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NEW VEHICLES AS OUR REALITY

Prof dr Nataša Tomić-Petrović, University of Belgrade, Serbia

Abstract: *The world is changing very fast. The future already arrived in industry. Europe and China expel classic automobiles and replace them with electrical. European Union predicts that till 2020 they will have 3,5 million electric cars and 800.000 stations for its filling. In Serbia according to the Ministry of Internal Affairs from 2011. only 114 vehicles on electric power and 90 hybrids were registered.*

The introduction of vehicles without a driver on the roads of the world will happen faster than lawmakers predicted. Recently, the countries began to discuss laws regulating autonomous vehicles, but only a few of them actually adopted such laws. California, Nevada, Michigan and Florida (USA) allow autonomous cars on the road, while their use on public roads in the states that have not enacted laws is neither illegal, nor specifically allowed.

Experts warn that it could take decades before legislators permit the production of vehicles without manual commands and it is possible that during the transitional period when conventional and vehicles without a driver would share the road, security really could be worse. In order to get a vehicle permit, with robots and electronics in them must also stand the man, as well as the system which in the case of emergency enables taking control by man.

The first passenger drone in the world that can independently carry one person by air got permission for testing in Nevada. In the race entered the Chinese, and the first flying car could have its first drive as soon as next year 2020. The Chinese company "Ehang" still in 2016 presented the model of unmanned aerial vehicle that can carry one person 30 kilometers by speed of 100 km/h. The "Airbus" vision of taxi that solves the problem of traffic jam by throwing away of wheels at a special station and hooking on for the roof the massive drone, to pick it up in the air at the critical moment, was presented.

Expectations are that in this type of traffic the number of accidents would decrease for at least 90%, what would save thousands of human lives, while those who due to some limitations are not able to drive a car would not be discriminated, but could use self-driving vehicles like everybody else.

KEYWORDS: AUTOMOBILES, LAW, WORLD, FUTURE, SERBIA

Introduction

In the 18th century, on the streets of the metropolis appeared vehicles using steam. The first vehicle driven on this drive in Paris was constructed by the French explorer Nicholas Joseph Kinjo. As the creator of the modern version of the car is considered the inventor Karl Benz from Mannheim, who was the first who sold in 1880 the vehicle that was working by its own power. Not until the last decade of the 19th century the car with four wheels was created.

There is a remarkable technology progres in the world, so it is believed that by 2025 robots will take over more than half of the jobs. The development of technology, automation and artificial intelligence can cause a loss of 75 million jobs by 2022, but also the creation of 133 million new job positions, according to a report titled "The Future of jobs in 2018". The world is changing very fast. The future already arrived in industry. Europe and China expel classic automobiles and replace them with electrical. European Union predicts that till 2020 they will have 3,5 million electric cars and 800.000 stations for its filling. In Serbia according to the Ministry of Internal Affairs from 2011. only 114 vehicles on electric power and 90 hybrids were registered.

Vehicles for the future – World experience

The homeland of the first modern electrical car is Greece. Today in Europe for example, BMW has unveiled a redesigned "series 7" and completely new look of the vehicle was obtained. For a long time, "series 7" is the bestseller on the Chinese market. After versions for Chinese and the US market "Volkswagen" has shown also refreshed "Passat" (B 8), continuing the life of the eighth generation of this popular model. It is planned that from May 2019 it will be offered to drivers, and it will be using the new technology that allows partially autonomous driving up to the speed of 210 kilometer/h. This car was first presented in March on the Salon in Genève. While the production of the new "Skoda" cars began, company "Volvo" has announced a recall of 167,000 of its automobiles. With the "Volvo" there was a long list of producers who will not appear on the Motor Show in Geneva ("Ford", "Opel", "Hyundai", "Land Rover Jaguar").

The introduction of vehicles without a driver on the roads of the world will happen faster than lawmakers predicted. Recently, the countries began to discuss laws regulating autonomous vehicles, but only a few of them actually adopted such laws. California, Nevada, Michigan and Florida (USA) allow autonomous cars on the

road, while their use on public roads in the states that have not enacted laws is neither illegal, nor specifically allowed.

In 1999 Gehring et al. formulated that the autonomous car (car without driver, self-driving car, robot car) is the vehicle that is able to sense its environment and run without contribution of the driver.¹ There are more degrees of autonomy of self-driving vehicles (Wood et al. 2012).

Experts warn that it could take decades before legislators permit the production of vehicles without manual commands and it is possible that during the transitional period when conventional and vehicles without a driver would share the road, security really could be worse. In order to get a vehicle permit, with robots and electronics in them must also stand the man, as well as the system which in the case of emergency enables taking control by man.

Since 2018, "Deutsche Bahn" that founded the branch "Joki" dedicated to electric mobility and the transport of the future, intends to test its station wagon in several German cities. Testing was conducted in the spa Bad Birnbach, in Bavaria in southern Germany, and this electric mini bus can carry 12 passengers and this is a new era of public transportation.

For the next year "Mercedes" announces the first self-driving vehicle, so driving licenses will not be required. During last year 1,3 million of these cars were sold in the world.

