (an ambulance, fire and other special vehicles) during the red light unchanged state the driver switches off the ISSS with the button and restarts the engine and can drive a vehicle.

We considered that expedient to use the method of measuring fuel consumption by volume during the testing process.



$$y_1 = f(X(t), Z(t), \tau(t))$$
$$X(t) = f(x_1, x_2, x_3, x_4)$$
$$Z(t) = f(z_1, z_2)$$
$$\tau(t) = f(\tau_s)$$

$$y_2 = f(X(t), Z(t), \tau(t))$$
$$X(t) = f(x_4, x_5)$$
$$Z(t) = f(z_3, z_4)$$
$$\tau(t) = f(\tau_{d.r}, \tau_{r.s})$$

Fig. 3: Gantt model of "Intelligent start-stop system"

Depending on the design capabilities of the test vehicle, fuel consumption is taken from the sensor readings on the tank. Currently, various indicators of fuel consumption are based on vehicle dynamics and are displayed on the on-board computer. It is defined as a standard [26].

where:

x_1 – engine temperature, $^{\circ}C$;
x_2 –charge level of the battery, % or (V);
x_3 – vehicle speed, km/h;
x_4 – position of the throttle valve,% or (V);
x_5 – position of clutch pedal;
z_1 – the traffic light area parameter;
z_2 – red light timing, t_r, (s);
z_3 – yellow light timing, t_y, (s);
z_4 – green light timing, t_g, (s);
y_1 – engine stop signal;
y_2 – engine restart signal;
τ_s^n – engine stop time (s);
$\tau_{d.r}^i$ – reaction time of driver (s);
$\tau_{r.s}^n$ – engine start time (s).

On the on-board computer of the Chevrolet Nexia, the display parameters change in the following order: average fuel consumption, current fuel consumption, average speed of the vehicle, odometer mileage, outside temperature, fuel range (Figure 4).

The fuel pump of the Chevrolet Nexia is manufactured at the Uz-SaeMyung Co company. In accordance with the requirements of technical specification TSh 64-16464049-13: 2016, in accordance with paragraph 3.2.1, the sensor parameters of the fuel tank are calibrated relative to the volume of the tank and marked with reference indicators. The measurement accuracy of the sensor is 1 in 100. The sensor shows the residual fuel in the fuel tank (l), the sensor voltage (V), the fuel reserve in the tank (%) and the resistance of the sensor resistor (Om).

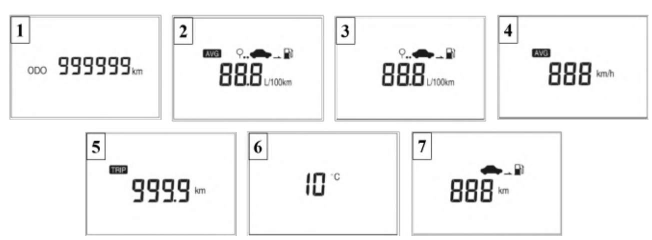


Fig. 4: On-board computer system of Chevrolet Nexia

According to the Situational Center of the Tashkent City Traffic Police, more than 900 000 vehicles are moving on the streets of Tashkent city every day. Based on this, the city of Tashkent was specified as the test object. For the test requirement, it is necessary to select the direction including

45-50 traffic lights at a distance of 25-30 km. Based on this requirement, the inner central streets of the small ring road of the city of Tashkent were selected (Figure 5).

According to the test method, the results obtained from the electronic control unit (ECU) of the engine are analyzed through the Scanmatic diagnostic device during the testing of the vehicle. Because all sensors of the vehicle are improved. This device receives data from more than 90 sensors of the vehicle using the onboard diagnostic system which is recorded on a computer using the software of Scanmatik.

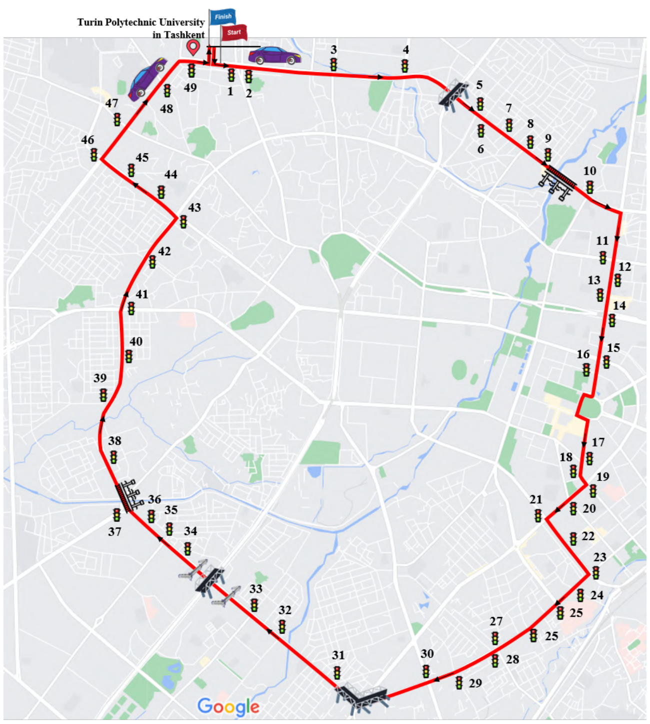


Fig. 5: Geo-map of the test direction in the Tashkent city

III RESULTS AND DISCUSSION

The dynamic variability of vehicle movement in an urban drive cycle depends on a several of factors. These factors are characterized by the width of the roads, the proximity of the distances between intersections, number of vehicle, the loss of a lot of time at traffic lights, traffic jams, and so on. As a result, fuel consumption increases [27].

The idling mode of the vehicle on the driving modes of the city of Tashkent was analysed separately in the experiment.

If the instantaneous speed of vehicle is $V_{a_i} = 0$ it is assumed to be in idle mode or stop mode [28].

$$V_{a_i} = V_c^n = 0 \tag{1}$$

where: n – number of idle mode or stop mode.

In theory, it is possible to save fuel in idle mode. That is, if

$$V_a = 0; \quad \omega_e = \omega_{i.m} > 0; \quad S = 0; \quad t > 0 \quad \text{is} \quad Q_f = 0 \tag{2}$$

The engine fuel consumption per hour in idle mode is usually determined experimentally with special equipment. The fuel consumption measurement was used DFL 3X-5 device in the trial department of the Engineering Products Department of UzAuto Motors JSC (Figure 6).

The measuring device is connected to the fuel supply system to determining the engine fuel consumption per hour in idle mode. To make the measurement process more accurate, the experiment was performed 3 times and the arithmetical average of the detected values was calculated.

The engine capacity of the Chevrolet Nexia was 1,5-liter, and the engine fuel consumption per hour in idle mode was $\Delta Q_{i.mh} = 0,7782$ (L/h) [29].

One of the considerations when using the method for determining fuel consumption by volume is the degree of accuracy of the sensor in the fuel tank. This aspect determines how much fuel is saved when ISSS has been used. The engine fuel consumption per hour in idle mode was determined using the Scanmatic device and $\Delta Q_{f.s.i\_i.mh} = 0,817$ (L/h).

So, the ratio of the values obtained from the fuel sensor through the Scanmatic device to the value determined on the DFL 3X-5 device was calculated as follows with its error rate $\Delta f.s.$

$$\Delta f.s = \frac{\Delta Q_{f.d.i} - \Delta Q_{f.s.i}}{\Delta Q_{f.d.i}} * 100\% \tag{3}$$

$$\Delta f.s = \frac{0,817 - 0,7782}{0,7782} * 100\% = 5\%$$

where:

$\Delta Q_{f.d.i}$ – DFL 3X-5 device indicators in fuel consumption per hour in idle mode in, (l/h);

$\Delta Q_{f.s.i}$ – Scanmatik device indicators in fuel consumption per hour in idle mode in, (l/h).

This analysis showed that, based on the fuel sensor indicators recommended above, its error rate was experimentally determined to be $\Delta f.s$=5%.

The movement of a vehicle which has been used and has been not used ISSS was analyzed on the city driving mode in Tashkent. The city driving mode of the vehicle was carried out during the morning, noon and evening at peak times of the day. During these times, the vehicle was determined at random stopping times at a red light of traffic lights in the specified direction (Figure 7).

These values were randomly determined in the example of the city of Tashkent in the framework of a cycle of variability

$t_r = 25 \div 90$ seconds at the standard minimum and maximum illumination period (tact) of the red light of traffic lights.

The most common infrastructure element in the city's road network is a traffic light. The operation of the ISSS in conjunction with the traffic light is required to determine the order parameter based on the principles of synergetics. The following filtering was performed on the detected main sets based on the ISSS efficiency when the red light off time is more than 10 seconds ($t_{r>10}$):

$$t_{r>10} = \sum_{i=1}^{m} t_{r.n} - \sum_{i=1}^{m} t_{r<10.n} \tag{4}$$

where: $t_{r.n}$ – the total number of stop times at red lights, (pcs); $t_{r<10.n}$ – the total number of stopping times at red lights of traffic lights less than 10 seconds, (pcs); m – number of experiments, (pcs).

In synergetics, it is important the speed of processes. Synergetics adapts existing technologies based on local conditions through ITS to solve problems of transport systems. In any multicomponent system are controlled by qualitative changes as called the order parameter. In the formation of the order parameter, the system is characterized by the presence of an open, dynamic imbalance and a nonlinear connection between the parts.

The order parameter is a slow variable that is related to the length, width, signs, and other infrastructure elements of the road. The flexibility parameter is a fast variable that includes vehicle speed, movement flow and other dynamic objects.

The flexibility parameter is characterized group of fast changing parameters in synergetics. This ensures interoperability between the existing intelligent systems in the vehicle and the elements of the infrastructure.

At a certain value of the order parameter, the movement of vehicles on existing roads is subject to the specified direction, speed and similar control parameters. It is variable in the range between 0 and 1 (0< k< 1).

So, we define the order parameter k as follows:

$$k = 1 - \frac{\sum_{i=1}^{m} t_{r>10}}{m \cdot N} \tag{5}$$

where:

$t_{r>10}$ – the total number of stopping times at red lights of traffic lights more than 10 seconds, (pcs); N – the number of traffic lights in the experiment, (pcs).

Using Equation (5), we determine k in the example of the Tashkent city driving mode:

$$k = 1 - \frac{236-32}{6 \cdot 49} = 1 - 0.69 = 0.31$$

This defined k represents the value of the order parameter is depending on the traffic light as an element of infrastructure. Its value approaching 0 means that the traffic light corresponds a lot to the red light. If it is close to 1, it is explained by the fact that the traffic light corresponds to the green light.

The function of the ISSS depends on the microcontroller installed on the traffic light. During an experiment in an urban condition, stopping and restarting the engine when the vehicle stopped at a red traffic light was imitated by the driver.

The calculation of fuel consumption for the test Q_{f_ISSS} is shown in the following equation:

$$Q_{f\_ISSS} = FC_{base} - FC_{ISSS}, \quad (L/km) \tag{6}$$

$$FC_{base} = \frac{\sum_{i=1}^{n} fc_{base}^{n}}{n}, \quad (L/km) \tag{7}$$

$$FC_{ISSS} = \frac{\sum_{i=1}^{n} fc_{isss}^{n}}{n} \quad (L/km) \tag{8}$$

where:

FC_{base} – fuel consumption of vehicle in, (L/km);

FC_{ISSS} – fuel consumption of vehicle with ISSS in, (L/km);

n – number of experiment.

Given the error-index of the fuel sensor calculated above, Equation (6) has the following changes:

$$Q_{f\_ISSS} = (FC_{base} - FC_{base} * \Delta) - \\ -(FC_{ISSS} - FC_{ISSS} * \Delta), \quad \text{(L/km)} \tag{9}$$

In the conditions specified in the driving mode, the fuel consumption at each restart of the ISSS engine after shutting it down is taken into account. This is found using Equation (10).

$$Q_{fuel\_cumulative} = \\ = Q_{f\_ISST} - Q_{\frac{fuel}{restart}} * N_{\frac{fuel}{restart}}, \quad \text{(L/km)} \tag{10}$$

where:

$Q_{\frac{fuel}{restart}}$ - fuel consumption at engine restart in, (g/s);

$N_{\frac{fuel}{restart}}$ – number of engine restarts.

During the test, the parameters from the sensor in the fuel tank do not allow to determine how much fuel is consumed during engine restart. To do this, the recommended fuel consumption Q_f in L/s can be calculated as follows [30].

$$Q_f = \frac{M_e * n_e * Q_{TS}}{3,6 * 10^9 * \rho_{gas}}, \quad (L/s) \tag{11}$$

where:

M_e – torque of the engine in, $(N * m)$;

n_e – number of revolutions of the engine crankshaft in, (rpm);

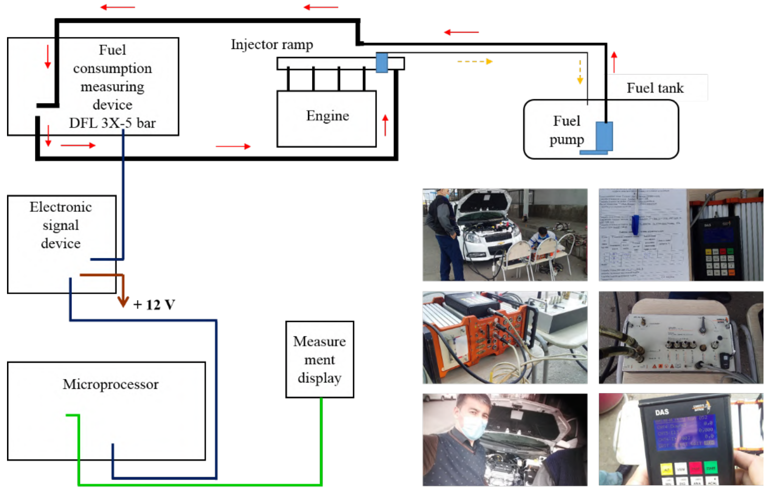


Fig. 6: Schematic and process for determining fuel consumption per hour while idling the Chevrolet Nexia engine using the DFL 3X-5

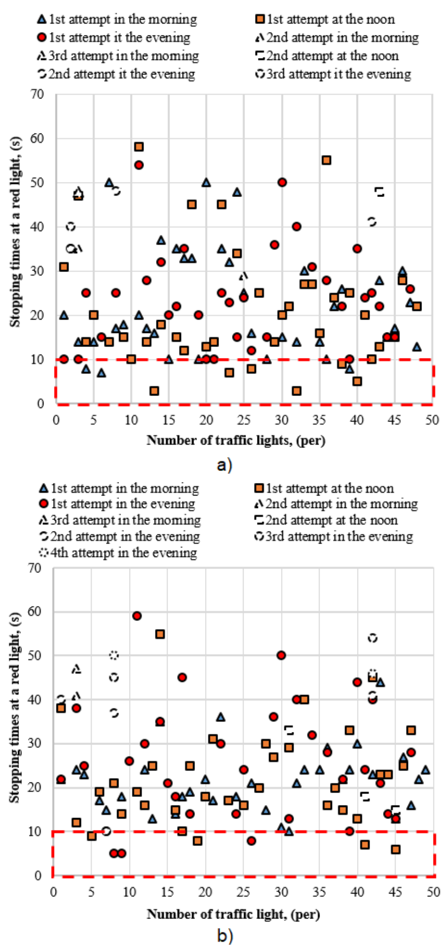


Fig. 7: a) Without ISSS, b) With ISSS. Graph of random stopping times of vehicle at a red light of traffic lights

ρ_{gas} – is the density of gasoline, whose value is 0,725 L/kg at the temperature of 20°C ;

Q_{TS} – fuel consumption rate in technic specification of vehicle in, $(l/100km)$.

The engine power, torque and fuel economy are determined by what vehicle it is installed on. The fuel consumption rate of the engine can be regarded as a function of engine torque and engine speed if the engine dynamics are neglected. Then, the fuel consumption rate can be expressed as follows [30].

$$Q_{TS} = f_e(M_e, n_e), \tag{12}$$

Such a connection can be constructed by theoretically calculating the external speed characteristic graph of the engine and conducting a practical experiment (Figure 8).

Considering M_e and n_e, determined by both methods, the fuel consumption according to equation (11) is calculated in L/s. For example:

Theoretically

$$Q_{(f.T\_800)} = 0,00035(L/s), Q_{(f.T\_1200)} = 0,00056(L/s)$$

Experimentally

$$Q_{(f.e\_800)} = 0,00025(L/s), Q_{(f.e\_1200)} = 0,0004(L/s)$$

In the experiment, the polynomial equations of fuel consumed in a vehicle which has been used and has been not used ISSS can be determined using the Lagrange interpolation formula.

$$L_n(x) = \sum_{i=1}^{m} y_i l_i(x); \tag{13}$$

where: $l_i(x)$ – m level basic polynomials.

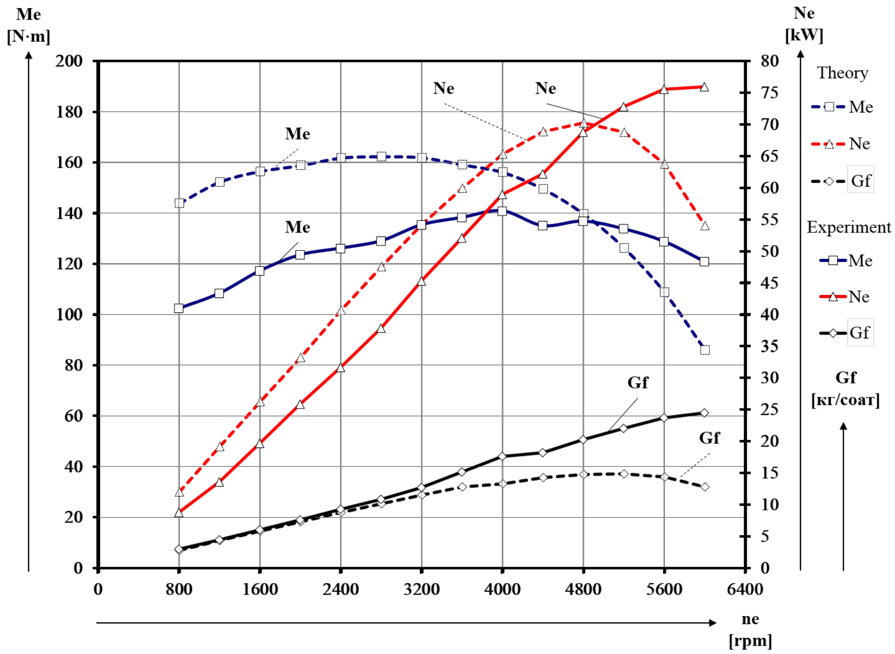


Fig. 8: The external speed characteristic graph of the engine (Chevrolet Nexia B15D2)

$$l_i(x) = \frac{(x-x_0)\ldots(x-x_{i-1})(x-x_{i+1})\ldots(x-x_n)}{(x_i-x_0)\ldots(x_i-x_{i-1})(x_i-x_{i+1})\ldots(x_i-x_n)}; \quad (14)$$

Depending on the number of points given the fuel consumption values, i.e. m=3, the above Lagrangian interpolation formula can be written as:

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

$$+y_2\frac{(x-x_0)(x-x_1)}{(x_2-x_0)(x_2-x_1)}; \quad (15)$$

The following is known for a situation where ISSS has been not used:

$$x_0 = 37,1; \quad x_1 = 35; \quad x_2 = 33.$$

$$y_0 = 35; \quad y_1 = 33; \quad y_2 = 30,8.$$

$$L_f(x) = 35\frac{(x-35)(x-33)}{(37,1-35)(37,1-33)} +$$

$$+33\frac{(x-37,1)(x-33)}{(35-37,1)(35-33)} + 30.8\frac{(x-37,1)(x-35)}{(33-37,1)(33-35)}.$$

$$L_f(x) = 0,04x^2 - 1098,02x + 47,08.$$

The following is known for a situation where ISSS has been used:

$$x_0 = 30; \quad x_1 = 28; \quad x_2 = 26.$$

$$y_0 = 28,1; \quad y_1 = 26,2; \quad y_2 = 24.$$

$$L_{ISSS\_f}(x) = 35\frac{(x-28)(x-26)}{(30-28)(30-26)} + 33\frac{(x-30)(x-26)}{(28-30)(28-26)} +$$

$$+30.8\frac{(x-30)(x-28)}{(26-30)(26-28)}.$$

$$L_{ISSS\_f}(x) = 0,63x^2 - 790,05x + 388,72.$$

In cases where ISSS has been used and not used, the vehicle's fuel consumption has been shown to significantly reduce fuel consumption using ISSS by comparing the residual fuel values at the start and end of the test in the tank (Figure 9).

In both cases, the polynomial equations determined from the Lagrange interpolation formula represent the spatial appearance of the fuel consumed during the experiment on the X, Y, and Z axes.