It is interesting that in 2018 /in April / US giant "Ford" ceased to produce passenger cars in its plants in North America. US factory produces only one old model, and it is focused on trucks and SUVs. There is no sentimentality in business! However one model maintained its position (while these models are not: "Fiesta", "Taurus", "Galaxy", "Fairline", etc.) ... that is the famous "Mustang"². It survived all the cuts, the oil crisis of the seventies, the transition to the SUV. It's been 54 years since the first "Mustang" came from the production line - then this model was presented as an alternative to expensive European sports cars. They say "Mustang" represents freedom.

¹ It is a motor vehicle that uses artificial intelligence, coordinates and sensors of the global positioning system GPS /Global Positioning System/ for driving without active intervention of the driver.

² At various tests this car is still passes better than "Porsche" 911. During the year 2017, "Ford" has sold 126,000 in even 146 countries. That was the best-selling sports car in the world.

At the Paris Motor Show opened on the 5th of October 2018, the 120 years of its existence was marked³, and all domestic producers were present ("Renault", "Citroen", "Peugeot") as well as "Mercedes-Benz", "BMW", while many important manufacturers were absent. The French are planning to present 8 new electric cars (record holder is the model "zoe"13, and soon the EV version of the "Quid", a small SUV that is sold on developing markets should join) before year 2022.

Japanese "Nissan" decided made a decision to abandon production new generation of its model "X-Trail" in England, due to the uncertainty related to Bregzit. New model will be produced only in Japan.

In early 2019, at the Consumer Electronics Show in Las Vegas "Mercedes" introduced a new generation of models, "CLA". This small limousine the German manufacturer is now longer, wider and lower than the previous one.⁴ This new generation of the "CLA" model inherited all the best from the A and B class (new digital instrument panel with two touch screen, and the drivers are also offered seats with massage and cooling functions). At the fair "CLA 250" is exposed, while the top version should be "Mercedes CLA 45". The price has not yet been announced to the public.

It is significant that more and more manufacturers are turning to modern technology and that the end of 2018 was marked by hybrids. "Subaru" represented "kroster plug-in hybrid," and "Honda" hybrid version of the model CR-V.⁵ Legend says that every seven days somewhere in the world appears new SUV, popular urban SUV. At the Fair in Los Angeles at the end of November 2018 was presented a hybrid version of the "kroster", which will use innovative technology "Stardrive" that integrates an electric motor, all-wheel drive, built-in lithium ion battery that offers a range of only 27 kilometers (braking is regenerative, so the braking energy is used for charging the battery, as well as on other models).

Smart Mobility in the World

Currently, at least 19 companies are working on the flying cars, especially big ones like "Boeing" and "Airbus". We hope that this idea will become a reality.

The first passenger drone in the world that can independently carry one person by air got permission for testing in Nevada. In the race entered the Chinese, and the first flying car could have its first drive as soon as next year 2020. The Chinese company "Ehang" still in 2016 presented the model of unmanned aerial vehicle that can carry one person 30 kilometers by speed of 100 km/h. The "Airbus" vision of taxi that solves the problem of traffic jam by throwing away of wheels at a special station and hooking on for the roof the massive drone, to pick it up in the air at the critical moment, was presented.

On the Fair in Las Vegas, in January 2019, the drone "Ehang 184" was presented. The most notable at the show in Las Vegas was "Bel nexus" with the hybrid system as the futuristic vehicle. The drone at the fair in Las Vegas thrilled the representatives of one biotechnological company, which announced the collaboration with "Ehang" in order to adapt the vehicle for transportation of organs for transplantation. "Ehang" is hoping to start testing this year.⁶

State of Nevada was one of the first states to permit testing of driverless cars. Last five years, Nevada has become the testing

ground for advanced means of transport. It is one of the first American states which have allowed test driving of cars without a driver on public roads.

"Google" car does that running on the roads - with no driver at the wheel. The idea is that the passenger simply enters the destination on the screen (diagonal of 30 cm), a drone does everything else, from navigation to communication with flight control. It would fly at the altitudes of up to 3.5 kilometers, at speed up to 100 kilometers per hour, using eight propellers on four knobs. The maximum flight length is currently 23 minutes.

However, since the completely autonomous land vehicles probably will not be widely available until the middle of next decade, we should not expect in the near future a taxi drones. "EHang" is hoping the testing of their taxi drone will be the first step in making the technology available to the masses. It's an innovative jump in drone technology.

At the time of law of obligations codification, special rules were set out concerning the responsibility of the state. Rules are also regulating causes of damage and compensation. The question is how long will it take to get a report on the accident and what will be the costs if the investigation takes months?

The "flying car" was produced in "Boing" to ensure that passengers can fly over the street jam, successfully passed all the tests, but the question is whether this will be the mean of transport of the future. Fully autonomous prototype successfully passed testing in the State of Virginia. For only one year, from concept to flying model was passed the right way. In just one year the road from concept to flying model was covered. The vehicle is electric, and the idea is to fly on its own, without a pilot. The length of the route for transportation of passengers will amount to 80 kilometers. Almost all aviation companies compete in this production and by the newest information the flying car should start with transportation of passengers already from 2020.

News from Serbia

Serbia has made great progress in the area of digitalization⁷, which is a great chance to be more efficient, with the motto "Proudly made in Serbia". New chance could be a new model "Fiat Gardiniera"⁸ that will be produced in the factory in Kragujevac in Serbia. Along with the classic version of this car in Kragujevac will also begin the production of hybrid version of "Fiat 500".