The calculated values were compared with the controlled fuel consumption per 100 km given in the linear norm according to the technical characteristics of the vehicle. It also showed that the fuel consumption in a vehicle with ISSS was

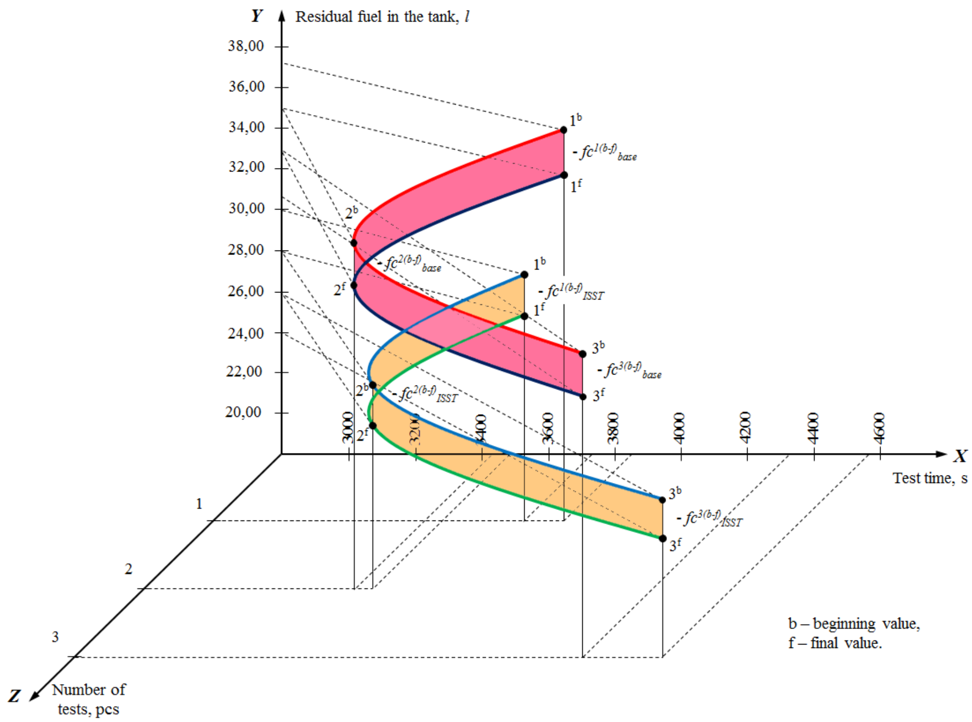


Fig. 9: Graph of residual fuel in the tank during the test, depending on the test procedure and time

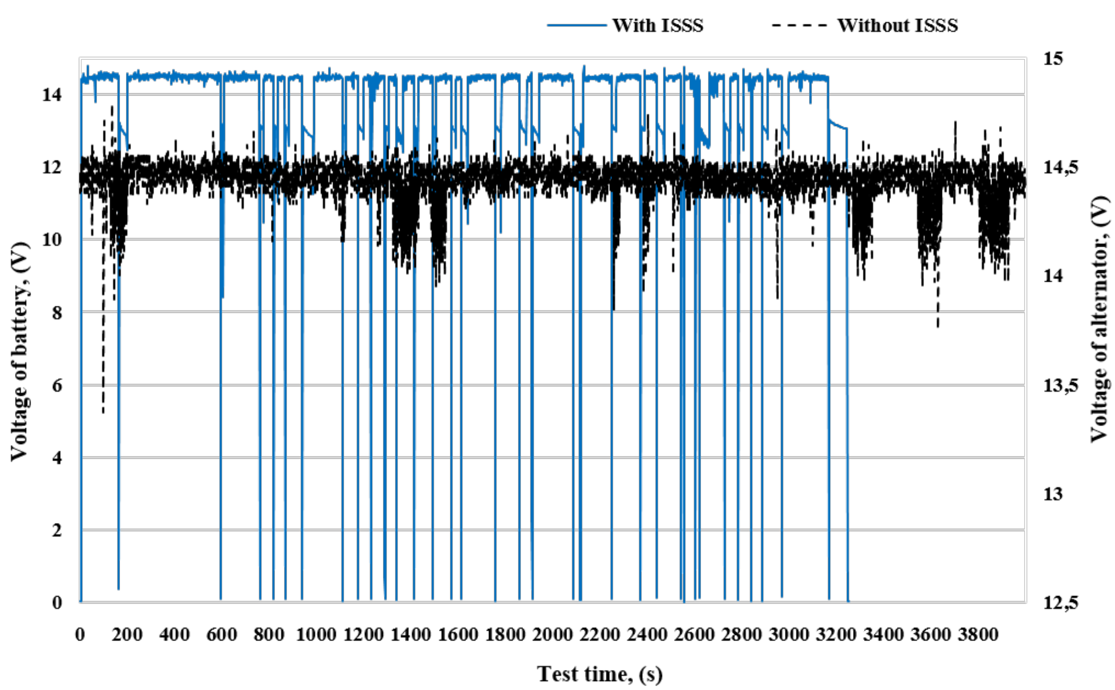


Fig. 10: Status of the vehicle power supply system in urban driving modes

saved as a percentage (%) or in liters (l) of the calculated values.

Voltage values from the power supply system of the Chevrolet Nexia were measured in the driving modes of Tashkent (Figure 10). These values indicated the ability of the existing parts in the vehicle to work in ISSS. The results were analyzed using practical-analytical methods to ensure compliance with the values specified in the technical description of vehicle parts.

The fuel consumption of the ISSS vehicle was calculated in L/km and the results are given in Figure 11.

Vehicle model	According to technical description, *L / 100 km*	Fuel consumption according to experiment in, L/75 km		According to the description of the experiment in, L/100 km		Difference, +/-, L/100 km		Percentage of fuel saved in, % (L/100km)
		Without ISSS	With ISSS	Without ISSS	With ISSS	Without ISSS	With ISSS	
Chevrolet Nexia	8	5,99	5,52	7,98	7,32	- 0,02	- 0,658	8,25

Fig. 11: Fuel consumption indicators of the vehicle in urban driving modes

IV CONCLUSION

When ISSS is used in the conditions of the autopolygon, the vehicle saved 7% of fuel per 100 km on the NEDC and 4.78% on the driving mode of Tashkent [31-32].

According to the above practical-analytical calculations, in urban conditions, a vehicle with ISSS saved 8.25% of fuel per 100 km. Emissions of harmful gases into the environment have also been minimized by about the same percentage. It was found that an average of 132 liters of fuel was saved when one vehicle traveled 20,000 km per year. Moreover, the idling time of the vehicle's engine was characterized by a reduction of 28 - 32% in 100 km of the total test distance.

Furthermore, many kinds of research have shown that the start-stop system saves an average of 5-10% of fuel in an urban condition and it is consistent with the values that we obtained from the experimental results.

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THE ISSUES OF DEVELOPING A UNIVERSAL ENERGY MODULE FOR COTTON CULTIVATION AREAS

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Abstract– This article gives a rationale idea for developing a universal energy module tool based on tractor TTZ for aggregation with unified harvesting machines for cotton areas.

Key words– cotton, tractor unit, universal energy module, sweeper, layout scheme, performance, pulling force, hinged system, self-propelled machines.

I Introduction

The trend towards the use of universal energy module (UEM) based on energy-saturated tractors can be aggregated with several kinds of agricultural machines and implements for cultivating and harvesting vegetables, garden, and especially for harvesting, forage, and grain crops, it is a characteristic feature of the development of modern agricultural machinery [1, 2].

The use of this technology allows for increasing productivity by 2-2,5 times, reducing the park of agricultural machines and the cost of agricultural products. Leading manufacturers of agricultural machinery, such as firms "Fendt" (Germany), "CLAAS", "Steyr" (Austria), "Rosselmash" (Russia), "Gomselmash" (Belarus) and others make various modifications of UET and self-propelled tractor chassis. Self-propelled chassis, unlike UEM, is intended for the cultivation of root crops, as well as for the transport operations also [3, 4].

"Gomselmash" the first of the manufacturers of agricultural machinery moved to block-modular construction of machines with the possibility of year-round use of the engine through the creation of a single energy tool for all means of functional machines. It complexes: KG-6 - for mowing grass and silage crops; KSN-6 - for the harvesting of sugar beet; KZR-10 for harvesting grain based on common energy means UES-250, UES-2-250 / 280 (Fig. 1.) [1,2].

The main advantage of these systems is that the basic power tool with a set of machines is in operation the whole year. However, there were disadvantages. The transport scheme is usual (tractor-trailer). With the traditional aggregating, in which the functional block modules can be connected only to the energy tool. Using suspension parts of modules with old arrangement types is not possible.

Fig. 1: Universal energy module UES 290 - Palesse 450 by Gomselmash, Belarus.

It saves the traditional harvesting scheme but requires additional transportation operations. The alternative of further development of modular machine configuration, consequently, can be obtaining a significant economic effect.

Started technical expertise of semi-self-propelled chassis for agricultural and other machinery, which applied the traditional hinging to the main frame chassis with a bearing assembly located in the rear axle, leading semi-axes of the tractor used for the main frame bearing.

Semi-self-propelled chassis consists of a basic, single-axis frame of the tractor, and acceding to the side frame having a drive wheel rotating on the drive wheel of the tractor.

The tractor, hinged to the main frame of semi-self-propelled chassis forms a tractor transport vehicle (TTV). The longitudinal and lateral stability of this type of hinging allows installation on the main frame of various functional modules. This may be the body for various purposes, including tanks, machinery, and assembly. For example: self-dumping body, fertilizer spreader, forage distributor, loader, tipper, etc.

TTV has become the main base transport module for the installation and integration of all of the above and other functional modules.This is the main difference from the TTV modular units, in which a basic unit is a power tool.

In this case, as a power tool, TTM can be operated throughout the year. For example, in the configuration with the body, it performs all year round on-farm transportation, significantly increasing the share of tractor transport without using special trailers.

It is well known that in the Republic of Uzbekistan the agricultural sector accounts for a large part of the state economy - in 2014 the country's 3,6 million hectares of cultivated land. The dominant crop is cotton, which is grown on 1,765 thousand hectares (gross collection of raw cotton in 2015 amounted to more than 3,4 million tons), followed by wheat on 441 thousand hectares (8,05 million tons), potato – on 80,3 thousand hectares (2,45 million tons), 191,3 thousand hectares of vegetables (more than 9,2 million tons), fruit, melons, grapes and others [1, 4].

These, as well as livestock meat dairy, produce more than 80 thousand farms with irrigated and non-irrigated land area in the range of 40 ... 500 hectares, except some multi agricultural unions at large industrial plants, having an area of thousands of hectares or more.

The level of mechanization of cultivation and harvesting of grain and forage crops is quite high, it uses various domestic (sowing and cultivation) and imported (harvesting of grain and fodder in part) agricultural machines.

The cotton industry is the top priority, while at the same time, in the most labor-intensive sectors of agricultural production, part of the operation, including the most time-consuming - harvesting is still not fully mechanized. It is mainly used by domestic appliances, of mounted cotton series tractors TTZ, classes of pulling 0,9 and 1,4 kN, which are at the stage of modernization due to several claims of consumers on the quality of workmanship and reliability [7]. The same tractor is aggregated with trailed and mounted harvesting machines, while often overloading power.

The structure of a typical farm, by type of crop, contains 40-50% cotton and 30-40% of cereals, mainly wheat, and the remaining parts are forage (Lucerne, corn), vegetables and melons. The area of stockbreeder is reserved mainly for fodder crops. This implies that farmers need to harvest harvesters or processors 4-6 species with an annual loading of 10-15 days (except for a harvest of Lucerne - in Uzbekistan with proper care can be a year makes mowing 5-6).

The analysis shows that the maximum available or rather put it within a month, the number of technical feasibility the updates MTA does not exceed 3 times. This explains the significant difference between the concepts of universality and mounted power tools.

Universality - a potential capacity of power tools used for various purposes. Aggregating capabilities means – the property of easily and quickly combined with a set of technological machines, transformed into a mobile unit capable of performing a wide range of agricultural, road-building, municipal, and other works.

If the power tool evenly loads, for at least 11 months of the year, it is permissible under heavy use; the annual load can reach 3 thousand and more motor hours. This would reduce the energy park by 4 ... 5 times, increase the return on assets by 2 ... 3 times, and make attractive repairs and services.

In the above conditions is obvious expediency of development and application of UEM to develop him loop replacement of machines and tools from the front linkage for the harvesting of cotton crops and residues, as well as feed, grain and other crops. Development and implementation will allow reducing the resistivity in the agricultural sector the number of highly specialized single-purpose self-propelled combine harvesters and agricultural machines, repair machines deficit during harvesting grain, forage and corn, cotton yield and its residues (stalks and patchwork).

The use of new systems of machines based on the UEM is relevant to the low solvency of the producers of agricultural goods when one farming industry for the timely implementation of all mechanized operations under limited agronomic conditions difficult to fully equip its park with highly specialized equipment required because of its high overall cost. At the same time, the cost of new machines based on UEM will be significantly lower than the total cost of replacement and highly specialized single-purpose machines, and using it in the machine and tractor parks will be particularly effective.

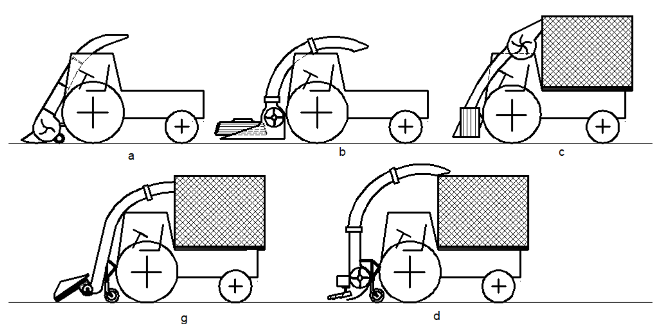

Fig. 2: The proposed layout diagrams harvesters based TTZ UEM: a - arrangement with a rotary mower-shredder, b - layout with forage machine; c - unit layout with the cotton; g - arrangement with strippers unit; d - layout with stubbing-chopper of cotton stalks.

For the first stage offered the following proposed layout diagrams (Fig. 2.) are harvesting blocks of green fodder and cotton harvest, mounted with a UEM based on a modernized, using advanced innovative technical solutions, TTZ tractor [3, 4].

II CONCLUSION

The priorities here, in our opinion, are to develop a feasibility study for the creation of UEM taking into account peculiarities of the market agricultural technology in the country, established the structure and prospects of development of farms by type of production, the size of cultivated areas and others factors (Fig. 3.).

Fig. 3: The perspective priorities of using UEM in Agriculture in Uzbekistan.

Research and development in the cotton UEM are desirable to maintain, together with the modernization of the tractor TTZ process involving joint ventures of the leading international companies in the production of agricultural and automotive vehicles operating in Uzbekistan.

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A DEVICE FOR ELECTRICITY GENERATION USING ALTERNATIVE RENEWABLE ENERGY SOURCES

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Abstract– This study is devoted to developing a new method of electricity generation using an alternative source of renewable energy. It is obvious that day and night temperatures are different. This difference forces matter to expand and contract periodically. The forces arising from the everyday thermal expansion and contraction of solid and liquid materials can be considered such a source. Based on this phenomenon, the possibilities of creating an electricity-generating device are discussed hereon. Theoretically, it is possible to design a machine using solely solids or liquids, but this requires materials and high-volume vessels that can sustain extremely high pressures and mechanical loads and the accuracy of the details should be very high, which would lead to exorbitant costs. A combined model allowing a reduction in costs is discussed in this work. The constructional dimensions and the principle of functioning of a prototype that can produce 100 kWh are presented. The techniques explored to develop more powerful machines using this novel method are attractive in light of renewable sources of energy.

Key words– Electricity generation; power; pressured vessels; thermal contraction; thermal expansion; renewable energy.

I Introduction

Human development depends on energy consumption. A major part of consuming energy is produced using natural fuel today. On the one hand, we are depleting natural resources, while on the other, we are devastating the ecology. The estimated share of renewable energy in global electricity production was 26.2% at the end of 2018 according to a report [1]. Existing renewable sources cannot be used everywhere and at all times due to the limitations of their origin and the principles on which their devices operate. Thus, a quest for new renewable sources of energy is encouraged. The scientists and professionals of the world have spectacular achievements in this respect. The young generation of our department is in the nascent stage of its development: the parameters of a solar panel have been estimated [2, 3], the types of solar panels have been studied [4], the perspective of using solar energy has been discussed [5] and the optimal method of controlling hydroelectric power plants has been considered [6]. The present research is devoted to developing a new method to produce electricity using an alternative source of renewable energy. The preliminary considerations and related work are discussed in our previous works [7, 8]. The method of producing electrical energy from thermal expansion and contraction of the matter was patented in 2018 [9].

Huge forces can arise from the thermal expansion and contraction of liquid and solid matter: liquids can rupture or deform containers or vessels and solids can destroy bridges, buildings or rails if adequate preventive measures have not been implemented with foresight. Finding ways to use these enormous forces to produce useful energy is the aim of our investigation. When discussing thermal expansion, liquids show good promise. To begin with, the thermal expansion coefficients of liquids are dozens of times greater than those of solids. Moreover, volume expansion can be used in liquids, while it is difficult to do so in the case of solids. The work performed by liquid thermal expansion is expressed as follows:

$$W = P\Delta V \tag{1}$$

where P is the pressure in the hermetically sealed reservoir and ΔV is the extra volume of the liquid arising from thermal expansion. Note that the thermal expansion of the vessel should also be taken into account. This will decrease the extruded volume, though insignificantly (Figure 1).

As it is clear from Figure 1, the liquid will move the piston due to the excess volume from thermal expansion and, in turn, the piston performs some work in moving the load. Theoretically, any amount of work can be obtained by changing the mass of the load if we have a large enough initial volume of the liquid and a change in temperature.

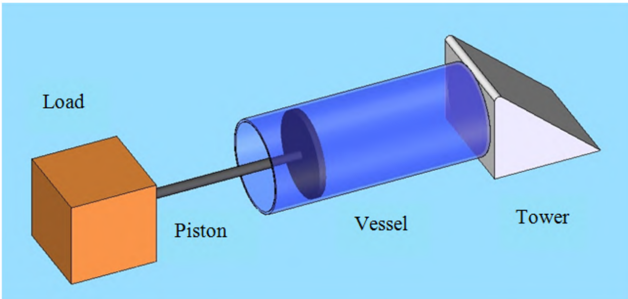

Fig. 1: The work is performed by the volume expansion of the liquid.

Note that the vessel should be able to sustain enough high pressure. Power can be defined as the work performed in time as follows:

$$Power = Work/Time \tag{2}$$

In the case of solids, as was mentioned above, linear expansion can be used solely to produce the energy. A long metal rod, one end of which is fixed and motionless, will elongate with the rise in temperature and drive the load (Figure 2). The work performed by the thermal expansion of a steel rod can be expressed as follows:

$$W = F\Delta l \tag{3}$$

where F is the force due to the linear expansion of the steel rod and Δl is the displacement of the load. In this case as well, we can obtain any amount of work by changing the mass of the load.

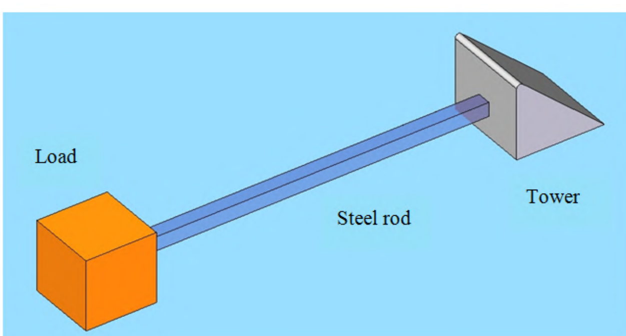

Fig. 2: The work is performed by the linear expansion of solids.

II THE METHODOLOGY

a. Use of liquid expansion

If we design the devices to generate electrical energy of 10, 100 and 1000 kWh using the thermal expansion of liquid (Figure 1), they should perform work of $3.6 \cdot 10^7, 3.6 \cdot 10^8$ and $3.6 \cdot 10^9 J/h$, respectively. Let the losses not be taken into account for the first approach and let us suppose that the work obtained according to Equation (1) is wholly transformed into useful energy. The excess volume ΔV can be computed as follows [10]:

$$\Delta V = V_0 \beta \Delta T \tag{4}$$

where V_0 is the initial volume of the liquid, β is the coefficient of volume expansion and ΔT is the change in temperature. Now, Equation (1) can be written as follows:

$$W = PV_0 \beta \Delta T \tag{5}$$

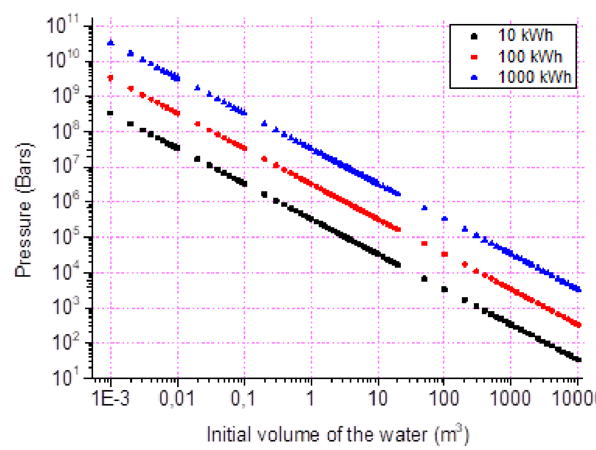

Fig. 3: Relations between the pressure and the initial volume of the liquid for devices of 10, 100 and 1000 kWh.

Figure 3 shows the relationship between the pressure and the initial volume of the liquid in the cylinder for the devices of 10, 100 and 1000 kWh power. The pressure is calculated using Equation (5) for the initial volume of the working liquid from 10^{-3} to 10^4 m^3. Pure water is chosen as the working liquid, the volume expansion coefficient of which is $\beta = 2.14 \cdot 10^{-4\circ} C^{-1}$ [11]. The temperature change, ΔT, is $50^\circ C$. Note the following assumption: the temperature changes linearly in 10 hours; the work is also calculated in 10 hours. As is seen from the figure, the device for 10 kWh with a volume 10^{-3} m^3 of water requires the pressure to be held by the vessel to be almost $3.365 \cdot 10^8$ bar $(3.365 \cdot 10^{13} Pa)$. The pressure decreases with an increase in the initial volume of water. If the initial volume increases up to 100 m3, the pressure is about $3.365 \cdot 10^3$ bar $(3.365 \cdot 10^8 Pa)$. In the case of the devices for 100 and 1000 kWh for the same initial volume of water, the pressures are 10 and 100 times more, respectively. Setting up vessels with such volume to hold the stated pressures is not feasible while considering the recovery of costs. Moreover, it was experimentally determined in our previous work that liquid works well in expansion, but its performance is less than desirable in the contraction process owing to the weak attractive forces between atoms [8].

b. Use of solid expansion

The work done is expressed by Equation (3). With a rise in the temperature of the steel rod, the force acting on the load begins to increase (Figure 2). When it reaches a certain value called the breakaway force [12], the load starts to move. The speed of the load is very less and it depends on the rate of temperature change. The character of this driving force is that it can provide enough large value depending on the mass of the load. In other words, one can choose any value of the force by changing the mass of the load. Although the distance Δl is very small, the force F can reach high enough values and we can obtain any amount of work desired. The linear expansion of solid material, Δl, is defined as follows [10]:

$$\Delta l = \alpha L_0 \Delta T \tag{6}$$

where $\alpha = 12 \cdot 10^{-6 \circ} C^{-1}$ is the linear expansion coefficient of steel, L_0 is the initial length of the steel rod and ΔT is the change in temperature. Now, Equation (3) can be written as follows:

$$W = F \alpha L_0 \Delta T \tag{7}$$

A steel rod with an initial length of 50 meters expands 0.03 meters when the change in temperature, ΔT, is $50^{\circ}C$ according to Equation (6). The compressive yield strength of steel is 152 MPa $(152 \cdot 10^6 Pa)$ [13]. If we take into account that it is defined as [14] $\sigma = Load/Area\ (kg/mm^2)$, it can be found that the force acting on the 1 mm^2 area corresponding to the compressive yield strength of steel is $F = 152kg = 1.491 \cdot 10^3$N. Considering that the forces due to thermal expansion will act on an area much larger than 1 mm^2, the expected compressive strength will certainly be appreciably smaller than the compressive yield strength of steel. In other words, the steel rod will not be bent or deformed by the expansion force in our case. The main problem is how to accelerate the slow motion of the end of the steel rod by thermal expansion: the load will shift 0.03 meters in 10 hours. The device that can solve this problem is suggested in this work.

III RESULTS AND DISCUSSION

The computer-aided design (CAD) of the device presented in Figure 4 consists of towers (1), a steel rod (2), lever system (3), piston (4) for shifting high pressured liquid, high-pressured vessel (5) filled with working liquid, two-side piston (6), low-pressure vessel (7), also filled with the working liquid, transducer (8), gear train (9), generator (10), free-moving piston (11) and reservoir for working liquid (12). In principle, the device can be designed for any amount of power. Here, we decided to design the device for 100 kWh. It can be cost-effective in supporting the electricity needs of small farms and plants as well as populations in remote places, providing electricity to distant locations related to valuable power lines and heavy losses.

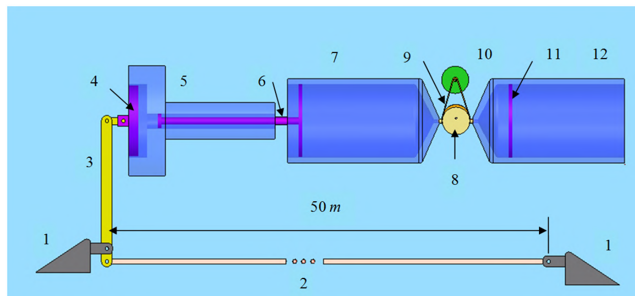

Fig. 4: CAD of the device. 1 – towers, 2 – steel rod, 3 – first-class lever system, 4 – high-pressure piston, 5 – high–pressuredvessel, 6 – two-side piston, 7 – low-pressure cylinder, 8 – transducer, 9 – gear train, 10 – generator, 11 – free-moving piston, and 12 – reservoir.

The dimensions of the device are calculated in the following way. As assumed, the temperature of the steel rod (2) changes by $50^{\circ}C$ and the free end of the steel rod (2) moves 0.03 m in 10 hours. Due to the first-class lever system, the distance increases by 10 times and the piston (4) moves 0.3 m. The work performed in the high-pressured vessel (5) can be expressed as follows:

$$W = P_1 V_1 \tag{8}$$

where P_1 is the pressure of the working liquid created in the pressured vessel (5) by moving the piston (4) and V_1 is the volume of the working liquid extruded from the vessel through its output. These parameters can be utilized for a generator of any power by changing the dimensions of the pressured vessel (5). In our case, the extruded volume,$V_1 = 3.76991\ m^3$, is defined as follows:

$$V_1 = \pi (r_{1input})^2 \cdot l_{1input} \tag{9}$$

where $r_{1input} = 2.0$ m is the radius of the vessel (5) at the input and $l_{1input} = 0.3$ m is the displacement of the piston (4). The pressure, P1computed using Equation (8) for the 100 kWh generator ($W = 3.6 \cdot 10^9$ J for 10 hours) is approximately 954.93 MPa ($954.93 \cdot 10^6$ Pa). The vessel (5) and the piston (4) should be able to hold such pressure. The dependence of the pressure (for different powers) and volume of the working liquid on the input radius of the vessel (5) is presented in Figure 5. The pressure can be decreased by increasing the radius at the input but this will lead to an increase in the volume of the working liquid. For example, increasing the input radius twice decreases the pressure four times and increases the volume of the working liquid four times.

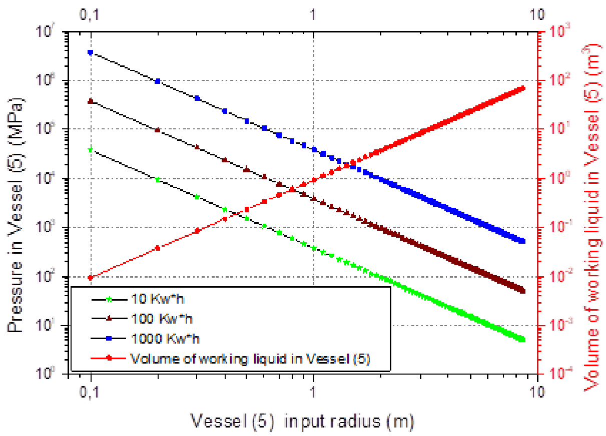

Fig. 5: Dependence of the pressure (for different powers) and volume of the working liquid on the input radius of the vessel (5).

To calculate the diameter of the right side of the two-side piston (6), we choose the pressure P_2 in the low-pressure cylinder (7) 40 Mpa ($40 \cdot 10^6$ Pa), at which normal working conditions for the transducer (8) can be provided. Then, the volume of the working liquid in the low-pressure cylinder (7), V_2=90 m^3, is calculated as follows:

$$W = P_2 V_2 \tag{10}$$

where P_2 is the pressure in the low-pressure cylinder (7). Now, we can find the inner diameter of the cylinder (7), which is equal to the diameter of the right side of the two-side piston (6), r_2=2.023 m, using the following:

$$V_2 = \pi r_2^2 l_2 \tag{11}$$

where l_2=7 m is the chosen length of the cylinder (7). Note that the equality of the lengths of the reservoir (12) and output side of the high-pressure vessel (5) to this size makes it easier to adjust these parts of the device. Now, we can define the output radius of the high-pressure vessel (5), $r_{1output}$=0.414 m, from the following Equation:

$$V_1 = \pi (r_{1output})^2 \cdot l_2 \tag{12}$$

Usually, the temperature in the environment starts to rise early in the morning until midday, and then it ceases to rise and after a while, begins to fall. This fall in temperature will continue until midnight. The device works in the following way. The steel rod (2), one end of which is fixed and motionless at the tower (1), will provide the device with driving force. As the temperature of the environment starts to rise, the steel rod (2) starts to elongate, acting on the piston (4), which begins to move when the force reaches the breakaway value. The first-class lever system will increase the distance by 10 times and due to this, we will decrease the pressure by 10 times in the high-pressure vessel (5). Note that the mechanical resistance of the generator depends on its power. The power of our generator is 100kWh and for the first approximation, we neglect all other friction losses. Then the breakaway force is defined by the power of the generator alone. The piston (4) creates pressure in the vessel (5). The pressure will increase until the liquid starts to displace the two-side piston (6) and after that, it remains almost constant. This is the working pressure of the vessel. Due to the small outlet radius of the vessel (5) compared to the inlet one, the two-side piston (6) will move a noticeable distance and drive the liquid from the low-pressure vessel (7) to the transducer (8). The latter, acting as a positive displacement flowmeter, will transform the linear motion of the liquid into circular motion and transmit to the generator (10) through the gear train (9). The generator (10) then starts to produce electricity. The working liquid, passed through the transducer (8), pushes the free-moving piston (11) and gathers in the reservoir (12). The process will stop when the temperature of the steel rod reaches the maximum level. After 10 hours, when the temperature starts to decrease, the backward process begins: the steel rod (2) starts to shrink, pulling the piston (4) backward through the lever system (3). The piston (4) creates the vacuum in the vessel (5). The vacuum pulls the two-side piston (6). The working liquid from the reservoir (12) returns to the low-pressure vessel (7) through the transducer (8). The transducer transforms the linear motion of the liquid into circular motion and transmits to the generator (10) through the gear train (9).

The working liquid in the high-pressure vessel (5) and low-pressure cylinder (7) performs additional work by thermal expansion and provides extra power. The approximate value of the total work of the liquid for our device for 10 hours, $3.0816 \cdot 10^7$ J, is calculated as follows:

$$W_t = P_1 \cdot \Delta V_1 + P_2 \cdot \Delta V_2 \tag{13}$$

where ΔV_1 and ΔV_2 are the excess volumes of the water in the high-pressure vessel (5) and low-pressure cylinder (7) due to thermal expansion, which are defined by equations similar to Equation (4). The temperature change across 10 hours, ΔT, is assumed as $20°C$. This work is less than 1% compared to the work of the 100 kWh device. It will increase if the temperature change ΔT increases. Another way to obtain more work is to choose the working liquid with a higher thermal expansion coefficient. Such a supplementary power can help compensate for the losses and increase the efficiency of the device.

IV CONCLUSION

The possibility of generating electrical energy from the thermal expansion of liquid and solid matter is considered. Setting up the device using solely the liquid thermal expansion and contraction phenomena requires high-volume vessels that should be able to sustain very high pressures, which is expensive and difficult to realize. In the case of using the thermal expansion and contraction of only solid material, the problems will include their small coefficients of thermal expansion compared to liquids, the impossibility of using the volume expansion, and very slow displacement velocity, which is difficult to accelerate. If both liquid and solid materials are used in combination, one can find reliable and cost-effective compromise variants of the device for different magnitudes of power.

The principle of the working of the device, designed using both solid and liquid materials, is presented. The small but powerful displacement will be transformed into high pressure and this pressure is transformed into liquid flow through the transducer. The latter transforms the flow into a circular motion and transfers this to the generator, which produces the electricity.

The new type of device, which uses a renewable energy source, requires high-pressure vessels. The pressure in the vessel (5) can be reduced by increasing its diameter: if the radius r_{1input} increases twice, the pressure P_1 decreases four times. On the other hand, decreasing the pressure leads to an increased volume of the working liquid, which is related to energy losses.

As the processes of thermal expansion and contraction are very slow, transforming them into fast enough linear or circular motion requires modern and very accurate techniques. It is important to find the optimal and compromise values of multiple operating parameters, such as the length of the steel rod, the pressures in the vessel (5) and the low-pressure cylinder, the diameters of the vessels, the volume of working liquid, the flow rate, and the speed of angular velocity of the shaft of the generator in creating the new type of renewable energy source. However, such a complex task can be simplified noticeably if we develop the high-pressure and high-volume cylinders: the power of the device is in direct proportion to the pressure, which can be sustained by the system. So, by increasing the pressures in the vessel (5) and cylinder (7) by 10 times, the same device can generate 1000 kW energy per hour in our case.

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A COMPARISON OF ENGINE OIL LIFE CYCLE IN DIFFERENT VEHICLES BY USING HYDROGEN-GASOLINE AND GASOLINE FUELS.

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Abstract– In this study, three different fuels named methane and gasoline AI-92 added hydrogen was used to test in a gasoline engine [1]. First of all, experiments were carried three different kinds of engine oils named Castrol (syntetic 5W40), Mannol (mineral 10W40) and Lukoil (semisynthetic 5W40), namely unused and used oils taken from three types of motor vehicles [2]. The change in characteristics of flash temperatures, number of alkali and kinematic viscosity of test oils were analyzed [3]. A theoretical model was established with the result by ISO 2592:2000 [4], ISO 2909 – 1981 [5], and laboratory ionizer I-160-MI. The test synthetic and mineral oils were obtained from cars that travel approximately 8,000-10,000 km in 250-310 days in the typical urban traffic condition of Uzbekistan. The recommended approach can provide some reference for end-users to drain their motor oil reasonably. The article deals with comparing the life cycle of unused and used engine oil in a vehicle by using a different types of fuels. Engine oil flash temperature, the number of alkali kinematic viscosity of lubricants are considered. Influence on the physicochemical and exploitation properties. Discussed the ways of prevention. Positive and negative effects of using hydrogen, gasoline and natural gas.

Key words– lubricants, physicochemical damage, wear, alkali, deterioration, cultivation, viscosity.

I INTRODUCTION

The main functions of lubricant are reducing friction by creating a film between two friction surfaces, preventing the machine from wear, corrosion protection, cooling by dissipating heat from surfaces, sealing, cleaning by transporting contaminating particles to filters and etc. The analysis of used oil is a crucial aspect of engine maintenance. It gives information about the oil's quality, appropriateness for further use, and to some extent, the condition of the machinery lubricated by the oil. Conducting a used oil analysis serves purposes: evaluate the oil's condition and make recommendations on its suitability for continued usage and oil change interval optimization, to analyze the engine's state to detect and hence prevent difficulties that, if left neglected, could risk the engine's reliable functioning. An examination of used oil after service is beneficial in determining the useful life of a lubricant in a particular application and in providing equipment conditions [6].

First of all, the flash point, kinematic viscosity and alkali number of the used and unused engine oil will be considered. Then the influence of types of fuels and their purpose will be reviewed. Further, the outcomes from several experiments have been discussed.

II THE METHODOLOGY

To determine the flash point of the used motor oil in the open housing was used determining the flash temperature device for testing motor oil by GOST 4333 and ISO 2592 (flash point limit 79°C - 360°C). It operates on alternating single-phase current, at a voltage of 220 V, at a frequency of 50 ± 1 GH, with power consumption not exceeding 400 W [7].

1-a. The device TVO for determination of the temperature of flash in an open crucible in accordance with GOST 4333 and ISO 2592 manually. The device TVO is intended for the test of oil products for the determination of the temperature of flash in the open crucible by the state standard specification 4333 and ISO method 2592.

1-b. A sample drawn from the engine oil up to the mark set on the 11^{th} crucibles put it on the heating plate 13, immerse the thermometer position 7 in the liquid by turning 9. We will continue to monitor if we turn on our equipment. We set the pressure on the scale from 1 to 9 to the approximate flashing temperature of the engine oil, put the 4 burner handles in the desired direction, turn the burner by turning 4 handles on the crucible every $5-10°C$, turn off the device when the flash occurs, return the temperature on the thermometer.

1-c. We used methane gas in the tube while determining the flash temperature of the engine oil in the institute's laboratory. When the temperature reaches $200°C$, we move the tube over the heated oil, if a spark comes out, the work is stopped and the point is recorded as temperature [8][9].

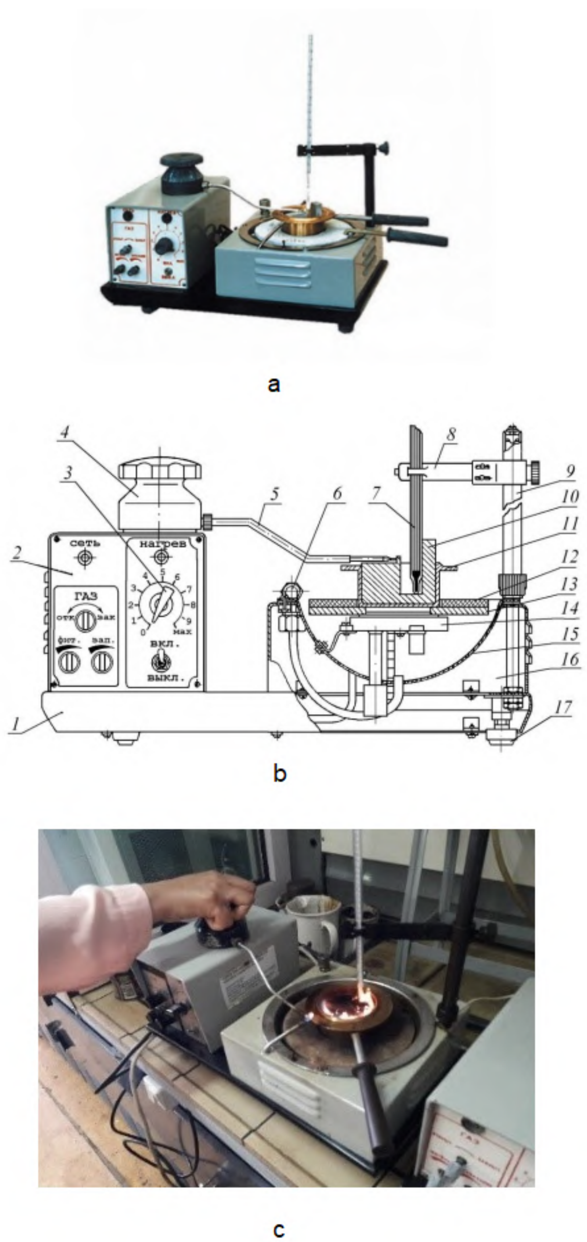

Fig. 1: The process of determining the flash temperature in the laboratory.

Used engine oil contains total alkali number (TAN) and total acid number (TAN). Generally, it is called the total base number (TBN). The number of alkalis is controlled to neutralize the acid number. The amount of sulfur in the fuel creates an acidic environment in the internal combustion engine. This leads to an increase in the wearing of details. Using I-160-MI, we can determine the alkaline number of engine oil under laboratory conditions. The I-160-MI laboratory ionizer is a device that directly and indirectly potentiometrically measures H + (pH) activity, monovalent and fission anion and cation (pH) activity, oxide potential, and temperature results in aqueous solutions. In the experiment, 1 g of engine oil was weighed on an electronic scale and mixed with HCL and placed in a centrifuge with the electrodes in place. To determine the amount of alkali, the solution (70 cm^3 Toluene-S_7N_8 (methylbenzene-$S_6N_5-SN_3$) + Alcohol C_2H_5OH) is added dropwise until the pH of the solution drops to 4. The obtained results are put into the formula and the alkali number is determined [10][11].

$$AN = \frac{c*5.61}{m}$$

where, c = HCl solution concentration; AN = number of alkali; 5.61 = equivalent amount of KOH solution; m = Motor oil mass;

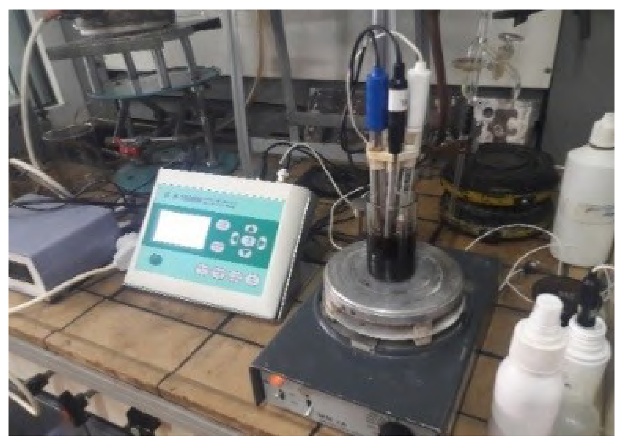

Fig. 2: The process of determining the alkaline number of engine oil.

The less the viscosity of the oil changes with the change in temperature, the better it is considered to be of good quality. Different viscosity-temperature constants characterizing the relationship of temperature with the viscosity of oils were adopted: viscosity ratio at two different temperatures, viscosity index, viscosity-weight constant, and so on. The changing nature of viscosity was adopted to determine the ratio of the kinematic viscosity at $40°C$ to the kinematic viscosity at $100°C$ with temperature change. The ratio of viscosities at two temperatures is a measure that estimates the deflection change of the viscosity curve in a given temperature range. The conditional constant that characterizes the temperature dependence of the viscosity of oils is the viscosity index (IV). Viscosity is one of the important factors characterizing the properties of liquids. The viscosity of motor oils characterizes their flexibility in operating conditions in engines, machines and mechanisms. Affects energy consumption in transmission. Kinematic viscosity can be determined experimentally or using a formula [12][13].

Fig. 3: The process of determining the viscosity of engine oil at temperatures of 40 and 100°C.

Typically, the kinematic viscosity v is found using the ratio between the dynamic viscosity of a given liquid or gas and its density.

$$v = \frac{\mu}{\rho}$$

where, v - kinematic viscosity; μ - dynamic viscosity, $kg/(m.sec)$; ρ - absolute density, kg/m^3;

Kinematic viscosity is measured in the SI system of units at v = $(1kg/(m.sec))/(1kg/m).1cm^2/check$, i.e., stocks (cm) serves as a unit of kinematic viscosity in the SGS unit system. One hundredth of the stocks is centi stocks (sCt). The viscosity index can be determined by the method of international standard GOST 25371-97 (ISO 2909-81), method A (viscosity indices from 0 to 100), B (viscosity index greater than 100), kinematic calculation of motor oil, using the given formula. In the laboratory, to determine the coefficient of viscosity (VI), samples of engine oil are placed on standard viscometers, and the thermostat TSJs are filled for 15-20 minutes after reaching $40°C, 100°C$. The test time is calculated at 2 times the flow time at 2S t and the average is found. The viscosity coefficient (VI) is calculated from the results in the following order [14][15].

$$V1 = \left\{ \frac{[(antilogN) - 1]}{0.00715} \right\} + 100$$

$$N = \frac{logH - logU}{logY}$$

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

$$H = 0.1684Y^2 + 11.85Y - 97$$

Method "B" is used to find the viscosity index VI of samples of Castrol 5W40, Mannol 20W50, Lukoil 5W40 Motor oils [16].