New industrial politics, the 4th industrial revolution which meant development of the new technologies, digitalization, production automation, smart factories and buildings, the development of energy storage systems and advanced IT technologies the future development of Serbia is based on. These are our strategic aims and especially the development of the infrastructural network (railway infra-structure and development of the new railroad tracks Belgrade, Serbia – Budapest, Hungary) is of the great importance. This fast railroad tracks should be open by 2023, with 60 road crossings what will significantly increase the level of security and the maximal speed of train will be determined by the computer at every moment.

We know that fulfilling the promises is difficult, but in these conditions possible.

On the highway from the capital town Belgrade to Niš were placed 56 cameras⁹ for those who escape from paying the toll or exceed the prescribed speed. Public Enterprise "Roads of Serbia" wants to increase the scope of toll payment from 99.92 to 100% and so prevent arrogant drivers to break down fences and exit the

³ In 1898. the first Motor Show was organized in Paris and it is held every two years.

⁴ The distance between axis was increased for 30 millimeters and it now amounts 2.729 mm. Trunk volume is 460 liters.

⁵ Hybrid CR-V can already be ordered, and delivery are planned to begin in February 2019.

⁶ The Chinese company will have to prove to the US Federal Aviation Agency that drones are safe for utilization in the air space, before they start to use them in the larger capacity,

⁷ Programming was introduced as a compulsory subject in schools in Serbia.

⁸ An extended version of the "Fiat 500" with places for 5 passengers and a slightly larger luggage compartment..

⁹ The cameras will be placed at the 28 existing portals in both directions.

highway without authorization on so-called "wild exits", as well as the trucks that are overloaded more than it is allowed. The new method of control on the highway will have the subsystem for notification of drivers on the situation on the highway, toll stations, border crossings, stoppages, as well as meteorological conditions.

"Fiat"¹⁰ remains in Serbia and is preparing the new model of automobile "601". The future of this company will be insured in Serbia. In the sections of the factory in Kragujevac are already ready for serial production of the model "550-L" with hybrid power. The capacity of the factory in Kragujevac is more than 185.000 automobiles yearly. Till September 2018, only 2% of "Fiat's 500 L" quota was sold in Serbia and the rest in Europe and the United States.

With improved infrastructure and transport means Serbia would be able to compete with the traffic of European countries. It is a hybrid model with an electric motor. The new "B-SUV" would be produced in Kragujevac in parallel with the existing model "500 L". And in this 2019 year Belgrade, our capital will be a candidate for the green capital of Europe.

The World arrived in Belgrade in the period from 22 to 31st of March 2019 at the International Car Salon. It was one of the most attractive fairs in the last ten or more years. The market of new cars in Serbia is recovering, however, the number of premieres depends on the Salon in Geneva, and more novelties of hybrid and electric vehicles were confirmed. The main theme were electric vehicles and hybrids, and the scientific meeting on electromobility was organized too. There were 400 exhibitors from 30 countries, and 48 premieres at the exhibition.

Conclusion

Autonomous vehicles are considered to be the technology that will change the city, public and private transportation, as well as the concept of mobility in general. Besides the undisputed safer driving, autonomous vehicles would be lighter than the existing and would contribute to the reduction of average fuel consumption (if the petroleum products would still be used to drive these cars).

Automobile Association of the Journalists of Serbia proclaimed the " **Peugeot 508**" as the "Car of the year 2019". The best-selling car in the competition of hybrids during 2018 was the "Toyota", and the best-selling electric car "model Volkswagen AP".

The expansion of autonomous vehicles will depend on the belief of the public that are selfdriving cars are considerably safer than those manually-controlled. Expectations are that in this type of traffic the number of accidents would decrease for at least 90%, what would save thousands of human lives, while those who due to some limitations are not able to drive a car would not be discriminated, but could use self-driving vehicles like everybody else.

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¹⁰ Today we have the museum for old timers, in which among other exhibits there is also the one with motor of "Fiat" popular "Fića" constructed by domestic intellect in Rakovica (it did not achieve to make a way through serial production, but on tests it showed excellent performances, better than "Fiat's" original). Many years ago our engineers M. Davidović, M.Popović and D. Koprivica completed bolide, little motor of 850 cubic meters that will reach speed of 160 km/h. Even to-day it is in excellent condition and they made it as a hobby. The whole Museum was made with love, old timers are today fixed up and all drivable. This Museum is today interesting and valuable place in the center of Belgrade.

EVALUATION OF THE EFFICIENCY OF THE VEHICLE WITH VARIOUS INTER-WHEELED DIFFERENTIALS FOR DIFFERENT CLUTCH CONDITIONS ON SIDES IN ACCELERATION REGIME

ОЦЕНКА ЭФФЕКТИВНОСТИ РАЗГОНА АВТОМОБИЛЯ С РАЗЛИЧНЫМИ МЕЖКОЛЕСНЫМИ ДИФФЕРЕНЦИАЛАМИ ПРИ НЕОДИНАКОВЫХ УСЛОВИЯХ СЦЕПЛЕНИЯ ПО БОРТАМ

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Abstract: *In this paper, the dynamics of acceleration and energy costs for cars with various types of inter-wheeled differentials are analyzed. The used dynamic models for drive with: a classical symmetric conical open differential, a fully locked differential, and limited-slip differentials for which the locking torque depends on the load or the relative speed of rotation are described. During the study, the ratios of the adhesion coefficients under the right and left sides were varied. As a result of the work, tasks are formulated for further more detailed analysis of limited-slip differentials.*

KEYWORDS: INTER-WHEELED DIFFERENTIALS, LIMITED-SLIP DIFFERENTIALS, ENERGY EFFICIENCY, ACCELERATION DYNAMICS.