III RESULTS AND DISCUSSION

The results showed the established theoretical model has the potential to quantitatively determine the remaining service time and operation mileage of the test oils with high accuracy and reliability.

1. $AN = \frac{c*5.61}{m} = \frac{0.92*5.61}{1020} = 5.06$
2. $AN = \frac{c*5.61}{m} = \frac{0.38*5.61}{1010} = 2.15$
3. $AN = \frac{c*5.61}{m} = \frac{0.33*5.61}{1015} = 1.82$
4. $AN = \frac{c*5.61}{m} = \frac{0.2*1.24}{995} = 6.92$
5. $AN = \frac{c*5.61}{m} = \frac{0.2*5.61}{1020} = 1.1$
6. $AN = \frac{c*5.61}{m} = \frac{0.52*5.61}{1025} = 2.84$
7. $AN = \frac{c*5.61}{m} = \frac{1.07*5.61}{996} = 6.06$
8. $AN = \frac{c*5.61}{m} = \frac{0.2*5.61}{1005} = 1.1$
9. $AN = \frac{c*5.61}{m} = \frac{0.52*5.61}{1025} = 2.84$

N	Cars	Fuels	Engine oils	Flash temperatures
1	New	New	Castrol 5W40	236°C
2	Chevrolet Lacetti	Hydrogen-gasoline	Castrol 5W40	185°C
3	Chevrolet Cobalt	Natural gas	Castrol 5W40	226°C
4	New	New	Mannol 15W40	222°C
5	Isuzu	Hydrogen-gasoline	Mannol 15W40	192°C
6	Chevrolet Damas	Natural gas	Mannol 15W40	218°C
7	New	New	Lukoil 5W40	220°C
8	Chevrolet Cobalt	Hydrogen-gasoline	Lukoil 5W40	198°C
9	Chevrolet Nexia	Natural gas	Lukoil 5W40	200°C

TABLE 1: ENGINE OIL FLASH TEMPERATURE RESULTS.

N	Vehicle	Fuel types	Engine oil types	Constant number	Mass of HCl (g)	Mass of engine oil (g)	Mass of engine oil
1	New	New	Castrol 5W40	5.61	0.92	1020	5.06
2	Chevrolet Lacetti	Hydrogen-gasoline	Castrol 5W40	5.61	0.38	1010	2.15
3	Chevrolet Cobalt	Natural gas	Castrol 5W40	5.61	0.33	1015	1.82
4	New	New	Mannol 15W40	5.61	1.24	995	6.92
5	Isuzu	Hydrogen-gasoline	Mannol 15W40	5.61	0.2	1020	1.1
6	Chevrolet Damas	Natural gas	Mannol 15W40	5.61	0.52	1025	2.84
7	New	New	Lukoil 5W40	5.61	1.07	996	6.06
8	Chevrolet Cobalt	Hydrogen-gasoline	Lukoil 5W40	5.61	0.2	1005	1.1
9	Chevrolet Nexia	Natural gas	Lukoil 5W40	5.61	0.52	1025	2.84

TABLE 2: ENGINE OIL NUMBER OF ALKALI RESULTS.

Castrol 5W40 (new)						
VPSH	⌀	c	T_1	T_2	T_{med}	$V_{100°C}$
4627	0.73	0.3232	360.91	360.50	360.705	116.6
VPSH	⌀	c	T_1	T_2	T_{med}	$V_{40°C}$
361	1.47	0.2719	245.72	245.53	245.625	66.8

TABLE 3: TEST RESULTS OF CASTROL 5W40 (NEW) VISCOSITY AT $V_{100°C}$ AND $V_{40°C}$.

1 Table 3

$$U = 116.6; \quad Y = 66.8; \quad H = 705.83$$

$$H = 0.1684Y^2 + 11.85Y - 97 = 705.83$$

$$N = \frac{log705.83 - log116.6}{log66.8} = 0.4285$$

$$V1 = \left\{ \frac{[(antilog0.4285) - 1]}{0.00715} \right\} + 100 = 335$$

Castrol 5W40 (hydrogen-gasoline)						
VPSH	⊘	c	T_1	T_2	T_{med}	$V_{100^\circ C}$
4627	0.73	0.03282	444.22	444.59	444.405	14.58
VPSH	⊘	c	T_1	T_2	T_{med}	$V_{40^\circ C}$
3470	1.47	0.3090	311.91	311.53	311.62	96.29

TABLE 4: TEST RESULTS OF CASTROL 5W40 (HYDROGEN-GASOLINE) VISCOSITY AT $V_{100^\circ C}$ AND $V_{40^\circ C}$.

Castrol 5W40 (natural gas)						
VPSH	⊘	c	T_1	T_2	T_{med}	$V_{100^\circ C}$
5732	0.73	0.03517	366.38	365.91	366.145	12.88
VPSH	⊘	c	T_1	T_2	T_{med}	$V_{40^\circ C}$
2639	1.47	0.2995	257.0	255.97	256.485	76.81

TABLE 5: TEST RESULTS OF CASTROL 5W40 (CH4) VISCOSITY AT $V_{100^\circ C}$ AND $V_{40^\circ C}$.

Mannol 15W40 (new)						
VPSH	⊘	c	T_1	T_2	T_{med}	$V_{100^\circ C}$
3081	0.82	0.3168	483.25	482.53	482.89	152.97
VPSH	⊘	c	T_1	T_2	T_{med}	$V_{40^\circ C}$
3470	1.47	0.3090	361.12	360.69	360.9	111.52

TABLE 6: TEST RESULTS OF VISCOSITY OF MANNOL 20W50 ENGINE OIL AT $V_{100^\circ C}$ AND $V_{40^\circ C}$.

Mannol 15W40 (hydrogen-gasoline)						
VPSH	⊘	c	T_1	T_2	T_{med}	$V_{100^\circ C}$
5732	0.73	0.03517	403.91	404.03	403.97	14.2
VPSH	⊘	c	T_1	T_2	T_{med}	$V_{40^\circ C}$
361	1.47	0.2719	400.94	400.44	400.69	108.94

TABLE 7: TEST RESULTS OF VISCOSITY OF MANNOL 20W50 (HYDROGEN-GASOLINE) ENGINE OIL AT $V_{100^\circ C}$ AND $V_{40^\circ C}$.

Mannol 15W40 (natural gas)						
VPSH	⊘	c	T_1	T_2	T_{med}	$V_{100^\circ C}$
4627	0.73	0.03282	416.75	417.03	416.89	13.7
VPSH	⊘	c	T_1	T_2	T_{med}	$V_{40^\circ C}$
2639	1.47	0.2995	266.03	267.72	266.875	79.93

TABLE 8: TEST RESULTS OF VISCOSITY OF MANNOL 20W50 (CH4) ENGINE OIL AT $V_{100^\circ C}$ AND $V_{40^\circ C}$.

Lukoil 5W40 (new)						
VPSH	⊘	c	T_1	T_2	T_{med}	$V_{100°C}$
3081	0.82	0.3168	360.91	360.50	360.705	114.3
VPSH	⊘	c	T_1	T_2	T_{med}	$V_{40°C}$
3470	1.47	0.3090	245.72	245.53	245.625	75.9

TABLE 9: TEST RESULTS OF VISCOSITY OF LUKOIL 5W40 (NEW) ENGINE OIL AT $V_{100°C}$ AND $V_{40°C}$.

Lukoil 5W40 (hydrogen)						
VPSH	⊘	c	T_1	T_2	T_{med}	$V_{100°C}$
3081	0.82	0.03168	452.66	455.75	454.205	14.39
VPSH	⊘	c	T_1	T_2	T_{med}	$V_{40°C}$
2639	1.47	0.2995	366.03	366.87	366.45	109.75

TABLE 10: TEST RESULTS OF VISCOSITY OF LUKOIL 5W40 (HYDROGEN-GASOLINE) ENGINE OIL AT $V_{100°C}$ AND $V_{40°C}$.

Lukoil 5W40 (natural gas)						
VPSH	⊘	c	T_1	T_2	T_{med}	$V_{100°C}$
3081	0.82	0.03168	366.38	365.91	366.145	11.6
VPSH	⊘	c	T_1	T_2	T_{med}	$V_{40°C}$
2639	1.47	0.2995	257.0	255.97	256.485	76.82

TABLE 11: TEST RESULTS OF VISCOSITY OF LUKOIL 5W40 (CH4) ENGINE OIL AT $V_{100°C}$ AND $V_{40°C}$.

2 *Table 4*

$$U = 96.29; \quad Y = 14.58; \quad H = 143$$

$$N = \frac{log143 - log96.29}{log14.58} = 0.14708$$

$$V1 = \left\{ \frac{[(antilog0.14708) - 1]}{0.00715} \right\} + 100 = 157$$

3 *Table 5*

$$U = 76.81; \quad Y = 12.88; \quad H = 118.7$$

$$N = \frac{log118.7 - log76.81}{log12.88} = 0.1713$$

$$V1 = \left\{ \frac{[(antilog0.1713) - 1]}{0.00715} \right\} + 100 = 167$$

4 *Table 6*

$$U = 111.52; \quad Y = 152.97; \quad H = 5656.2$$

$$H = 0.1684Y^2 + 11.85Y - 97 = 5656.2$$

$$N = \frac{log5656.2 - log111.52}{log152.97} = 0.779$$

$$V1 = \left\{ \frac{[(antilog0.779) - 1]}{0.00715} \right\} + 100 = 800$$

5 *Table 7*

$$U = 108.94; \quad Y = 14.2; \quad H = 138.2$$

$$N = \frac{log138.2 - log108.94}{log14.2} = 0.089$$

$$V1 = \left\{ \frac{[(antilog0.089) - 1]}{0.00715} \right\} + 100 = 132$$

6 *Table 8*

$$U = 79.93; \quad Y = 13.7; \quad H = 131.2$$

$$N = \frac{log131.2 - log79.93}{log13.7} = 0.1908$$

$$V1 = \left\{ \frac{[(antilog0.1908) - 1]}{0.00715} \right\} + 100 = 177$$

7 *Table 9*

$$U = 75.9; \quad Y = 114.3; \quad H = 3457.515$$

$$H = 0.1684Y^2 + 11.85Y - 97 = 3457.515$$

$$N = \frac{log3457.515 - log75.9}{log114.3} = 0.801$$

$$V1 = \left\{ \frac{[(antilog0.801) - 1]}{0.00715} \right\} + 100 = 844$$

8 *Table 10*

$$U = 109.75; \quad Y = 14.39; \quad H = 139.9$$

$$N = \frac{log139.9 - log109.75}{log14.39} = 0.089$$

$$V1 = \left\{ \frac{[(antilog0.09) - 1]}{0.00715} \right\} + 100 = 134$$

9 *Table 11*

$$U = 76.82; \quad Y = 11.6; \quad H = 102.8$$

$$N = \frac{log102.8 - log76.82}{log11.6} = 0.12$$

$$V1 = \left\{ \frac{[(antilog0.12) - 1]}{0.00715} \right\} + 100 = 144$$

IV CONCLUSION

When we used hydrogen in the lubrication system of an internal combustion engine, the number of alkalis was around 1 i.e. an acidic environment was formed inside the engine. Second, since the flash temperature is less than 200 degrees, the heat resistance of the engine parts needs to be reconsidered. Analysis with other types of oils showed that the kinematic viscosity was significantly reduced. Be causes the surfaces to erode. Analysis by the device is one of the best methods of finding the viscosity of engine oil at temperatures of 40 and 100°C. After knowing the leakage time, we used the VI equation, to find a coefficient of viscosity (VI) by method A. The main drawback of the viscosity test is the high wear value which creates a series of external damages.

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ENGINE EMISSIONS AND FUEL CONSUMPTION ASSESSMENT FOR STOP-START SYSTEM IMPLEMENTED COMPRESSION-IGNITION INTERNAL COMBUSTION ENGINE

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Abstract– A number of current technologies for internal combustion engines aimed at reducing the fuel consumption and engine noxious and greenhouse gas emissions emerge mainly due to adverse impact of transportation sector on ecology and global warming. The aim of this paper is to study the advantage in terms of fuel consumption and engine emissions, gained through the implementation of stop-start system on diesel ICE and compare the results with conventional engine. To achieve this, a short description of vehicle backward modeling is provided and simulated for NEDC, WLTP driving cycles. Simulation is done for 2 modes: conventional ICE and ICE with stop-start system. Finally, the comparative analysis is done for the results for the two modes through the tabular and graphical representation. Chevrolet Sail 2010 (1,25 L CI), equipped with 5-speed manual transmission system light duty vehicle has been chosen as a reference. Matlab/Simulink environment is used for modeling and simulation purposes.

Key words– Stop-start system, Engine emissions, fuel consumption, greenhouse gases, nitrogen oxides, carbon dioxide emissions, backward modeling

I INTRODUCTION

The issues concerning air pollution, ecology and global warming have set strict limitations for automotive manufacturers for the amount of pollutant and greenhouse gases of a vehicle. These rules are being regulated by authorities and governmental agencies and impose the eligibility of selling vehicles at a particular territory. Moreover, according to 2019 statistical database of US environmental protection agency [1], the transportation sector is a main contributor of greenhouse gases, thus, the question of CO2 emission from automotive sector has become actual today. In addition, a matter of instability for fuel price and the depletion of oil resources have attracted attention of automotive engineers and forced them to take the advantage of internal combustion engines (ICE) in a most efficient way. To achieve this target, a number or researches have been conducted on the development of engine systems that can improve the efficiency of ICE and reduce engine emissions and fuel consumption. One of the clear examples of these systems is engine stop-start system. This system was introduced to achieve the target of fuel consumption and engine emission reduction by means of cutting idle fuel consumption [2].

Engine stop-start system shuts down an ICE when a vehicle is stationary, so that idle fuel consumption is avoided [3]. Therefore, by reducing the amount of time the ICE spends idling, it is possible to reduce fuel consumption and pollutant emissions. This system then restarts the engine by the response [4]. This device was first patented in 1982 by Uchida Shigekatsu et al. for automatically stopping and starting an engine in accordance with the operating condition [5]. The maximum advantage of this system can be taken when a vehicle is driven in urban conditions, when a vehicle spends a significant amount of time in traffic jams. Indeed, the implementation of this system requires the usage of more robust starter-motor device [6]. Due to frequent stops and starts of an engine, starter-motor should be able to crank the engine fast enough so that after releasing brake pedal driver can immediately start moving [7].

Second chapter of this paper shortly describes the methodology of modeling the fuel consumption and engine emissions (CO_2 and NO_x emissions) by using backward modeling and reverse engineering approach. Simulation of a vehicle is performed for 2 modes of operation: conventional ICE and ICE with stop-start system. The reference vehicle for the simulation is chosen to be 2010 Chevrolet Sail, a light-duty B segment vehicle, equipped with 1.25 L compression-ignition engine and 5-speed manual transmission. Vehicle is simulated over European type-approval homologation driving cycles (NEDC-Figure 1 and WLTC-Figure 2). Third chapter provides in tabular and graphical form and discuss the results of simulation. Finally, chapter 4 concludes the research paper.

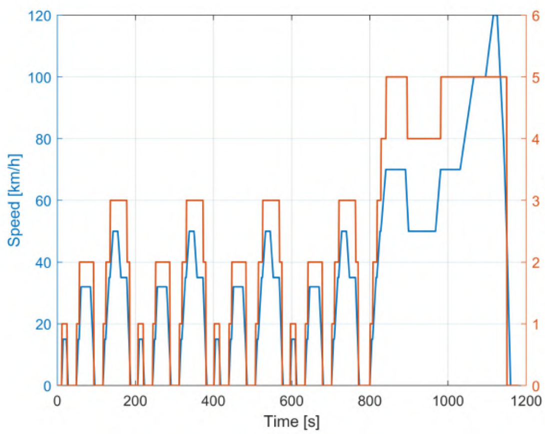

Fig. 1: NEDC driving cycle

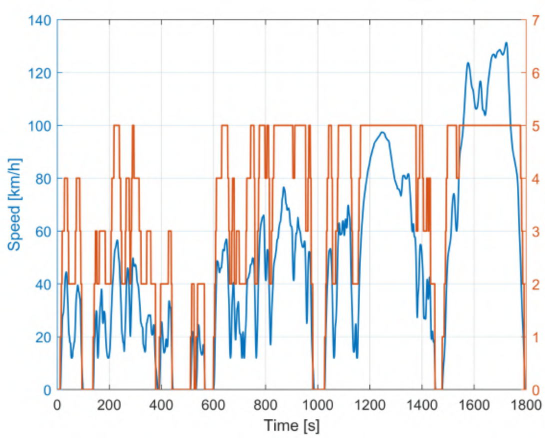

Fig. 2: WLTC driving cycle

II Methodology

Vehicle backward modeling approach is used for the calculation of power demand of the engine. The technical characteristics of 2010 Chevrolet Sail vehicle is presented in Table 1. From the vehicle longitudinal dynamics, it is possible to calculate the total force acting at a tire-ground contact. Aerodynamic drag, rolling resistance, road grade and vehicle acceleration inertia forces constitute the total resistance force. In this analysis, road grade is taken null.

$$F_{tot} = 1/2\rho v^2 A_f C_d + k_r M g + M\frac{dv}{dt} + J_{wh}\alpha_{wh} \tag{1}$$

Where F_{tot} is total resistance force; F_{aer} an aerodynamic resistance force; F_{grade} a resistance due to road grade; F_{in} a resistance due to an acceleration (inertia); ρ an air density; v a speed of a vehicle; A_f a vehicle frontal area; C_d an aerodynamic drag coefficient; k_r a rolling resistance coefficient; M a vehicle mass; g a gravitational acceleration; J_{wh} a wheel inertia; α_{wh} a wheel angular acceleration.

By taking into account inertia of the engine and transmission efficiency, ICE torque and speed can be calculated as follows,

$$T_{ice} = \frac{F_{tot}}{R_{wh}\eta_{gb}\tau} + J_{ice}\alpha_{ice} \tag{2}$$

$$w_{ice} = \frac{v\tau}{R_{wh}} \tag{3}$$

$$\alpha_{ice} = \frac{a\tau}{R_{wh}} \tag{4}$$

$$\tau = \tau_{gb}\tau_{fd} \tag{5}$$

Where T_{ICE} is a torque output of an engine; w_{ice} an engine angular velocity; τ_{gb} a gearbox reduction ratio; τ_{fd} a final drive reduction ratio; α_{ice} an engine angular acceleration; J_{ice} an engine moment of inertia; a a vehicle longitudinal acceleration; η_{gb} a gearbox efficiency and R_{wh} a wheel radius.

Finally, ICE fuel consumption and NOx emissions can be approximated using a reverse engineering approach, which necessitates the creation of suitable maps produced through a laboratory experiment [8]. Fuel consumption and NOx emissions are calculated as a function of engine torque and angular speed using a dyno stand. Figure 3 shows a fuel consumption map.

$$m_{fuel} = f(T_{ice}, w_{ice}) \tag{6}$$

$$m_{NO_x} = f(T_{ice}, w_{ice}) \tag{7}$$

Where m_{fuel} is a mass fuel flow rate and m_{NO_x} a mass flow rate of nitrogen oxides.

Engine start-stop system can be modeled by setting the following condition,

$$m_{fuel} = 0 \quad if \quad v = 0 \tag{8}$$

Parameters	Label	Unit	Values
General vehicle specifications			
Mass	M	kg	1124
Body type	[-]	[-]	Sedan
Length	L	mm	4249
Width	W	mm	1690
Height	H	mm	1503
Frontal area	A_f	m^2	2.54
Aerodynamic drag coefficient	C_d	Ns^2m^2	0.3
Rolling resistance coefficient	f_r	[-]	0.01
Radius of the wheel	R_{wh}	m	0.285
Inertia of the wheel	J_{wh}	kgm^2	2.78
Air density	ρ_{air}	kg/m^3	1.2
Dynamic characteristics			
Maximum speed	v_{max}	[km/h]	160
Acceleration time (0-100 km/h)	t_{0-100}	[s]	16
Gearbox specifications			
Type	[-]	[-]	Manual 5 speed
Reduction ratio (1st gear)	τ_1	[-]	3.9
Reduction ratio (2st gear)	τ_2	[-]	2.24
Reduction ratio (3st gear)	τ_3	[-]	1.44
Reduction ratio (4st gear)	τ_4	[-]	1.03
Reduction ratio (5st gear)	τ_5	[-]	0.767
Gearbox efficiency	η_{gb}	[-]	0.94
ICE specifications			
Maximum power	$P_{em,max}$	BHP	74
Speed at maximum power	$w_{em,Pmax}$	rpm	4000
Maximum power	T_{em}	Nm	190
Engine displacement	V_d	cm^3	1248
No. of cylinders	N	[-]	4
Fuel type	[-]	[-]	diesel
Fuel consumption	V_{100km}	[L/100 km]	4.52 (Combined)
Inertia of ICE	J_{ICE}	kgm^2	0.183

TABLE 1: 2010 CHEVROLET SOUL 1.25L DIESEL TECHNICAL SPECIFICATIONS

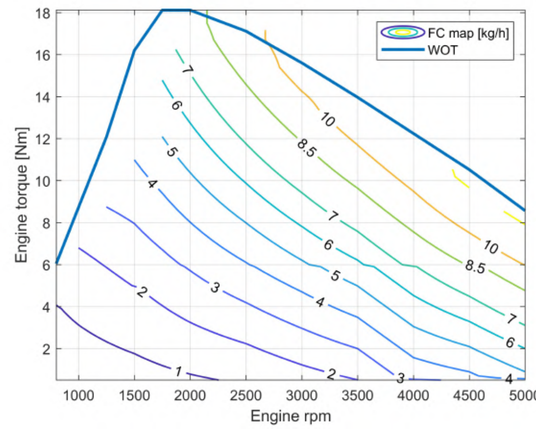

Fig. 3: Fuel consumption map

From mass conservation principle, the total number of carbon atoms is equal to the sum of carbon atoms from carbon dioxide, unburned hydrocarbons and carbon monoxide. This can be formulated as follows

$$n_{fuel} = n_{CO_2} + n_{HC} + n_{CO} \tag{9}$$

Where n_{fuel}, n_{CO_2}, n_{HC} and n_{CO} are number of moles of diesel fuel, carbon dioxide, unburned hydrocarbons and carbon monoxide. Since the values of n_{HC} and n_{CO} are negligible in comparison with n_{CO_2}, their values can be taken null. Therefore,

$$m_{CO_2} = m_{fuel} \frac{\mu_{CO_2}}{\mu_{fuel}} \tag{10}$$

Where m_{CO_2} is mass flow rate of carbon dioxide; μ_{CO_2} a molar mass of carbon dioxide and μ_{fuel} a fuel molar mass.

III RESULTS

All the calculations are performed in Matlab/Simulink environment and a proper block diagram is constructed. The results for the simulation over NEDC are illustrated in Figures 4, 5 and 6 and for WLTP driving cycle in Figures 7, 8 and 9 respectively. Figures 4 and 7 show break mean effective pressure (bmep) and engine speed evolution, while Figures 5 and 8 instantaneous fuel flow rate and cumulative fuel consumption and Figures 6 and 9 instantaneous NO_x flow rate and cumulative NO_x emissions over NEDC and WLTC cycles for the cases of conventional and stop-start implemented engines respectively. Finally, obtained data are normalized with respect to traveled distance and numerical results for total and specific fuel consumption, NO_x total and specific emissions, specific CO_2 emissions and driving cycle data are summarized in Table 2 for NEDC cycle and in Table 3 for WLTC cycle.

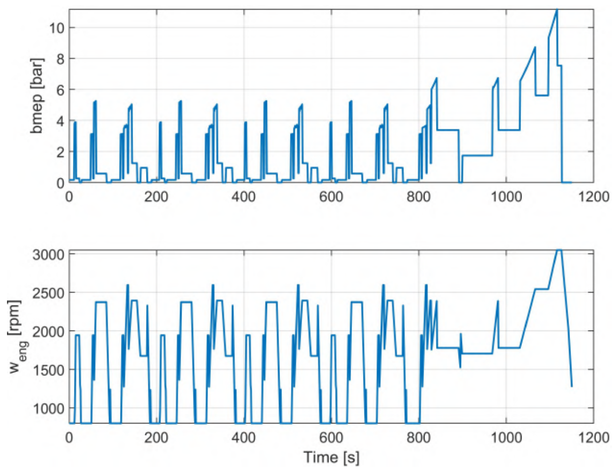

Fig. 4: Engine speed and rpm for NEDC cycle

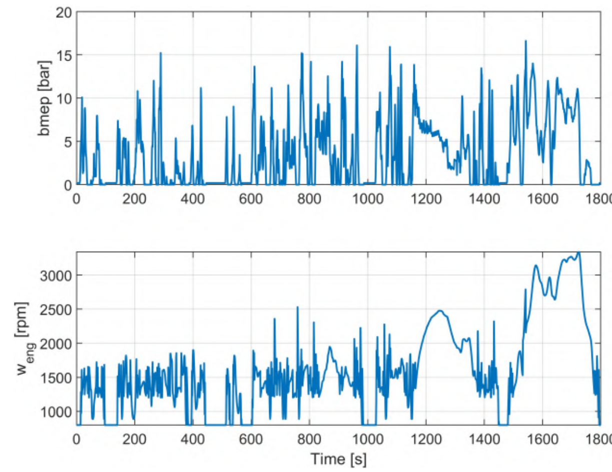

Fig. 7: Engine speed and rpm for WLTC cycle

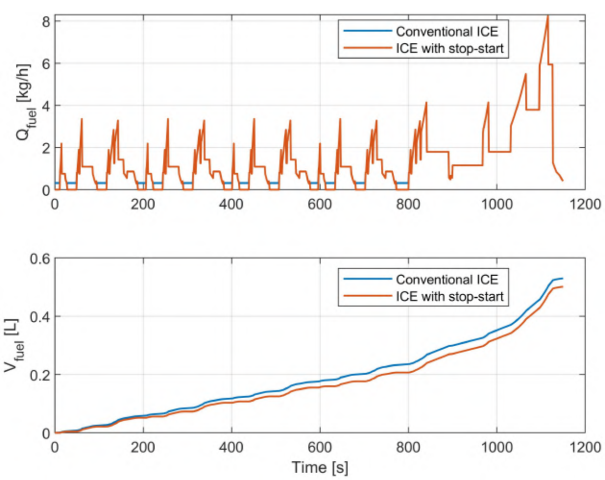

Fig. 5: Fuel consumption for NEDC cycle

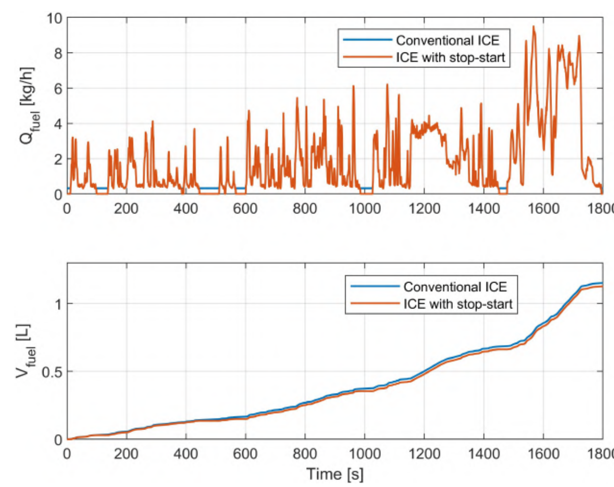

Fig. 8: Fuel consumption for WLTC cycle

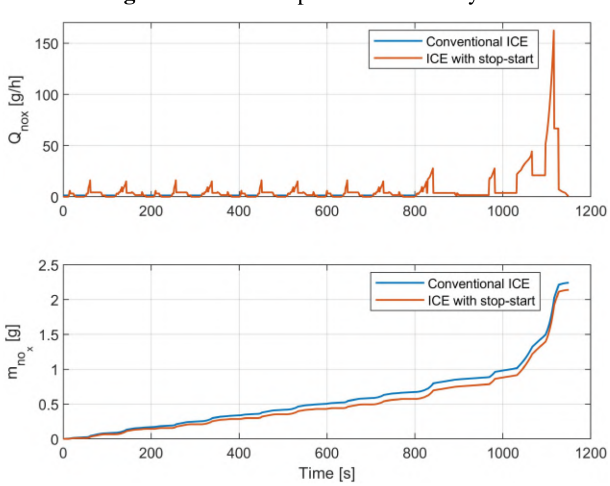

Fig. 6: NOx emission for NEDC cycle

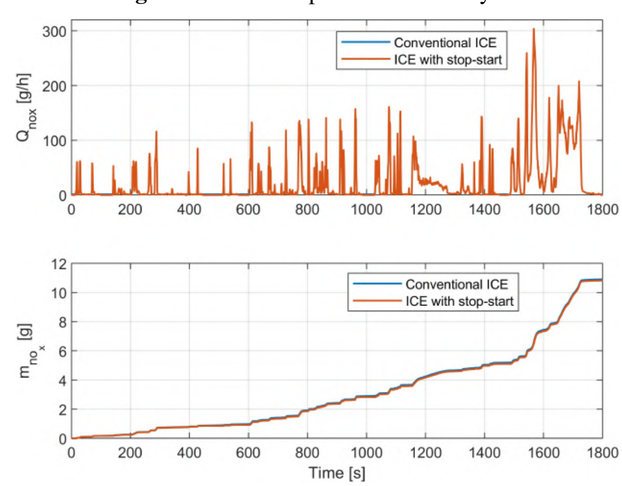

Fig. 9: NOx emission for WLTC cycle

Parameters	Unit	Value	Value	Diff.
[-]	[-]	Conv. ICE	With stop-start	[-]
Cycle duration	s	1150	1150	0%
Maximum speed	[km/h]	120	120	0%
Total distance	km	11	11	0%
Total fuel consumption	L	0.53	0.5	5.7%
Total NO_x emission	g	2.24	2.14	4.5%
NO_x specific emission	mg/km	204.5	195.3	4.5%
Fuel economy	L/100km	4.84	4.58	5.4%
Specific CO_2 emission	[g/km]	128	121.4	5.2%

TABLE 2: TABULAR RESULTS FOR THE SIMULATION OVER NEDC CYCLE

Parameters	Unit	Value	Value	Diff.
[-]	[-]	Conv. ICE	With stop-start	[-]
Cycle duration	s	1800	1800	0%
Maximum speed	[km/h]	130	130	0%
Total distance	km	23.3	23.3	0%
Total fuel consumption	L	1.15	1.13	2.2%
Total NO_x emission	g	10.9	10.8	0.9%
NO_x specific emission	mg/km	468.5	464.8	0.8%
Fuel economy	L/100km	4.95	4.84	2.2%
Specific CO_2 emission	[g/km]	131.1	128.3	2.8%

TABLE 3: TABULAR RESULTS FOR THE SIMULATION OVER WLTC CYCLE

It is clear that the advantage taken from stop-start system is more evident for NEDC cycle, since it differs from WLTC with its prolonged idling time (280 seconds for NEDC and 235 for WLTC). Considering NEDC driving cycle, it can be seen that the economies in terms of fuel consumption and NO_x emissions are nearly at 5.5 percents and 4.5 percents respectively, while carbon dioxide emissions can be reduced up to 5.2 percents. Since WLTC is a more dynamic and power demanding driving cycle, the advantage due to stop-start system is expected to be not significantly noticeable, and the obtained results are the proof for that. Nitrogen oxides emission are decreased only to almost 1 percent, whereas fuel can be saved slightly more than 2 percents. Finally, CO2 emissions are declined to approximately 3 percents.

IV CONCLUSION

This research paper presents an estimation technique of advantages in terms of fuel consumption, nitrogen oxides emissions and carbon dioxide emissions as a result of implementation of stop-start system. Primarily, a vehicle modeling technique, based on backward and reverse engineering approach is presented. By using proper technical data and input driving cycles, the load and speed on the engine are calculated, while fuel consumption and NO_x maps serve as a transfer function for the computation of relevant flow rates. Stop-start system working principle can be modeled by setting fuel consumption and emissions flow rate at zero while the vehicle is motionless. Finally, the data and the variance between two working modes are summarized in relevant tables and figures in numerical and graphical way respectively. It is evident that idle fuel consumption can be avoided, so the both fuel fuel consumption and emissions can be reduced. The amount of reduction strongly depends on the conditions of driving, specifically, on the amount of idling time.

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DEFINITION OF INTERPHONEME TRANSITIONS OF UZBEK WORDS BY DISCRETE WAVELET TRANSFORMS

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Abstract– The article refers to the field of information processing theory on the example of evaluating the use of discrete wavelet transform for processing and recognition of speech signals. The difficulties of recognizing speech signals are described and the advantages of discrete wavelet transform over other traditional methods of signal processing, such as Fourier transform, are given. An algorithm based on a discrete wavelet transform is defined and described in detail. The speech signal is processed on the basis of a discrete wavelet transform. A detailed algorithm for finding the most informative level (scale), which is one of the basic parameters of the discrete wavelet transform, is presented. For the analysis, a speech signal with a sampling frequency of 22050 Hz was used, which was decomposed in scales from 3 to 6 and then using an algorithm to identify the informative level, the level (scale) that most closely describes the original signal was selected and determined. When determining the informative level, the type of the mother wavelet is important. In this article, we used the mother wavelet from the Daubechies family, namely the 4th order Daubechies. The second main parameter of the discrete wavelet transform - shift is determined based on practice (16-20 ms) and is equal to 256 samples. Also described is a step-by-step algorithm in combination with a discrete wavelet transform, which allows segmenting a speech signal into phonemes, as a result of which it becomes possible to switch from an analog signal to text. Based on the proposed algorithms, the results of the process of segmentation of a speech signal into phonemic units are presented. Based on the results of the work done, a number of conclusions were identified that had not previously been identified due to the traditional Fourier transform used.

Key words– discrete wavelet transform, signal segmentation, multi-scale analysis, speech recognition.

I INTRODUCTION

One of the most important tasks in automatic speech processing systems is the task of segmentation in accordance with the phonetic transcription of the language. For voice verification, the characteristic features of the voice must be calculated on certain segments of the speech signal. So, the frequency of the main tone, inherent in the speaker, should be calculated on vowel-like sections of the signal, the shape of the vocal tract is characterized by formant frequencies measured on known vowel sounds, the speed of articulation is determined by the duration of transient processes between articulatory-acoustic segments.

Segmentation is necessary to solve the inverse problem - restoring the shape of the vocal tract from an acoustic signal [11], which can be used in the following areas: systems of compression and transmission of speech in mobile telephony [12], speech synthesizers from arbitrary text [13], systems of automatic speech recognition, systems of teaching foreign language pronunciation.

In the late XX - early XXI centuries. processing of more complex signals has significantly supplanted the position of traditional methods of signal processing based on the Fourier transform, both in the field of theoretical research and in practical applications [1-3, 9-10]. Various types of wavelet analysis are widely used: continuous wavelet transform, wavelet series, wavelet frames, analytical wavelet transform, discrete wavelet transform, stationary wavelet transform, wavelet packets, etc. Each of the above methods for analyzing signals by individuals have their own advantages and disadvantages [3].

Today, the segmentation of a speech signal into phonemic units is a rather urgent problem in automatic speech processing systems [1]. Segmentation is necessary when solving the problem of speech recognition and highlighting the characteristic features of the voice on certain segments of the speech signal. It is important to note that until now the segmentation of the speech signal into phonemic units has been performed for many languages with the exception of Uzbek. In this regard, it is extremely important to carry out this procedure over the Uzbek speech, considering all the features of this language [2,3].

II THE METHODOLOGY

1 WAVELET TRANSFORMS

It is known that the speech signal consists of quasi-stationary areas corresponding to vocal and hissing phonemes, interspersed with areas with relatively rapid changes in the spectral characteristics of the signal (inter-phonemic transitions, explosive and semantic phonemes, intrasyllabic speech-pause transitions). Within the constraints of the stationary sections the spectral characteristics of the speech signal, determined by the transfer characteristic of the speech path that changes during the articulation process, play a significant role in the analysis of the speech signal. We can say that the speech signal is characterized by nonlinear fluctuations of different scales. Therefore, it is very effective to analyze the speech signal with a multiple scale analysis and wavelet transform.

Segmentation of the speech signal (SS) implies the allocation of signal sections corresponding to individual structural units of the SS. If phonemes are considered as such units, then the segmentation task is reduced to detecting inter-phoneme transitions. Within the framework of traditional approaches, solving this problem is very problematic. However, the Wavelet transform allows us to solve this problem, at least for phonemes corresponding to relatively extended quasi-stationary regions of the SS [2].

The fact is that on inter-phoneme transitions the signal undergoes significant changes at once on many scales of study, and, accordingly, is characterized by an increase in wavelet coefficients for many levels of detail, while on stationary sections of phonemes, the wavelet coefficients are grouped near certain scales. Thus, the search for inter-phonemic boundaries can be reduced to finding the times of the increase in the wavelet coefficients at a significant number of zoom levels. In this case, it is important to choose a wavelet basis, which should allow one to describe a stationary SS with a relatively small number of nonzero coefficients [6-8].

At the first stage of sound analysis, the human hearing uses frequency processing [2]. For this reason, it is appropriate to use DWT (Discrete Wavelet Transform) as a solution.

The original signal and its wavelet spectrum have 16 bit of precision. Wavelet transform belongs to the group of frequency transformations. To obtain DWT coefficients to obtain DWT coefficients, it is necessary to decompose a speech signal of length N using the selected (mother) wavelet, which is the following sum:

$$f(t)=\sum_{k=0}^{\frac{N}{2^n}-1} s_{nk}\varphi_{nk}+\sum_{j=1}^{n}\sum_{k=0}^{\frac{N}{2^j}-1} d_{jk}\psi_{jk} \tag{1}$$

Moreover, n is the level of detail, s_{nk} and d_{jk}– approximating and detailing coefficients of wavelet expansion at the n-th level, ψ_{jk}– scaling function and φ_{nk} – basic (mother) wavelet.

2 FAMILIES OF MOTHER WAVELET

One of the features of the DWT is the formation of a family of wavelets by shifting and scaling of the mother wavelet. There are a number of mother wavelets that have common properties and satisfy a number of conditions:

- Haar (haar)
- Daubechies (db)
- Symlets (sym)
- Coiflets (coif)
- Biorthogonal (bior)
- Reverse biorthogonal (rbio)
- “Discrete” FIR approximation of Meyer wavelet (dmey)
- Gaussian wavelets (gaus)
- Mexican hat wavelet (mexh)
- Morlet wavelet (morl)
- Complex Gaussian wavelets (cgau)
- Shannon wavelets (shan)
- Frequency B-Spline wavelets (fbsp)
- Complex Morlet wavelets (cmor)

3 SCALING FUNCTION

Based on equation (1), it is easy to verify that when using the wavelet transform, there is a large excess of data. In this connection, it becomes important to identify the most informative level for the decomposition of the original speech signal. It is known that the wavelet approximation coefficients for orthogonal wavelets correspond to the transfer characteristic of the low-pass filter, and the detail to the high-pass filter, therefore, we can consider the behavior of the speech signal in different frequency ranges [1].

The frequency range below 125 Hz is not used, since it does not contain information important for the segmentation task. This is due to the nature of human speech, spanning the 150-4000 Hz range. Thus, 6 levels of decomposition are sufficient (table 1).

Level of detail	**The frequency range of the wavelet**	
	Daubechies 16	**Meyer**
1	2000-4000 Hz	2756-5512 Hz
2	1000-2000 Hz	1378-2756 Hz
3	500-1000 Hz	689-1378 Hz
4	250-500 Hz	345-689 Hz
5	125-250 Hz	172-345 Hz
6	86-172 Hz	-

4 THE ALGORITHM USED TO FIND THE MOST INFORMATIVE LEVEL

There are various methods of segmenting speech signals [2,8]. The algorithm used in this study is described below:

1. Search for the informatic level

The criterion for selecting the most informative level decomposition is known. For the j-th level of decomposition, starting from the third, the following inequality is checked:

$$\frac{E}{N} < \frac{E_j}{N_j} \qquad (2)$$

where N_j – is the number of detail ratios at the j-th level, greater than 0.5

$$E = \sum_{i=0}^{N-1} s_{0i}^2$$

$$E = \sum_{i=0}^{\frac{N}{2^j}-1} d_{ji}^2$$

The first level, for which condition (2) is satisfied, is the most informative.

2. Built numerical sequence

Having the detail coefficients of the most informative level: at the chosen j-th level of the expansion, a numerical sequence $\{e_{ij}\}_{i=1}^{N/128}$ was built

$$e_{ij} = 10lg \sum_{k=0}^{n_j-1} d_{j,i+k}^2$$

where i- sliding window number, $n_j = n/2^j$ - the size of the sliding window at the j-th level, n - is the size of the window in the original signal (256 samples).

3. Phoneme border detection

The boundaries of the proposed segments are defined between windows with numbers i and i + 1, for which the following inequality is true:

$$\left|e_{i+1,j} - e_{i,j}\right| \geq 3,5$$

5 MATLAB'S GRAPHICAL CAPABILITIES FOR DWT

For experiment a discrete wavelet transform (DWT) was used over the original signals which taken from the limited vocabulary (table 2). In the figure 1 showed the graphic view one of the words "BAHODIR". The word "BAHODIR" was chosen due to the fact that in this word transitions and conclusions are clearly demonstrated

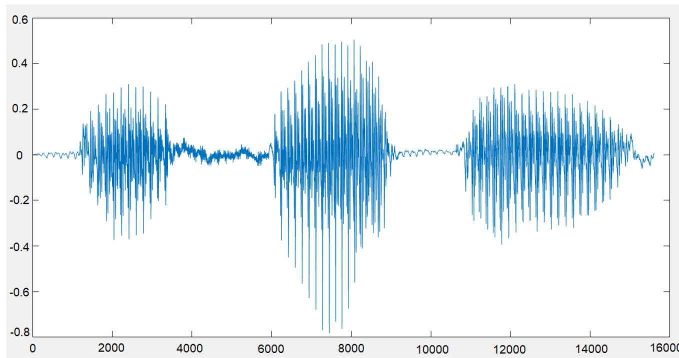

Fig. 1: Graphical view of the signal

Initially, for decomposition speech signal, we need to select the mother wavelet. Usually, the parameter determining the choice of the "mother" wavelet type is the external similarity between the type of the signal under study and the transform function.

On this basis, the Daubechies wavelets were used as the "mother" wavelet function in the study. In our case, it was selected Daubechies 4th. Then we have to set the border for the scale.