1. Introduction

The need for inter-wheeled differentials arose immediately after the appearance of the first vehicles with a two-wheel drive on the same axle. The most noticeable this need was manifested when the car turns and drives on roads with irregularities. The absence of an inter-wheeled differential in transmissions leads to the appearance of power circulation, unjustifiably large additional loads on the drive axle and wheels, increased fuel consumption, and large tire wear. With the invention of the classical conical symmetrical inter-wheeled differential, these problems were solved. However, other problems associated with the phenomenon of slippage in severe road conditions are appeared. Naturally, there was a large number of technical solutions to this challenge that somehow smoothed out the problem, but did not solve it in a all-inclusive manner.

The simplest and chronologically the first solution to combat slippage of one of the driving wheels was a complete interlock of the differential on demand (manual control). As a rule, the locking is effected by a gear or cam clutch. In this case, the process of turning the clutch on or off requires a complete stop of the vehicle. In severe road conditions, this requires the driver to activate the described device in advance. Such a locking provides maximum traction capabilities of the wheeled propeller, since it allows to transmit up to 100% of the power to any of the wheels, which is able to accept it under the conditions of adhesion to the supporting surface. If the implementation of a complete locking is structurally solved using a friction clutch, it no longer requires the vehicle to stop. This design is relatively easy to automate, but is usually associated with an increase in the size and weight of the differential and the main gear, as well as a decrease in ground clearance. Full locking of the differential requires mandatory shutdown after entering to the road with a hard surface or a dry dirt road.

The second solution to the slip problem was the invention of a whole group of self-locking differentials or limited-slip differentials. Depending on the design, these may be Torque sensitive differentials (HLSD) or Speed sensitive differentials. In recent decades, there have been design solutions in which the degree of blocking is electronically controlled by a given algorithm, as well as drives in which the traction control system directly controls the torque applied to each drive wheel. Especially effectively they work in the case of electric or hydrostatic motor-wheels.

In the scientific and technical literature, the distribution of power between wheels and axles in modern cars is given a lot of attention. There are a large number of publications describing the work of different types of differentials [1–6] and considering a scientific approach to determining their optimal characteristics [7–10]. However, in most cases when analyzing the differentials for

cars operating in difficult road conditions and off-road, the issues of proper patency are considered.

The papers [11–14] also consider the efficiency of using differential drives primarily for all-wheel drive vehicles. Especially intensive in this direction works the scientific school headed by Andrei Keller from the South Ural State University (Russian Federation). However, the complex comparative analysis of the dynamics of acceleration and losses on slippage for various types of inter-wheeled differentials has not been found in the literature. This issue, despite the rapid development of electronic control systems and individual electric drives, remains relevant for military wheeled vehicles and all-wheel drive vehicles of multi-purpose use, in which the full lock of differentials with manually operating is still most often used.

2. Materials research.

2.1 Formulation of the Problem

In this paper, the authors posed the task of performing a comparative analysis of the classical (open) conical symmetric differentials, of the limited-slip differentials, of the traction control systems (TCS) based on anti-lock brake systems (ABS) and of the completely locked differentials, from the point of view of the dynamics of the acceleration of the machine, the magnitude of the slip losses and the magnitude of the moment of resistance to turning. The study was carried out for vehicles under conditions where dry and pure asphalt concrete is located under one of the sides of the machine, and under other side the coupling properties of the road surface change from dry asphalt to an icy road. The car was considered as all-wheel driven, but the type of the inter-axle differential and the method of power distribution between the axes at this stage of the research was adopted rigid (blocked). In this case, the wheel propeller on each of the axles can realize the traction force proportional to the coupling weight. This was done to assess the effect on the investigated factors of the imbalance of the adhesion coefficients under the sides and the specific power for any single axis.

2.2 The Description of the Mathematical Model of the Vehicle Acceleration and the Calculation Assumptions Accepted Assumptions, Baseline Data and Variable Parameters.

- 1) The entire weight of the all-wheel-drive vehicle is reduced to one axis and is considered constant during the entire acceleration time. Vibration processes in the suspension of the vehicle are not considered.
- 2) We considered a plane model of vehicle rectilinear motion on a horizontal surface during acceleration without lateral displacement and skidding.

- 3) The change in the instantaneous radius of the driving wheel with respect to the static radius under the influence of the driving torque and centrifugal forces is not taken into account.
- 4) The resistance of air during acceleration is not taken into account, since acceleration is considered up to 10 m/s.
- 5) We accept that the left wheel is always in better conditions of grip with the road than the right one.

The work examines the acceleration from the place of the all-wheel drive wheeled armored personnel carrier BTR-4, which is in conditions when the adhesion coefficient of wheels with the road under left side meets the dry clean asphalt $\varphi_l = 0,8$, and under right side the adhesion coefficient varies in different arrivals from dry asphalt $\varphi_r = 0,8$ to the icy road $\varphi_r = 0,1$.