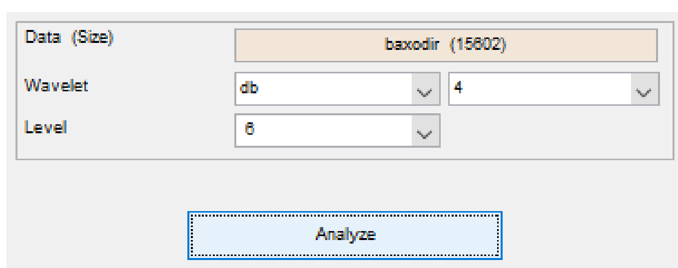

Fig. 2: Setting initial parameters

In graphic windows, the number of charts will depend directly on the level indicator (Figure 2.) Any function S(t), including the speech signal, can be represented as a linear combination of wavelet functions at different scales (decomposition levels) and a scaling function at the largest scale resolution [14,15]. With the help of DWT, the original speech signal was decomposed into 6 levels (Figure 3). The SS,

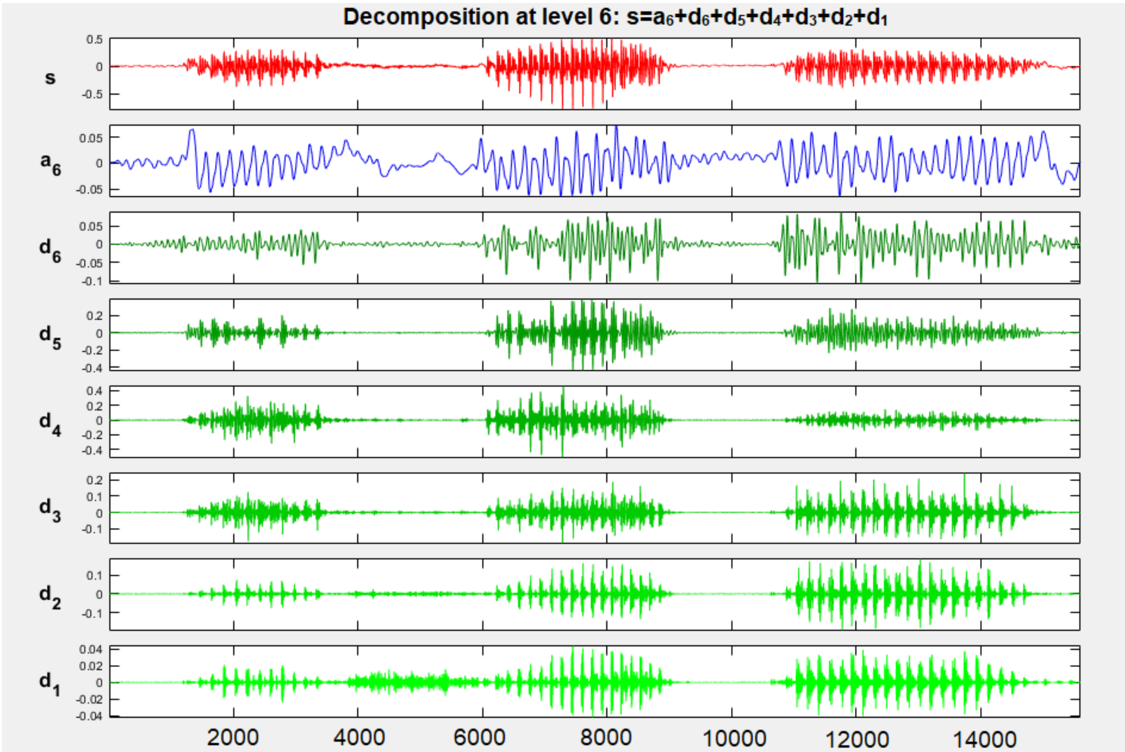

Fig. 3: Decomposition of the original signal into levels

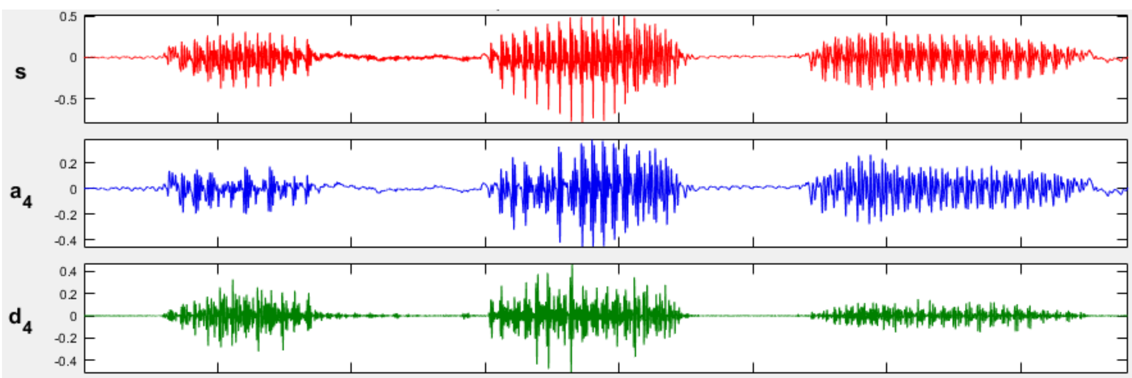

Fig. 4: Decomposition of the original signal at 4th level

digitized with a sampling rate of 22050 Hz, is divided into overlapping windows of 16 ms, which corresponds to 256 samples.

Applying the above algorithm to determine the most informative level, it was found that at the 4th level, the original signal is most accurately decomposed using the mother wavelet Daubechies-4 (Figure 4).

Figure 4 shows that S - graph of the original signal, a4 and d4 are approximating and detailing coefficients of the signal S that is decomposed at the 4th level by DWT.

III RESULTS AND DISCUSSION

Words of different complexity were selected for the experiments: sounds, simple words, complex words (Figure 5). Announcers of different gender and age categories (20-25 years old and 30-35 years old) recorded audio files in wav format with mono type and with a sampling rate of 22050 Hz.

Figure 6 shows a visual segmentation of the speech signal based on the discrete wavelet transform and the above algorithm. According to Fig. 6 b) it is easy to notice the beginning, end and transitions in the audio signal, which is displayed in several scales. Thus, we can say that the DWT is an excellent tool for determining signal boundaries and establishing transition points from one sound to another.

Words	Type of word	Accuracy (percentage)
Ол	simple word	100
Кел	simple word	100
Кўй	simple word	98
Бир	simple word	99
Салом	complex word	100
Китоб	complex word	97
Қалам	complex word	98
Фаол	complex word	97
иқлим	complex word	94
Қарға	complex word	90
Баходир	complex word	93
Таннаффус	complex word	82
Қаноат	complex word	88
Саркарда	complex word	86
Уддабурон	complex word	83
Мустаҳкам	complex word	84
Тилшунос	complex word	85
Average accuracy		**87%**

Fig. 5: Words used for experiments

Figure 6 shows the "!" corresponds to a segment with a pause and an explosion, and the "#" sign indicates an extra segment that appears in words with stressed and unstressed -a, -o.

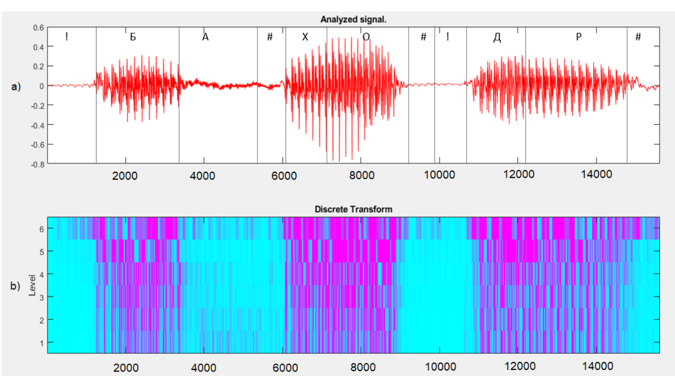

Fig. 6: a) Segmentation of the original signal into phonemic units b) Scalegram of the original signal at all level

Thus, the speech signal segmentation algorithm based on Dobeshi wavelets demonstrated its efficiency, high accuracy of segmentation of phoneme boundaries, long and affricative consonants, sibilants and diphthongs, regardless of the speaker's articulation, pronunciation speed, voice pitch and timbre. The presence of post-processing reduces the likelihood of false phoneme boundaries, increasing the reliability of the recognition process. Experiments were conducted with difficult to segment words pronounced by speakers of different ages and gender. The segmentation accuracy was 87% of correct recognition of the total number of processed words.

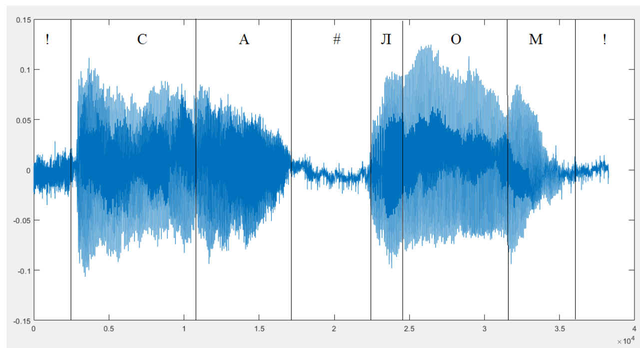

Fig. 7: Segmentation of the original signal "SALOM" into phonemic units

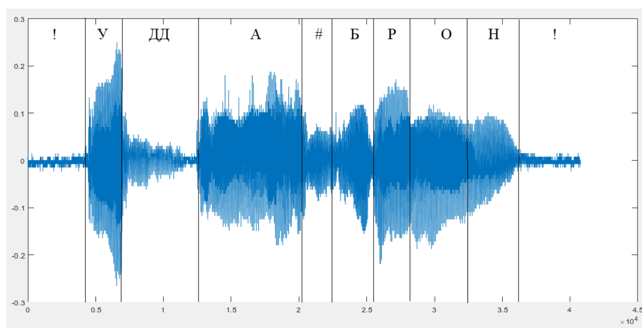

Fig. 8: Segmentation of the original signal "UDDABURON" into phonemic units

Based on the results of the work done on signals with Uzbek words, the following results were revealed:

- explosive consonants in front of the vocal are divided into 2 segments corresponding to pause and explosion (in Figure 6 it is marked as "!");
- sounds -r- stand out well(Figure 6, Figure 8);
- in the stressed and unstressed -a, -o an extra segment may stand out (Figures 6-8);
- two voice sounds standing next to each other are not separated, for example, -oa-, -ao, (in the words FAOL);
- sounds - and between plosive consonants are not distinguished, for example, -dir-, -bir-, -pir- (Figure 6).

IV CONCLUSION

Based on the results of the work done, given in the article, the following conclusions can be drawn:

1. Discrete wavelet transform has a number of advantages over other methods, and also solves a number of problems that are beyond the power of the Fourier transform. One of these tasks is the segmentation into phonemes.

2. An algorithm for identifying the most informative level for decomposition of the SS using a discrete wavelet transform is a convenient method to avoid excess data.

3. The proposed algorithm for segmentation of a speech signal based on a discrete wavelet transform is effective, as evidenced by impressive results on segmentation of the signal into phonemic units.

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PROSPECTS FOR THE DEVELOPMENT OF ELECTRIC VEHICLES IN UZBEKISTAN

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Abstract– The development of the electric vehicle industry in the world, as well as in Uzbekistan, is one of the promising areas in the field of transport aimed at improving the environment. The development of this industry requires the solution of a number of problems, as well as the development and formation of solution methods and the development of infrastructure. The formation of an infrastructure for electric vehicles requires the creation of new markets for innovative products and therefore needs active support in various industrial and social sectors of the state. It is also necessary to constantly analyze the state and dynamics of the development of the electric vehicle market in the world and in Uzbekistan.

Key words– Electric car, development prospects, statistics, ecology, transport.

I INTRODUCTION

The development of the electric vehicle industry in the world, as well as in Uzbekistan, is one of the promising directions in the field of transport aimed at improving the environment. The development of this industry requires the solution to several problems, as well as the development and formation of solutions and infrastructure improvement. The formation of infrastructure for electric vehicles requires the creation of new markets for innovative products and therefore needs active support in various productive and social sectors of the State [3]. Constant analysis of the state and dynamics of the market for electric vehicles in the world and in Uzbekistan is also necessary.

A study of individual companies and analysts on the prospects for electric vehicles and their components is needed [7;9]. Conducting research and studies in this area will contribute to the solution of tasks outlined in the Decree of the President of the Republic of Uzbekistan PP-4477 of 04.10.2019. "On approval of the Strategy for the transition of the Republic of Uzbekistan to a "green" economy for the period 2019 - 2030", as well as the Decree of the Cabinet of Ministers N-812 of 2020. "On additional measures to support the rental and leasing of motor vehicles, as well as the expansion of the use of electric cars, motor vehicles and bicycles to move around the country [1;8].

II MAIN PART

Between January 2022 and April, 96,378 Chevrolet vehicles and 1,435 non-Chevrolet vehicles were produced.

The total number of electric vehicles (including plug-in hybrids) sold in the world in 2021 amounted to 6.75 million units, which is 108% better than the result of 2020. The share of electric vehicles in global passenger car sales was 8.3% compared to 4.2% in 2020. All-electric vehicles accounted for 71% of sales, while plug-in hybrids accounted for 29% [6].

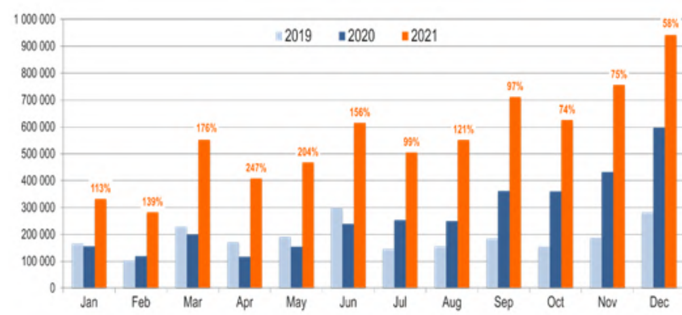

Fig. 1: Global monthly plug-in vehicle sales and y-o-y- growth light vehicles volumes [6]

In 2019 and 2020, sales of electric vehicles in China grew, and while total passenger car sales recovered only 4.6% compared to the crisis year 2020, the growth of electric vehicles by 108% means a doubling of their market share. However, the differences between market regions are strong: in Europe, the share of electric vehicles increased from 10% to 17%, peaking at 26% in December, with a consistently weak overall market. In North America, the share of electric vehicles was 4.4% (2.3% in 2020), in China their share increased from 5.5% to 13.3%. For the remaining 70 markets we track, the combined share of electric vehicles was 1.5% [5].

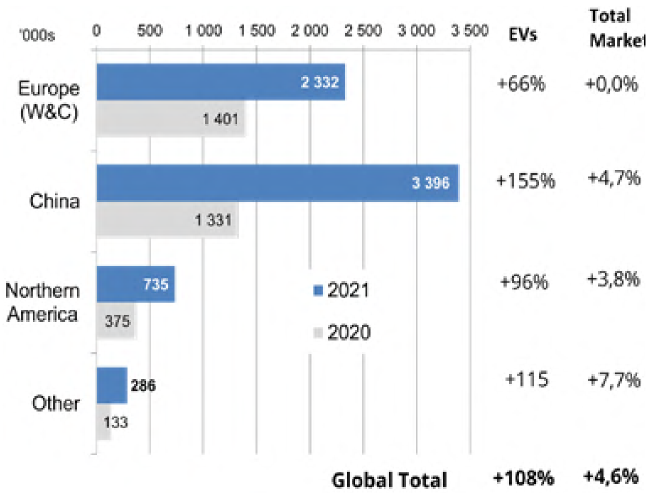

Fig. 2: BEV+PHEV sales and % growth [5]

BEV model range increased by 1% in the scope of electric vehicles, with the most of the rise occurring in the second half of 2021. Their volume increased to 4.80 million units, 1.94 million units were sold by PHEV, and 15,400 units by FCEV [6].

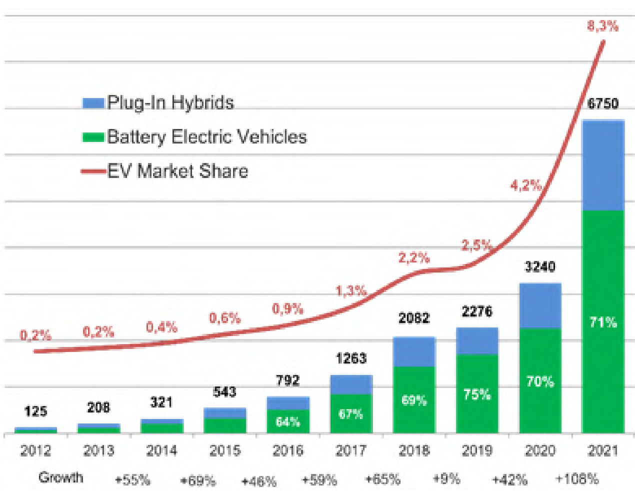

Fig. 3: Global BEV and PHEV sales [6]

By 2030, by some estimates, all new cars sold will be electric. Table 1 shows the plans of automakers.

For the first half of 2021 Uzbekistan imported 452 electric vehicles worth $13.2 million, which is 5 times less than a year later [4].

Manufacturer	Volume of planned investments, bln. dollars	Model number
FORD	11	24 PHEV 16 BEV
GM	8	20 BEV FCEV
Toyota	13,3	10 BEV
Volkswagen	40	BEV
Daimler	11,7	-
Changan Automobile Co	15	12 PHEV 21 BEV
SAIC Motor	3	-
Great Wall Motor	10	-
BMW	10	13 PHEV 21 BEV

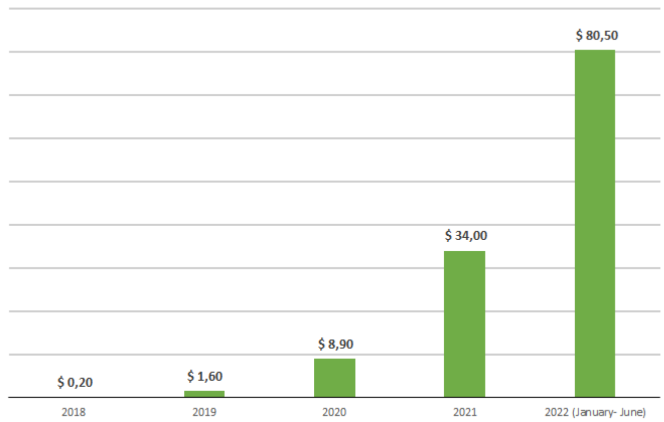

Fig. 4: Dynamics of changes in the import of electric vehicles, mln. $

III RESULTS AND DISCUSSIONS

Over the past 4 years, the demand for electric vehicles in Uzbekistan has increased dramatically: if in 2018 only 14 units of vehicles with an electric motor were imported, then by 2021 this figure has increased by almost 100 times and amounted to 1,303 units, which indicates the impact of the global energy transition trend [4].

Some European countries intend to ban the sale of cars with internal combustion engines after 2035.

In 2021, 24,231 passenger cars were imported for a total of $563.9 million. Of these, 1,296 units were imported. - electric vehicles, in the amount of $34 million. 22,935 units. – other cars and motor vehicles in the amount of $529.9 million [3].

In the first half of 2022, 16,887 passenger cars were imported for a total of $426.1 million. Of these, 2,425 units

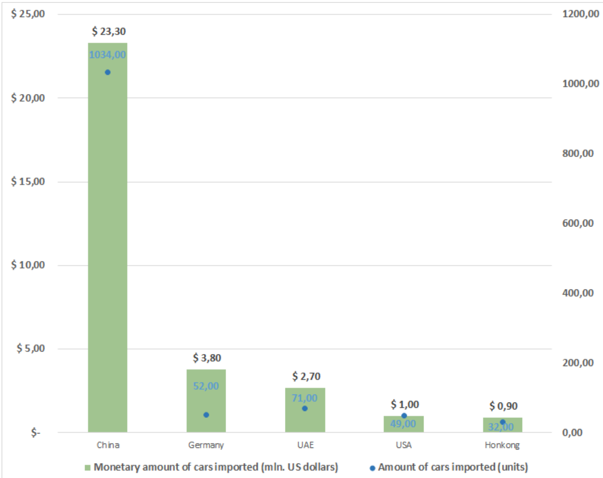

Fig. 5: Top 5 countries imported electric vehicles and cars to Uzbekistan in 2021, dollars mln.[3]

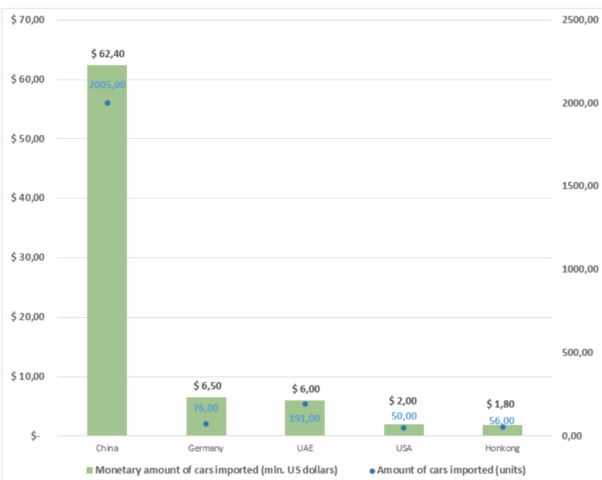

Fig. 6: Top 5 countries imported electric vehicles and cars to Uzbekistan for the first half of 2022, dollars million [3]

were imported. - electric vehicles, in the amount of $80.5 million. 14,461 units. – other cars and motor vehicles in the amount of $345.6 million.

The share of lithium stocks worldwide is shown in Figure 7. Lithium is the main element in the production of batteries for electric vehicles [5].

The main advantages of electric vehicles are shown in Figure 8.

Summarizing the advantages, we can claim that [2]:

• EVs possess zero green-house gas emissions as well as produce quite low noise from the powertrain compared to the ICE counterparts;

• Less level of vibrations;

• The spare parts repair and change is easier than in the

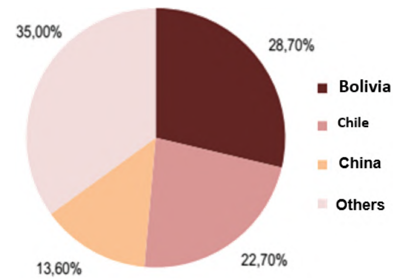

Fig. 7: Share of lithium reserves worldwide [5]

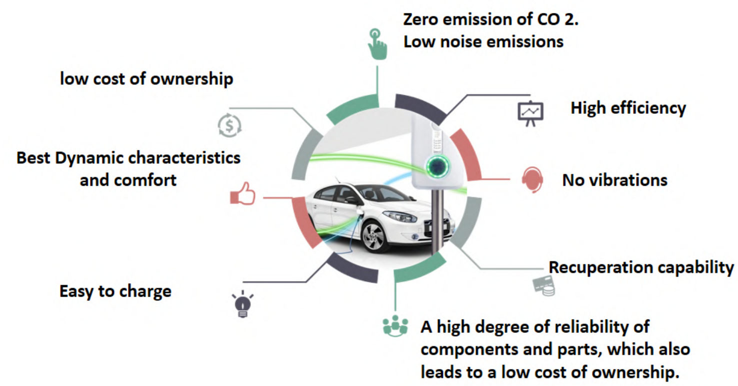

Fig. 8: Advantages of electric vehicles

case of conventional vehicles;

• A better dynamic performance and comfort at start is guaranteed by the presence of an electric traction components;

• EVs have the possibility to recuperate some amount of energy during the braking process which adds some value to fuel economy.

IV CONCLUSION

As a result of the research, the authors formed the following conclusion:

Based on the forecasts of the analysis carried out in the automotive industry, the approximate intensive development of the infrastructure of electric vehicles in Uzbekistan will be possible in 4-5 years, taking into account the interest of the population in the transition to electric vehicles, infrastructure development and the creation of relevant regulations for the successful implementation of their individual areas.

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ON THE ORGANIZATION OF THE USE OF MOBILE WEIGHT AND DIMENSIONS CONTROL STATION OF VEHICLES IN THE TASHKENT REGION

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Abstract– At the present time on the roads of the Republic of Uzbekistan the intensity of traffic is increasing, and the axle loads of trucks are increasing. Despite the existing regulatory and legal restrictions, there is an excess of normative axle loads and gross vehicle weights (HGV). This is due to the desire of carriers to obtain additional profits, despite the possible consequences. The condition of the country's roads is deteriorating, the main reason being the uncontrolled movement of overloaded trucks. At the same time, there is no experience of weight and dimensions control of cargo vehicles in the country, and research on this problem has not been conducted. In the presented work the research of weight and dimensions control of trucks on the international road in the Tashkent region was carried out. An experimental mobile weight and dimensions control station (MWDCS) on the basis of a car equipped with mobile scales was used for the research. Introduction of vehicle weight control system in the Republic of Uzbekistan is an important task.

Key words– weight and dimensions control of vehicles, mobile weight and dimensions control station, overloaded trucks, international roads.

I INTRODUCTION

Currently, on the main highways of the Republic of Uzbekistan and foreign countries the intensity of traffic is increasing, and the axle loads of trucks are increasing. Despite the existing regulatory and legal restrictions, in almost all countries of the world there is an excess of normative axle loads and gross vehicle weights. This is mainly due to the desire of carriers to obtain additional profits, regardless of the possible consequences. In the USA up to 20% of all road damages are caused only by exceeding the permissible axle loads of motor vehicles. In Denmark 10...15% of all trucks are overloaded. In Spain 46% of trucks with single axles are overloaded more than 10 tons. In Ireland in spite of the law about responsibility of carriers and consignors for ATV overloading introduced in 1998 about 20% of the transport is overloaded by 4...6 t [1, 2, 3, 4].

According to Russian experts, in Russia up to 30% of truckers violate the established norms. The average overweight is 78%, which increases the road destroying effect by 5.06 times. The annual amount of damage to highways of the Russian Federation as a result of the passage of heavy vehicles is 2.6 trillion rubles [5, 6, 7].

The destructive impact of heavy vehicles increases significantly due to "chronic under-repair" of road network and insufficient thickness of road structures. The insufficient thickness of road structures is explained by the fact, that modern normative axial loads 10.0...11.5 t are 1.15...1.66 times higher than the estimated 6...10 t, for which a support network of the Russian automobile roads was built in 70-80-ies of the last century. The total thickness of the old (worn-out) structures is 40...55 cm which is much less than the thickness required by the traffic conditions of modern automobiles - 60...80 cm [8, 9, 10].

As a result of insufficient strength, the roadway has rutting up to 15...18 cm, and a network of cracks on the runway.

This is also typical for the Republic of Uzbekistan, since the roads in Russia and in the Republic of Uzbekistan were designed and built according to the same regulatory documents. The problem of the negative impact of overloading of trucks on pavement and artificial constructions is not given sufficient attention, target studies have not been conducted.

However, the condition of the country's roads continues to deteriorate, the main reason being the uncontrolled movement of overloaded trucks (Figure 1, Figure 2) [11, 12, 13].

Fig. 1: Overloaded trucks on the roads of the Republic of Uzbekistan

Fig. 2: The results of the negative impact of the movement of trucks with overload on the roads of the Republic of Uzbekistan

II Main part

To study the problem of overloading of trucks in the Republic of Uzbekistan, the specialists of the Unitary Enterprise "Center for the exploitation and analysis of the technical condition of automobile roads" of the Committee on Roads under the Ministry of Transport of the Republic of Uzbekistan in December 2020 conducted field studies of overloading of trucks on the example of Tashkent region.

A section of a road of international importance in Tashkent region was chosen as an object of the study.

Tashkent region is located in the north-east of Uzbekistan between the western part of the Tien Shan Mountains and the Syr Darya River. Its area is 15,300 km^2 (Figure 3).

Most of the territory of Tashkent region is a foothill plain. In the north and north-east there are ridges of the Western Tien Shan up to 4,299 m high.

The oblast borders Kazakhstan in the north and northwest, Kyrgyzstan in the northeast, Namangan oblast in the east, Tajikistan in the south, and Syrdarya oblast in the southwest.

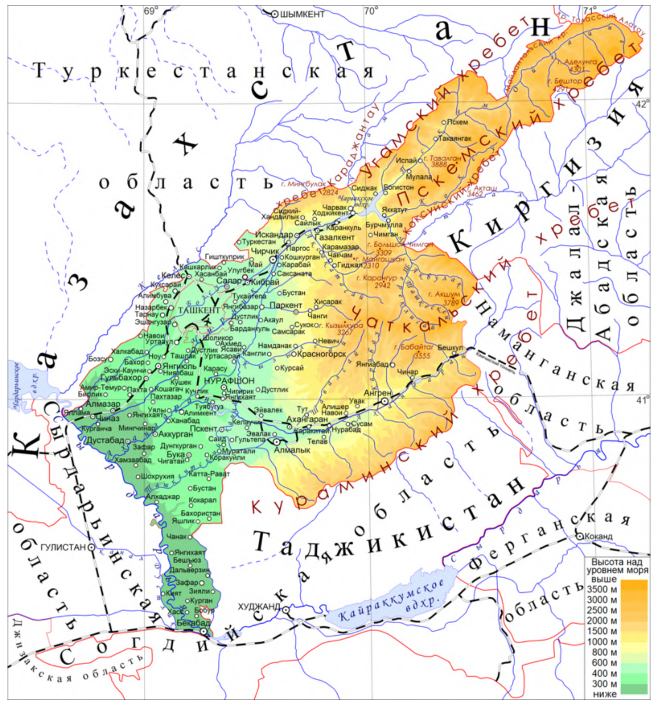

Fig. 3: Map of Tashkent region

The economic potential of the Tashkent region.

Because of its geographical features, the Tashkent region (Figure 4, Figure 5) is the main transit base of both the country and the whole Central Asian region in longitudinal and transverse directions throughout the territory of the Republic of Uzbekistan, so it plays an important role in the development strategy.

Tashkent region has a high level of economic development. The high concentration of population in Tashkent region, the intersection of highways and historical development made it an important industrial center of the republic. The favorable business environment in recent years allowed making significant changes in the structure of the economy. The adoption of measures on diversification, modernization, technical and technological renewal of the industries have made it one of the fastest growing industries. The role of the Tashkent region has significantly increased in structural changes taking place in the country. A number of measures were taken to increase the economic potential and competitiveness of the region.

The basis of the regional economy is the processing and production of food and agricultural products. The building materials industry is also developing rapidly. Technical modernization and expansion of production with effective use of local raw materials are carried out in the region.

Fig. 4: Location of the Tashkent region

The share of investments in the industrial sector remains high. The Tashkent region has a high industrial potential. A diversified and highly developed industry has been created on its territory. These are enterprises of ferrous and non-ferrous metallurgy, mechanical engineering, chemical, electric power, construction materials, light and food industries, covering almost all branches of industry. Over the past five years, the volume of industrial production in the region increased by 3.63 times, and in the country – by 3.56 times. The volume of industrial production per capita amounted to 12160 thousand sums. In the republic, this indicator is 6,944.7 thousand sums. It means that the average indicator in the region is higher than the average indicator in the country.

In recent years, the region's industry has been rapidly developing. Gross Regional Product (GRP) of the region is 9,4% of the country's GDP and per capita it is 13333,4 thousand sums. This is 107.8% of the national average. The share of industry in GRP is growing. Its share is still higher than the country's contribution to GDP (14.3%). The region also produces 10.7% of the country's agricultural output. Reforms in industry and agriculture make the region the leading (second) country in terms of export share (11.2%). The region's proximity to the capital makes it one of the most profitable regions.

At the same time, the volume and importance of road transportation in Tashkent region is increasing.

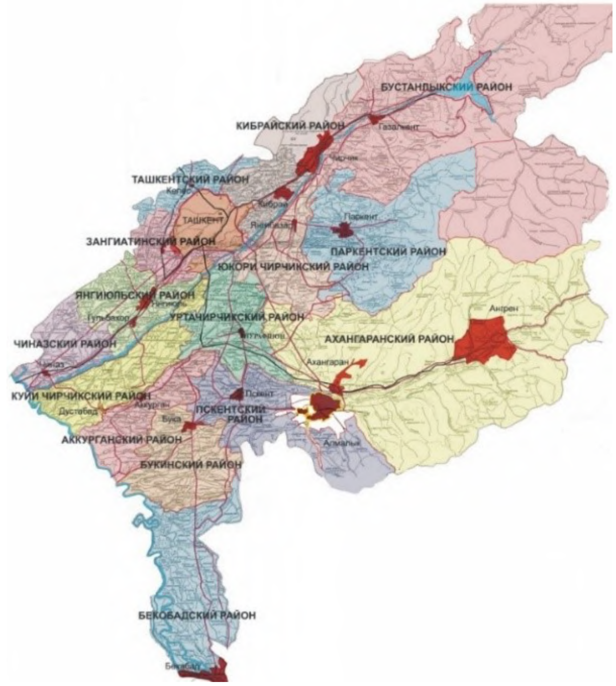

Fig. 5: Map of Tashkent region by district

Selection of an automobile road:

Highways of international importance are key to the development of the country's economy and are important for the development of the country's transit potential. Highways of international importance account for a little more than 9% of the total length of the public road network and provide about 40% of all road transportations and 100% of all transit road transportations.

In view of the above, roads of international importance were chosen as the object of study.The choice of roads is based on the location of commercial and industrial cities, the importance of the corridors that run along these roads, which connect the west and east, north and south of the country. The development of the road network and the economy are interrelated. The volume of commercial traffic and its growth rate reflects the state of development in the area. Traffic data from these areas is reliable and typical.

During the study of traffic with congestion four highways of international importance, passing through the territory of Tashkent region were selected as an object of research:

1. Road of international importance M-39 "Almati - Bishkek - Toshkent - Shaxrisabz - Termiz" (806-871 km);

2. Road of international importance M-34 "Toshkent - Dushanbe" (9-70 km);

3. Internationally important highway A-373 "M39 highway - Guliston - Buka - Angren - Koukon and Andijon - Osh" (59-193 km);

4. International importance highway A-373a "Toshkent shahriga" (0.0-45.0 km).

The location of each of the considered highways is shown on the map of the Tashkent region (Figure 6). All roads belong to the first category.

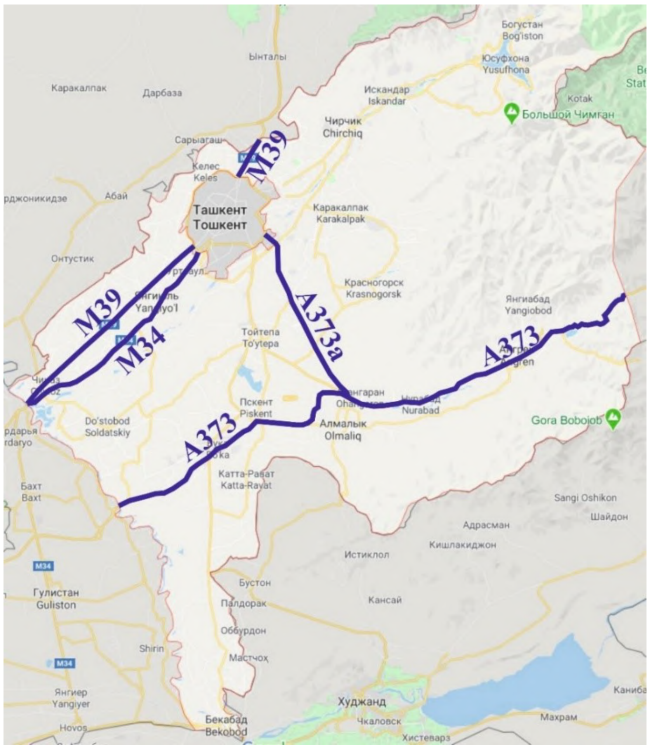

Fig. 6: Location of the roads under study.

As the object of the study, the section of the road of international importance M39 "Almati - Bishkek - Toshkent - Shaxrisabz - Termiz" (806-871 km) passing through the territory of Tashkent region was chosen.

III RESULTS AND DISCUSSIONS

Analysis of experimental data.

During the research, despite the fact that there are cars and buses in the traffic flow of the studied section of the road; the researchers - employees of UE “Center for the exploitation and analysis of the technical condition of automobile roads” did not stop them to study the axial load. All types of vehicles were taken into account in the traffic volume survey, because the traffic volume survey had to take into account the percentage of freight vehicles in the total traffic flow, so it was necessary to get a complete and reliable representation.

Equipment used.

A vehicle-based mobile weight and dimensions control station (MWDCS), equipped with mobile scales, was used to conduct the research.

This prototype MWDCS of the vehicle was equipped on the basis of Hyundai H-1 minivan (fig.7) by the specialists of UE “Center for the exploitation and analysis of the technical condition of automobile roads” in 2020 on the basis of the analysis of serially produced MWDCS.

The MWDCS is designed to monitor compliance with permissible parameters of heavy vehicles in terms of weight and dimensions when solving the problems of road safety in the Republic of Uzbekistan. The MWDCS allows to quickly control the flow of cargo vehicles, equipped with all necessary equipment and fully prepared for work.

Fig. 7: MWDCS UE “Center for the exploitation and analysis of the technical condition of automobile roads”

The mobile weight and dimensions control station provides:

- calculation of the gross weight of vehicles and trains;
- automatic registration of axle loads, both single and twin wheel pairs;
- execution of the protocol of measurements;
- protocol of weight control in hard copy with the date, time, wheel and axle loads, gross vehicle weight, etc.

The MWDCS is equipped with portable scales BA-15C-2 with the possibility of installing them on the roadway (or equivalent) for axle and overall weight of heavy-duty vehicles [10].

All the equipment is combined into a single MWDCS control and measurement system based on a personal computer and can be used as a checkweigher.

In the passenger compartment of the car there is a specially equipped operator's workplace, which provides the work of the employees of the weight control.

The BCPS can be equipped with various additional equipment as needed. In December 2020, specialists of UE "Center for the exploitation and analysis of the technical condition of automobile roads" carried out weight and dimension control of vehicles on the 871 km of the road of international importance M39 "Almati - Bishkek - Toshkent - Shaxrisabz - Termiz" direction Samarkand - Tashkent (Fig. 8).

Fig. 8: Process of weighing vehicles at the MWDCS

A traffic police officer stands at a post on the road and sends each truck under study for weight and dimensions control. The MWDCS was installed in front of the traffic police posts on the highway under study in such a way that the research would not seriously affect the traffic flow. A vehicle moves quite slowly on this section of the road, so it is easier to stop it, because the vehicle is already ready to pass the traffic police post Figure 9-10.

Fig. 9: Preparation of the MWDCS

Fig. 10: Process of weighing of cargo transport vehicles at the MWDCS

It should be noted that the presence of a traffic police officer is mandatory, as drivers and carriers in general ignore any attempt to stop the vehicle to pass the VGC.

When weighing, each truck stops in front of the scales. Then the cargo vehicle is slowly moving at a speed of less than 10 km/h. When the wheel of the first axle was in the middle of the scales, the vehicle is stopped and the static weight is measured. This procedure is repeated until all the axles of the cargo vehicle are weighed. The result is the axle load and the total load of the vehicle.

The details and sequence of the weighing procedure are shown in Figure 11.

Fig. 11: Process of weighing of cargo transport vehicles at the MWDCS

Figure 12 shows the results of weighing trucks in December 2020. As can be seen from the figure, from the total number of weighed 583 vehicles with overload were 238 vehicles or 41

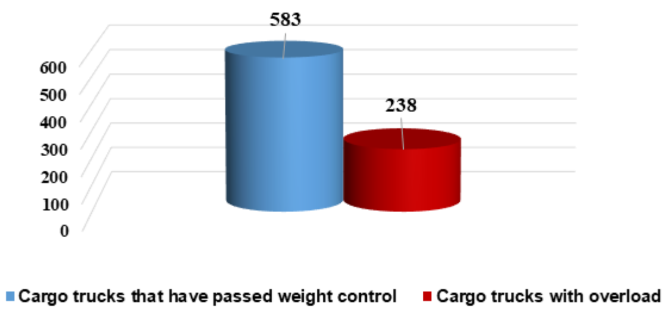

Fig. 12: Results of weight and dimensions control of trucks: 1 - total number of weighted trucks; 2 - number of overloaded trucks.

As studies have shown, the main type of violations of weight and dimensions of trucks is exceeding the established axle loads (over 40% of the total number of violations), which eventually leads to intensive wear and tear of roads, creating conditions that threaten traffic safety.

IV CONCLUSION

In connection with the fact that in the republic there is no experience of weight-dimensional control of cargo vehicles and research on this problem has not been conducted and based on analysis of the experience of foreign countries to solve these problems, a research on weight-dimensional control of cargo vehicles was organized and conducted on the road section of international importance in Tashkent region.

As the research showed the main type of violations of weight and dimensions parameters of freight vehicles is exceeding the established axle loads (over 40% of the total number of violations), which eventually leads to intensive wear and tear of roads, creating conditions that threaten traffic safety.

Based on the experience of leading foreign countries in terms of objective growth in road transport volumes to ensure the normative operational characteristics of roads and road structures, road safety, accessibility and speed of movement of goods, the introduction of the system of weight and dimensions control of vehicles in the Republic of Uzbekistan is an important task. This will ensure:

- development of automatic control of compliance with the established weight and dimensional parameters of vehicles;
- integration of the functions of measuring the weight and dimensions of vehicles, identification of vehicles, monitoring traffic, fixing traffic violations, approval of permits for transportation of heavy goods in a single system;
- reduction of economic losses caused by imperfect measurement technology and data transfer, the need for unscheduled routine repairs of roads and road structures caused by excessive weight loads;
- continuous automatic control of all vehicles transported on the roads, with real-time transmission of information about violations to the Main Department of Road Safety of the Ministry of Internal Affairs;
- improvement of law enforcement in the sphere of road transportation.

The result of such measures will be to ensure the safety of roads and improve road safety.

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MATHEMATICAL MODEL OF A POSITIONING HYDRAULIC DRIVE

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Abstract– Today, the hydraulic drive is widely used in road construction equipment and has become an integral part of modern multitasking machinery and industrial equipment. Cars in developed countries cannot be imagined without a hydraulic drive. It allows you to adjust the speed without steps, make full use of the power of the drive motor, improve the utilization rate and improve the productivity of the machine.

Key words– digging modes, digging forces, hydraulic drive, multipurpose machines.

I INTRODUCTION

Improving the hydraulic systems of multipurpose machines is a pressing scientific and practical task at now, based on existing research. In previous research, a method for choosing rational parameters of the hydraulic system of the proposed multi-purpose machine and analyzing the selected schemes was proposed. However, the creation of mathematical models of individual parts (digging, drilling, pushing, and lifting) and their integrated calculation using a computer has not yet been completed [1, 2].

II DEVELOPMENT OF THE MODEL

Low inertia does not affect the dynamic properties of the drive, reduces the cycle time. The number of gears is 1000 or more in hydromotor hydraulics operating with high torques.

Due to the fact that the mounting components of the hydraulic system are situated separately, the ideal placement of these components within the vehicle may be determined. Overwork is prevented in the safety valves, check valve, differential pressure relief valve, brake valve, valve block drive motor, hydraulic system, and other components. This is the most essential aspect of hydraulics [3, 4, 5]. The compactness and low mass of the hydraulic system's components is due to the absence of heavy wear parts, such as gears, chain reducers, couplings, pulley drums, chain hoists, and cables. There are disadvantages to hydraulic lubricants, such as the fact that their performance and integrity depend on the ambient temperature, i.e., the viscosity and other properties of the working fluid are temperature-dependent [6].