The middle coefficient of resistance to movement (drag coefficient) also changed in various races from dry clean asphalt ($f_m = 0,02$ for tires with adjustable pressure) to wet dirt road $f_m = 0,08$.

The drive to the differential was stepless with constant power, which was limited to the maximum torque with a value providing a specific traction force equal to unity. This limited the slippage of both wheels during the acceleration process.

For carrying out the calculations, the data needed were taken using the example of the wheeled armored personnel carrier BTR-4, namely:

- armored vehicle weight $G = 24$ tons;
- static wheel radius at normal tire pressure $R_w = 0,525$ m;
- reduced moment of inertia of a wheel with a wheel gear and a semiaxis $I_{l(r)} = 1,5$ kg·m²;
- moment of inertia of the drive (engine and transmission) in the first gear $I_{in} = 5$ kg·m²;
- the maximum torque on the differential case when the specific thrust force is limited to unity $M_{in}^{max} = 7275$ Nm.

Structure of the Mathematical Model.

The calculation scheme for modeling the process of accelerating the machine is shown in Fig. 1. Here the following forces and torques are indicated:

- G_M – weight of the armored personnel carrier, per axle;
 - $N_r = N_l = G_M/2$ – normal reaction of soil (road) in the contact spot of one wheel;
 - P_{Dl} and P_{Dr} – The traction forces realized on the left and right driving wheels that calculated as functions of the coefficients of slipping and grip on each of the wheels $P_{Di} = f(\sigma_i, \varphi_i)$;
 - P_{Rl} and P_{Rr} – rolling resistance forces on the left and right driving wheels, calculated as the product of the mean under the right and left sides of the drag coefficient f_m and normal ground reaction N_i ;
 - $P_{Rl} = P_{Rr} = N_i f_m$, where $f_m = (f_l + f_r)/2$;
 - M_{in} – input (driving) torque on the differential case;
 - ω_{in} – angular velocity of the input link (differential case);
 - I_{in} – the moment of inertia of the differential case and the associated rotating parts of the drive;
 - M_l and M_r – torque on the left and right driving wheels;
 - ω_l and ω_r – angular speeds of rotation of the left and right driving wheels;
 - I_l and I_r – moment of inertia of the left and right driving wheels with a wheel gear and a semiaxis;
 - V_M – linear speed of the machine along the coordinate axis X .
- Three generalized speeds are identified in the model:
- ω_{in} – angular velocity of the input link (differential case);
 - $\Delta\omega$ – the difference between the angular velocities of the right and left semi-axes or driving wheels (in the absence of wheel gears), determined by formula $\Delta\omega = \omega_r - \omega_l$;
 - V_M – linear speed of the machine along the coordinate axis X .

For these generalized velocities, according to the d'Alembert principle (Newton's second law), differential equations are constructed that describe the accelerated motion of these masses:

$$(1) \quad \frac{d\omega_{in}}{dt} = \frac{M_{in} - M_l - M_r}{I_{in} + I_l + I_r};$$

$$(2) \quad \frac{d\Delta\omega}{dt} = \frac{(M_l - M_r)\eta_{cg}^2 - M_{fr}}{I_l + I_r};$$

$$(3) \quad \frac{dV_M}{dt} = \frac{P_{Dl} + P_{Dr} - P_{Rl} - P_{Rr}}{G_M/g},$$

where η_{cg} – coefficient of efficiency of differential with conical straight teeth ($\eta_{cg} \approx 0,95...0,96$); M_{fr} – additional frictional torque, formed on the limited-slip differentials or on brake mechanisms of ABS to prevent intensive slippage.

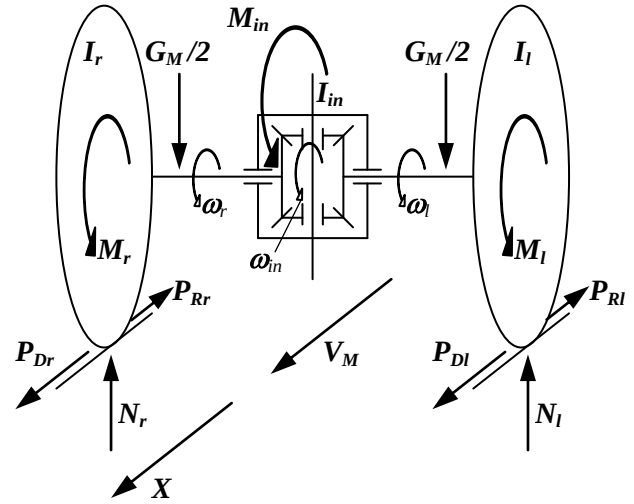


Figure 1 – Calculation scheme for modeling the process of the machine accelerating

Regardless of the type of modeled differential, the torque input is applied to the system input, which is calculated according to the following algorithm:

- for a specific power and current angular velocity given in a particular experiment, the input torque is determined for one of the four axes

$$M_{in} = \frac{N_s G_M}{4\omega_{in}};$$

- if $M_{in} > M_{in}^{max}$, then we accept $M_{in} = M_{in}^{max}$;
- to determine the traction forces P_{Dl} and P_{Dr} , we first calculate the theoretical and actual speeds of the wheels along the sides and the corresponding skid coefficients:

$$\sigma_l = \frac{(\omega_{in} - 0,5\Delta\omega)R_w - V_M}{(\omega_{in} - 0,5\Delta\omega)R_w} \quad \text{and} \quad \sigma_r = \frac{(\omega_{in} + 0,5\Delta\omega)R_w - V_M}{(\omega_{in} + 0,5\Delta\omega)R_w},$$

and then, using known dependencies $P_D = f(\sigma, \varphi)$, we determine the traction forces P_{Dl} and P_{Dr} as a function of the corresponding skid coefficients and the current values of the adhesion coefficients φ_l and φ_r ;

- then the torques on the wheels M_l and M_r are determined by multiplying the corresponding traction forces by the radius of the driving wheel R_w .