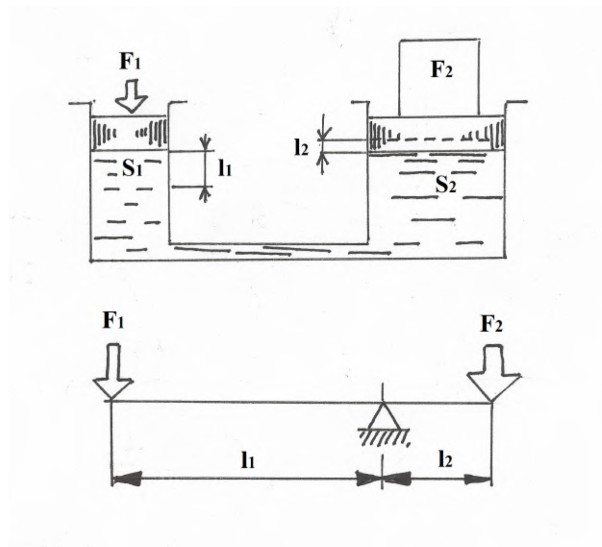

Fig. 1: High torque hydraulic motors

III RESULTS AND DISCUSSION

In accordance with the movement of the primary working component, hydraulic drives can be classified as either translational or rotating. These motions are accomplished using a hydraulic motor, hydraulic cylinder, or rotating hydraulic motor [7]. Hydraulic drives can be classified as adjustable, non-adjustable, manually regulated, or automatically regulated based on their adjustability [8, 9]. In variable hydraulics, the output shaft speed is variable.

The hydraulic system's operating principle is based on Pascal's law [10, 11]. It simultaneously transmits the external pressure acting on the open surface of a liquid in a closed volume to all sides of the liquid [12]. The value of pressure is determined by the force perpendicular to the piston's surface - F:

$$P = \frac{F}{S} \quad (1)$$

If the closed volume is filled with liquid, the second volume is connected through a pipe. According to Pascal's law, pressure P passes through it, acting on its walls with a force F. Thus, in hydropower, power is transferred to another distance through a pipe (Figure 1). Two vessels (volumes) in the figure are closed by pistons 1 and 2, connected to each other by branch pipe 3. The force F_1 acting on the piston with surface S_1 creates pressure in the system:

$$P = \frac{F_1}{S_1} \quad (2)$$

To balance this pressure, a force $F_2 = PS_2$ must be applied to piston 2 in the second reservoir. Equating the two formulas above, we get the following expression:

$$\frac{F_1}{F_2} = \frac{S_1}{S_2} \quad (3)$$

It follows that the force on the pistons is directly proportional to their surface, and their thrust is inversely proportional to the surfaces l_1 and l_2, i.e. the "law of leverage" is respected: we win in strength and lose in distance, but the first one can be greater. The most important advantage of hydraulic motors is the ability to transmit high power due to small dimensions. However, we move piston 1 to a distance l_1 and squeeze out a certain volume of liquid from it:

$$V = S_1 l_1 \quad (4)$$

The same volume of fluid moves into the second volume and pushes piston 2 a certain distance:

$$l_2 = \frac{V}{S_2} \quad (5)$$

From equations (4) and (5) we obtain:

$$\frac{l_1}{l_2} = \frac{S_2}{S_1}$$

Substituting this relation into (3), we obtain:

$$\frac{F_1}{l_1} = \frac{F_2}{l_2} \quad (6)$$

This equation is similar to the type 1 lever equation (Figure 2). Using a hydraulic lever, you can create a gear ratio 10 ... 50 times greater than that of a mechanical lever.

The working fluid (WF) in the visible hydraulic drive is propelled by pumps that are powered by an internal combustion engine. Depending on the rotation of the working fluid (WF), it is possible to open and close hydraulic circuits (Figure 2). In the open hydraulic drive, with the three-position

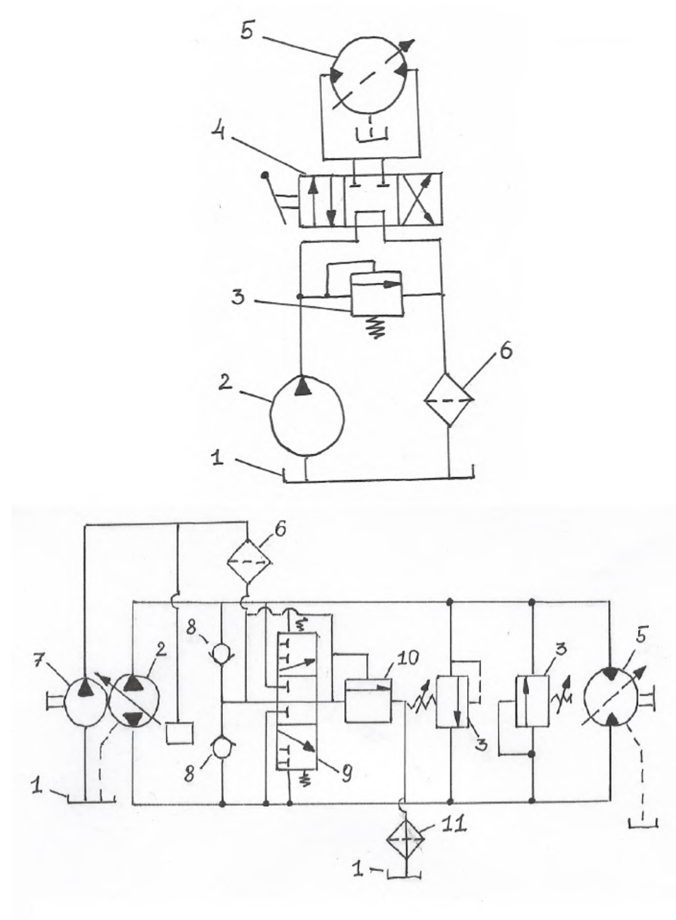

Fig. 2: Open and closed hydraulic circuits depending on the rotation of the working fluid

distributor 4 in the operating position, pump 2 draws WF from tank 1 and sends it to the adjustable hydraulic motor 5, where it performs useful work before returning to the tank.

When the distributor valve is moved to the reverse operating position, the direction of the WF flow changes, as does the direction of movement of the cylinder rod and the direction of rotation of the output shaft of the hydraulic motor. Additionally, the position of the manually operated distributor 4 connects the pump to the tank, thereby relieving the pump of excess pressure. In uncontrolled hydraulic machines, the movement speed of the hydraulic cylinder rod or the speed of the hydraulic motor shaft is controlled by restricting the WF flow in the distributor or by employing flow controls.

In closed hydraulic mode, the pump sends the WF to the hydraulic motor; liquid from the hydraulic motor bypasses the tank and returns to the pump's suction chamber. In variable pump-motor hydraulics, the rotational speed and direction of the actuator are regulated by varying the performance of the pump or hydraulic motor (or both at the same time). Due to volume losses in the pump and motor, less WF is given to the suction blade of the pump; its quantity is equal to that which seeps into the tank through the drain line. In order to reduce leakage, an auxiliary pump (7) is put in the closed hydraulic drive. It delivers the WF to the low-pressure line at a pressure between 0.7 and 1.5 MPa, which can be adjusted using the relief valve (10) in the auxiliary hydraulic line.

Under the influence of the pressure differential in the pump's operating hydraulic lines (2), the hydraulically controlled distribution valve (9) is pushed to connect the low-pressure hydraulic line to the relief valve (10). Thus, the WF in a closed circuit circulates and cools continuously. Check valves (3) transfer IS from the high-pressure hydraulic line to the low-pressure line and lower dynamic stresses when the working body or machine movement mechanism becomes obstructed or halted.

The WF flows from the auxiliary pump (7) through the filter (6) and one of the check valves (8) into the pump's low-pressure hydraulic line (2), with the excess entering the tank via the distribution valve (9) and relief valve (10).

Benefits of closed hydraulic systems:

- The working volumes of the hydraulic motor dictate the volume of the WF, and the size of the tank is governed by the effectiveness of the auxiliary pump, which compensates for volume losses in the pump and hydraulic motor.

- Excessive pressure at the pump's inlet ensures operation even at low speed, permitting the use of a volumetric hydraulic system using MG-15V oil in cold areas with a smaller-volume pump (i.e., smaller dimensions, weight and cost). In addition, surplus pressure allows the machine to be started without overheating even when the MG-15V oil temperature is below minus 400C.

- WF has no direct interaction with the environment. This prevents contamination of the hydraulic system, extends the life of the WF, and enhances the hydraulic resource.

- Adjustable, reversible, axial-piston pumps of direct-flow hydraulics permit changing the rotational direction of the hydraulic motor shaft without the use of a hydraulic distributor, hence enhancing the efficiency (the valve is used in the direct-flow hydraulic drive).

Special hydraulic oils, MG-15V and MGE-46V, have been produced in compliance with GOST specifications to ensure the reliable functioning of hydraulic equipment in the climate of Central Asia. The first one (analogous to VMG3) is utilized year-round in northern regions and during the winter in Asia. It is made by combining chemicals that provide viscosity, resistance to low temperatures, and anti-foaming qualities to a viscous raw material. This oil can be hydraulically started without preheating and can be used continuously at temperatures ranging from -53^0C to +53^0C without seasonal replacement. Hydraulic oil MGE-46V (similar to MG-30) is designed for use in hydraulic drives of mobile machines and industrial equipment in temperate climates, outdoors, and during the summer, can be used year-round in warm climates. Can be utilized at temperatures ranging from -20^0C to +75^0C; created by combining a selective oil cleanser, anti-corrosion, anti-foam, and pour point-depressing ingredients. Additionally, MGE-46V has excellent lubricating qualities, is resistant to oxidation and resin deposits, and does not froth.

The replacement interval for the most common types of hydraulic oils is between 3,500 and 4,000 hours, or at least once every two years. If there are no primary varieties, they are changed seasonally: MG22A in the winter and H-30A in the summer.

For the reliable operation of pumps, hydraulic motors, and other components of hydraulic systems, the working fluid must be thoroughly filtered for mechanical contaminants and maintained at the proper level. The cleaning of WF must comply with ISO 4406 class 19/15 or GOST 17216-2001 classes 13 through 15. In this instance, the absolute filtration fineness is 25 micrometers. WF filtration in hydraulic systems with improved reliability and service life requirements: up to class 16/13 per ISO 4406, cleanliness class 11 according GOST 17216-2001. Absolute filtration fineness is 10 micrometers.

The EO-2621 excavator is used to automate modest earthworks and earthworks. Designed for processing I...III types of soils, loose and crushed building materials; 0.25 m^3 bath volume.

According to studies conducted in a variety of industries, hydraulic machines, hydraulic drives, and hydraulic devices produced in them have high comparative indicators, including high efficiency. However, the overall efficiency of a hydraulic system decreases when this hydraulic equipment is utilized. In addition to increasing energy consumption, hydraulic systems and machines' dependability and longevity are diminished. This is due to the power loss circulating within the vehicle, which increases the internal deflection. We shall evaluate a hydraulic drive of construction and road machines by way of illustration.

The functional and energetic features of hydraulic systems and hydraulics are largely determined by the power supply architecture. For instance, the design of single-flow hydraulic systems based on a single pump is straightforward and economical, and throttling hydraulic distributors are utilized to ensure the simultaneous operation of multiple executive hydraulic motors with mutually independent speed modes (a combination of work operations on the machine).

Figure 1 illustrates the inaccuracy of the downward throttling distribution in hydropower. Let's imagine that this approach is utilized in a forklift's hydraulic drive. HD_1 conducts a translational movement (such as when lifting a crane boom), whereas HD_2 performs a rotating movement (for example, in a pulley mechanism). A pump with capacity Q and operating pressure R is utilized by the system. When the position of the throttle valve (2) is adjusted to a different operational position, the pump supplies the hydraulic motor HD_2 with liquid. Its load on the working body has a specific weight. In this instance, a pressure drop is produced in the throttling element of the spool, which is dependent on the Q_2 and R_2 indications of the hydraulic motor.

When the valve position is constant and there is no back pressure from the hydraulic motor, Q_2 and R_2 are also constant. If the value of the load HD_1 on the hydraulic cylinder support is significantly greater than HD_2, then the pressure stored in the hydraulic system (single-flow) while changing the states of valves 1 and 2 is equal to the pressure (HD_1) that overcomes the load of the most heavily loaded hydraulic motor. Due to the pressure drop across the valve, the power provided to the hydraulic motor HD_2 differs from the needed value Q2 in this instance (2). Consequently, when HD_1 and HD_2 are used concurrently, the needed rotational speed of the HD_2 hydraulic motor will not be consistent. Therefore, the combination of work processes in such a hydraulic system is unfeasible due to the inability to maintain constant operating parameters during operation.

Currently, the standards for road construction machines are growing more demanding. This approach is distinguished by its high energy intensity, adaptability, the breadth of hydro-communication networks, a large number of hydraulic motors, and the necessity for deeper integration of work processes. This combination is distinguished by the ability to provide load-independent adjustable steady speeds for the working bodies of road-building equipment and the ability to shift the entire power of the primary drive engine to a separate executive hydraulic motor. The efficacy of road building machines is determined on their large-scale integration.

The operation of MM systems relies on the preservation of a constant pressure differential in the throttling parts. Such parts are edges of the proportional hydraulic cylinder that have been carefully cut. Excessive consumption during throttling causes energy loss in the system via the storage valve leading to the tank.

It is common knowledge that the flow rate of a hydraulic motor is solely dependent on the pressure drop:

$$Q = CeA(2(\frac{\Delta P}{\rho}))^{1/2} \tag{7}$$

Q is the flow rate, m^3/s; A is the cross-sectional area, m^2; C is the flow rate; ΔP – pressure drop, Pa; P - working density, kg/m^3.

Thus, maintaining a steady flow rate is intended to preserve a pressure differential. Consider the operation of multifunctional systems with reference to a simpler approach.

The system comprises of a non-adjustable pump (N) that constantly controls the differential pressure (BF), hydraulic cylinders A and V, throttle valves TV_1 and TV_2, constant pressure valves PV_1 and PV_2, pilot-operated check valve CV, accumulator valve AV, and pressure gauges.

When pump P is coupled to pipes TV_1 and TV_2, pressure is transferred. Due to the closed portion of the throttling parts, however, the pressure rise impacts the pump regulator and offers a minimum pump transfer, which compensates for system lubrication and internal leakage. As the cross area of the TV1 throttle increases, the pressure on it quickly drops. The PV_1 valve logs this data. If $P_{A1} \angle P_A + P_{spo}$ then the compensator PV_1 is removed and consumed until the condition $PA_1 = PA + P_{spA}$ is met.

Consequently, the opening of the PV_1 valve decreases P_a. Therefore, the PR pump regulator raises the transmission of the pump under the influence of the spring force P_{sp} (set to 20 bar) and restores $P_1 = P_A + P_{sp}$.

We can conclude that this is one of the conditions for $\Delta P_A = P_{A1} - P_A = P_{spA}$, or $\Delta P = P_1 - P_A = P_{sp}$ equality. It follows that the pressure drop due to the valve PV_1 (let's call it as ΔP_{PV1}) is always preserved, and the pump regulator with PV_1 is equal to the difference in the force of the springs $PR(P_{sp})$.

The pressure difference created by the pressure valve PV_1 and the throttle valve TV_1 is always constant and $\Delta P = P_1 - P_A = P_{sp} = 20$ bar. It will, that is, the adjusting force of the pump regulator spring will be equal to P_{sp}.

All pressure levels are recorded via a row of pressure gauges. When the TV_2 valve section is opened, the flow is transmitted to the hydraulic cylinder V: its load is significantly smaller than A (50 bar), therefore the LS signal to the pump controller is shortened through the PR valve, as the pressure from hydraulic cylinder A is high. Consequently, the PV_2 valve maintains constant pressure via the TV_2. As above, the pressure difference is $\Delta P_B = P_{spB} = 7$ bar.

Consequently, the velocity of the hydraulic cylinder V is unaffected by variations in line pressure. When the pressure within the hydraulic cylinder V multiplies, the reversing valve PR is triggered and the pump controller PR controls the flow of fluid to the hydraulic cylinder B.

Consider the functioning of the circuit in Figure 3 in comparison to the operation of the simplest hydraulic circuit.

The image depicts a straightforward hydraulic circuit. It is made up of a permanent transmission pump (H), a hydraulic motor, a throttle valve (TV), and an accumulation valve (AV). The figure also depicts an energy consumption graph. The operation of the circuit is quite straightforward. As shown on the graph, the greatest amount of power consumed by such a system is equal to the entire rectangle's area.

$$N_{max} = P_0 Q$$

where P_0 - adjusted relief valve pressure, Q – pump max transmission.

The force required to move the hydraulic cylinder, or the usable force:

$$N_{hyd} = P_2 Q_2$$

where P_2 – pressure in the hydraulic motor, Q_2 – power supply to the hydraulic motor.

When the pressure P_1 reaches P_0, the valve will open and surplus consumption will flow into the tank. This is known as "loss of power."

$$N_{lostP} = P_1 Q_2 = P_1 - (Q_H - Q_2)$$

Also, part of the energy is lost due to pressure differences in the throttle element (it is lost as heat due to the large resistance):

$$N_{thr} = Q_2(P_1 - P_2)$$

Thus, such a system loses full power:

$$N_{nom} = N_{thr} + N_{nk} = Q_2(P_1 - P_2) + P_1(Q_H - Q_2)$$

$$N_{nom} = P_1 Q_H - Q_2 P_2$$

It can be observed that the power loss increases as the hydro motor's pressure P_2 and consumption Q_2 drop, that is, as the hydro motor's speed lowers. This signifies a high energy consumption and decreased energy efficiency, leading to the early failure of vital system components.

Now let's explore how the MM control system operates.

Power loss is calculated as follows:

$$N_{max} = Q_{max} P_0$$

In this case, the safety valve SV, MM is installed in the control line. P_{1A} or P_{1B} provides the required transmission, protecting the pump system from overvoltage when the pressure increases. In this scheme, the useful power in hydro motors A and B was calculated as follows:

$$N_{usP} = Q_a P_A$$

or

$$N_{nB} = Q_B P_B$$

Q_A, P_A – A consumption and pressure in the hydraulic motor;

Q_B, P_B – B consumption and pressure in the hydraulic motor.

The "lost" energy consists of the loss in the control of the hydraulic actuator A (due to the pressure difference between TV_1 and PV_1) and the loss due to the pressure difference on the load side of the valve PV_2 ("lost" power N_{thrB}).

$$N_{thr} = Q_H \Delta P = Q_H P_{np}$$

where Q_H – max transmission of the pump, $P_n p$ – PR pump regulator spring adjusted pressure.

$$N_{thr} = Q_B(P_A - P_b)$$

where $P_A - P_B$ - The difference in the loading pressure in hydraulic motors A and B. Q_B – B consumption in the hydraulic motor.

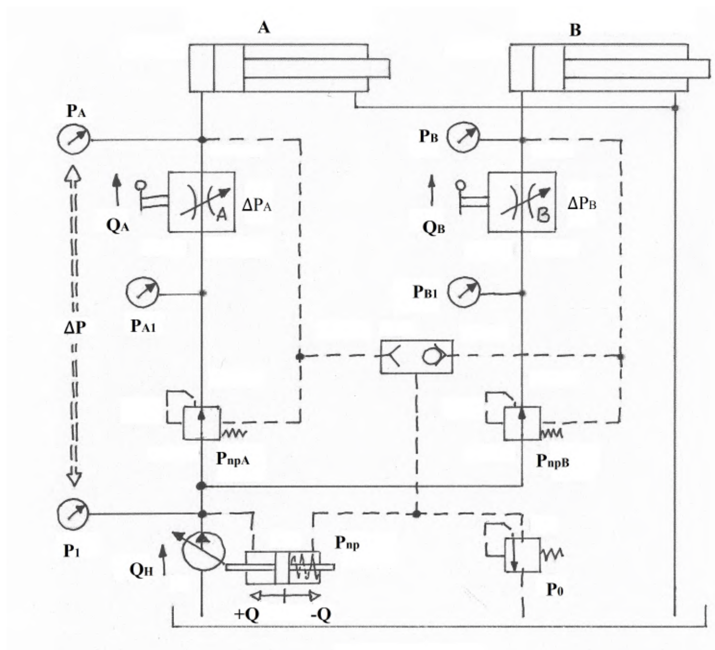

Fig. 3: Multifunctional Systems Diagram

At modest differences in loading pressure on the working bodies of hydraulic motors, the minimum power losses associated with the dissipation of liquid energy into heat are obtained.

It should be emphasized that, compared to the conventional system, the system with LS control is substantially less demanding on energy consumption, and the "lost" power of such a system is significantly smaller, depending only on the pressure drop and pump supply. Therefore, the service life and energy efficiency of a hydraulic system with LS control are multiplied.

IV CONCLUSION

Many mobile equipment and hydraulics continue to employ antiquated hydraulics that are costly to operate and repair. These hydraulics fail to satisfy contemporary standards for quality, performance, dependability, and safety.

Customers' needs were met through the employment of hydraulic valves, hydraulic motors, and pumps with many functions. A characteristic of these hydraulic valves is that the position of the distributor's primary valve is fully proportional under all working scenarios when the pressure or flow from the hydraulic motor is irrelevant. This characteristic of multifunctional systems is a crucial aspect in the workflow, as the amount of time spent on the work of road construction machinery is drastically decreased.

In addition, multifunctional systems offer the following benefits:

- energy savings;
- extended maintenance intervals;
- reduced energy losses;
- low noise levels.

In general, the use of control systems for multifunctional machines improves the dynamics of the moving elements of the hydraulic system, the overall efficiency, reduces costs, accelerates and simplifies work processes; however, the safety of work processes is given the utmost importance.

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