In the simulation of the blocked inter-wheeled differential in equation (2), it is assumed that $\Delta\omega = 0$ and $\frac{d\Delta\omega}{dt} = 0$.

When modelling the limited-slip differentials, the additional frictional moment is determined depending on the type of differential or traction control systems as follows.

For differentials in which the degree of blockage depends on the load (torque sensitive differentials):

$$M_{fr} = M_{fr0} + k_M(M_l + M_r),$$

where M_{fr0} – initial value of additional locking torque; k_M – coefficient of proportionality.

For differentials in which the degree of blockage depends on the difference in the speed of the wheels rotation $M_{fr} = k_{\omega} \Delta \omega$ or $M_{fr} = k_{\omega} \Delta \omega^2$ depending on the type of differential, where k_{ω} – corresponding coefficient of proportionality.

When using TCS based on ABS, the algorithm for determining the additional frictional moment is as follows:

– if $\Delta \omega < \Delta \omega_0$, then $M_{fr} = 0$;

– if $\Delta \omega > \Delta \omega_0$ and $\frac{d\Delta \omega}{dt} > 0$, then there is an increase in the frictional moment with a high speed in proportion to time $M_{fr} = k_t t$;

– if $\Delta \omega > \Delta \omega_0$ and $\frac{d\Delta \omega}{dt} < 0$, then the value of the frictional

moment is fixed from the previous calculation step and does not change.

It should be noted that when using TCS based on ABS, in equation (1) the additional friction moment is also added, since it additionally loads the drive:

$$\frac{d\omega_{in}}{dt} = \frac{M_{in} - M_l - M_r - M_{fr}}{I_{in} + I_l + I_r}.$$

The acceleration of the machine was carried out to a speed of 10 m/s, while at each step of solving the system of differential equations the work performed by the drive was calculated, summing over the entire period of acceleration.

2.3. Calculations results

In fig. Figures 2-5 show the calculation results for the various inter-wheeled differentials, described above, for the BTR-4 armored personnel carrier. On all graphs, the horizontal scale is presented in relative units $\Delta \varphi = \frac{\varphi_r}{\varphi_l} \in [0,125; 0,5]$, characterizing the balance of

adhesion coefficients under the sides. The right boundary of the range was calculated to $\Delta \varphi = 1$, but due to the low information content on this site was limited to $\Delta \varphi = 0,5$.

Calculations were carried out for the following types and characteristics of differentials: w_{10} , w_{20} and w_{40} – differentials in which the locking factor depends on the difference in wheel speeds with coefficients, respectively: $k_{\omega} = 10, 20, 40$ Nm·s; qw_{05} , qw_{1} , qw_{15} and qw_{2} – differentials in which the locking factor depends on the square of the difference in wheel speeds with coefficients, respectively: $k_{\omega} = 0,5; 1,0; 1,5; 2,0$ Nm·s²; M_{02} , M_{04} and M_{06} – differentials in which the locking factor depends on the load with coefficients, respectively: $k_M = 0,2; 0,4; 0,6$; TCS – traction control system based on ABS with $\Delta \omega_0 = 5$ s⁻¹, $k_t = 20000$ Nm/s.

In all graphs, the results are presented in relative units relative to the indicators obtained for the blocked differential. Since the blocked differential has the best performance in straight-line motion, all the values shown in the graphs are greater than one.

The graphs do not show curves for an open conic differential, since they differ significantly from other indicators and have a bad effect on the scale. For average coefficients of resistance to movement $f_m = 0,02$ and $f_m = 0,08$, the relative excess of the acceleration time to 10 m/s with an open differential is 1,91 and 5,19 respectively. And the relative excess of energy costs for the same conditions is 2.13 and 5.85 respectively.

All the charts in the work, as mentioned earlier, were built for the wheeled armored personnel carrier BTR-4, which as standard has a specific power of 14.58 kW / t (19.83 hp / t).

This moment is significant, since the change in specific power, both in the smaller and in the larger direction, substantially distorts the obtained graphical dependencies not only in absolute, but also in relative dimension.

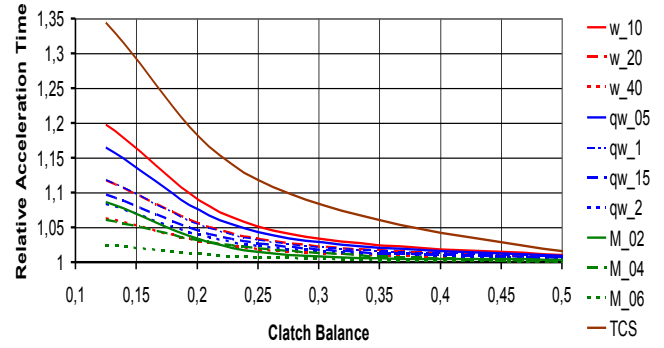


Figure 2 – Comparison of the relative acceleration time during the acceleration up to 10 m/s of armored personnel carriers with different types of differentials on a road with an average drag coefficient $f_m = 0,02$

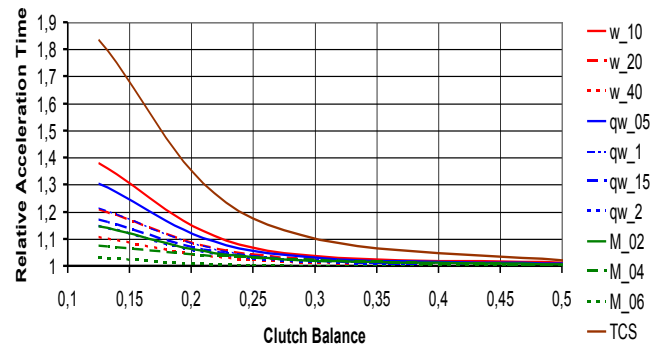


Figure 3 – Comparison of the relative acceleration time during the acceleration up to 10 m/s of armored personnel carriers with different types of differentials on a road with an average drag coefficient $f_m = 0,08$

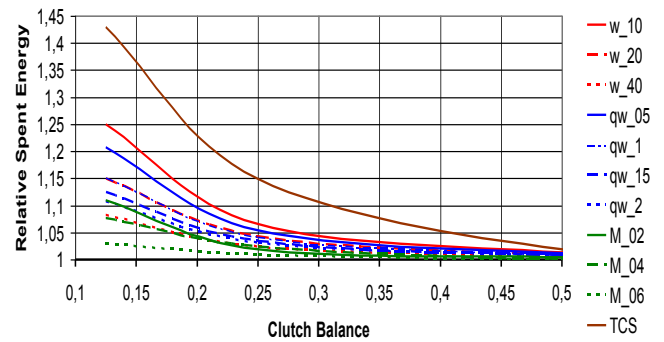


Figure 4 – Comparison of the relative spent energy during the acceleration up to 10 m/s of armored personnel carriers with different types of differentials on a road with an average drag coefficient $f_m = 0,02$

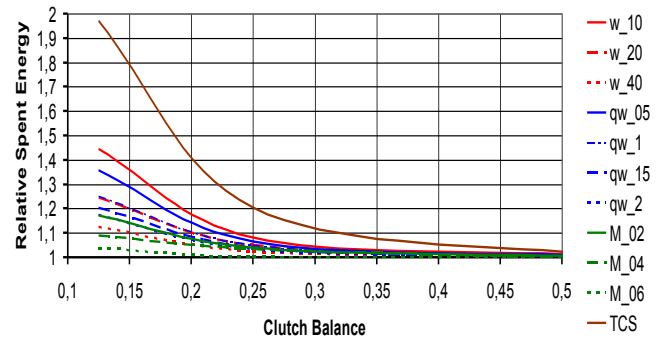


Figure 5 – Comparison of the relative spent energy during the acceleration up to 10 m/s of armored personnel carriers with different types of differentials on a road with an average drag coefficient $f_m = 0,08$

3. CONCLUSIONS

In accordance with the goals and objectives set for the results of the work done, the following conclusions can be drawn:

1) Non-blocked open conic differentials and fully-locked differentials were considered only to determine the boundaries of the worst and best overlocking performance indicators.

2) The comparative data obtained are given for the average values of the system adjustment factors. Therefore, for final conclusions about the advisability of using a particular limited-slip differentials or TCS based on ABS, taking into account the influence of the differential on the controllability of the machine, it is necessary to optimize by the setting factors.

3) From the preliminary consideration of the problem, it can be stated that all the limited-slip differentials in terms of the efficiency of straight-line acceleration are close to the characteristics of the locked differential in the following sequence:

- fully-locked differentials;
- differentials in which the locking factor depends on the difference in wheel speeds;
- differentials in which the locking factor depends on the square of the difference in wheel speeds;
- differentials in which the locking factor depends on the load;
- TCS – traction control system based on ABS;
- open conic differentials.

4) Differentials with TCS based on ABS are most appropriate for relatively small values of imbalance of adhesion coefficients along the sides of the machine and to integrate them with systems for maintaining directional stability, which allow, depending on the situation, to change the values of the coefficients of the system settings.

5) Limited-slip differentials, in which the blocking moment depends on the square of the difference in the speed of rotation of the wheels, can have high energy parameters during acceleration with minimal negative impact on the controllability of the machine and at the same time rely not on electronic control systems, but on their own internal automatism.

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FEATURES OF THE HYBRID VEHICLES WORK MODE CONTROL STRATEGY

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Abstract: The transmissions of HEVs or so-called hybrid transmissions (HT) are essentially power split transmissions, which almost always require planetary gears to split or sum up power. An essential prerequisite for reading and studying hybrid transmissions is the knowledge of planetary gear function and calculation. For example, the Toyota hybrid system can only be clarified using the principles of the planetary mechanism. In addition to Toyota's decision, there are two modes of transmission (BMW, Daimler and GM) and many patent applications with similar ideas.

Technically speaking, these solutions are power split transmissions that turn into a hybrid system by adding an electric motor (EM), an electric generator (EG) and an electric storage battery (SB). These transmissions perform the functions required for vehicles with an internal combustion engine, such as the HEV.

These functions are launching, torque and speed conversion, reverse gear, and rapid gear-shifts in ascending or descending order. In addition, the requirements for HT are realized with the help of electronic control. For parallel HEV, a conventional gearbox plus EM is used. The automatic transmissions used in the mixed HEVs are designed with planetary gearboxes and are also known as automatic HTs.

This article discusses the features of planetary gearboxes used in HEVs transmissions.

Keywords: HEV, WORKING MODE, STRATEGY

Automotive sensors and actuators are widely used in modern vehicle control systems [1]. It is important to understand and design management programs and also be able to use tools and software to generate such programs. [3].

Modern cars are subject to even tougher requirements regarding power, torque, fuel economy and environmental performance [4]. In all high-tech systems of modern cars a CAN protocol is used for communication between individual controllers [2]. The reliability of the entire vehicle control system is determined by the reliability of the most vulnerable components [5].

The HEV control strategy is essentially an algorithm that defines the operating points of the HEV drive components [6]. The main purpose of the control strategy is to ensure that the driver's demand is met and the efficiency of the power system optimized. The main inputs of the control controller are the vehicle speed and pedal inputs. The secondary inputs for traffic information, traffic and GPS can also be used in more controllers. Controller outputs are command signals for powertrain components, such as torque control of internal combustion engine (ICE) and EM, and commands for switching on / off certain components.

The charge state (SOC) of the SB or energy storage system should also be maintained within levels that prolong the SB resource. The control strategy determines when and how much the energy storage system will allow a deep dilution of the SB in order to meet the driver's requirement. In addition, the kinetic energy of the vehicle can be restored and stored in the energy storage system using regenerative braking when the HEV stop command is set by the driver.

Additional targets targeting the control strategy algorithm include all or some of the following: Increasing drive efficiency and / or fuel economy, reducing emissions and maintaining good manageability. Improving fuel efficiency and reducing emissions is an increased requirement; an optimization algorithm can be used to determine the best operating points of the ICE and EM. User-friendliness is also a key parameter for HA's market demand; the controller must ensure that the driver's feel is almost the same as that of the conventional ICE car. Changes in the management of the various drive components must be carefully coordinated to maintain the high quality of HEV control. Convenience can be measured in terms of gear shifting and drive vibration.

The deterministic, rule-based method of the management strategy is further developed with the help of mixed HEV entities. Mixed components with two EDs and one ICE can be implemented either by means of a planetary mechanical control device or using modal (electronic) control. The strategies for choosing the mode of operation of split (series-parallel) HEV are discussed below.

1. Operating modes with mechanical control of torque distribution

The mechanically-controlled mixed-mode hybrid drive uses a Planetary Power Distribution Device (PPDD) without clutches in the drive. The concept of power distribution using a set of planetary gears was first introduced by TRW [7,8]. The gearbox, which is connected to the PPDD, offers uninterrupted variations in torque (CVT) and power, while allowing three drive components to be mounted in one transmission. Mechanical power distribution management has quickly become the choice of design for hybrid sedans, light trucks and SUVs. The mechanical design offers compactness and ease of assembly with EM, EG and ICE mounted in one transmission.

The scheme for driving a mixed HEV with the PPDD similar to Toyota Prius is shown in Figure 1 [6]. The PPDD has three gears: an ring wheel, a sun wheel and an arm. The crankshaft of the ICE is connected to the arm of the PPDD. The mechanical power is transmitted to the main transmission (end-drive) from the ICE and EM via the ring wheel. There is no direct link between the ICE and the final drive. The EG is connected to the sun wheel; EM along with the drive wheels is connected to the ring wheel. The power of the ICE can be divided and part of it transferred to the final drive and the wheels and thence through the sun wheel to EG for producing electric power. ICE drives EG, which loads SB or feeds EM or performs both. The work of EG produces resistance torque on the waterline to which the crankshaft of the ICE is connected. EM can add torque to the sun wheel to provide additional power to the drive wheels. The EG can also operate in EM mode during peak acceleration to add torque to the PPDD which is then transmitted to the drive wheels via the solar wheel. Both electric machines can operate either in engine mode or in generator mode. During regenerative braking, EM acts as EG for the use of kinetic energy at regenerative braking, which is converted into electrical energy and stored in SB. Several

possible modes of operation are described in more detail by linking the PPDD and the reversible modes of operation of the EM and EG [9].

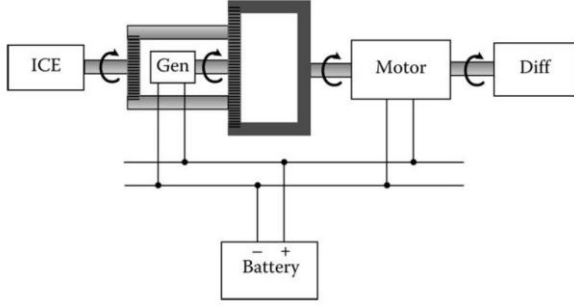


Fig.1. Location of the power components of mixed HEV with the PPDD [6]

The power ratio of HEV is the sum of the capacities of the ICE and EM [1] and is given by the dependence (1):

$$P_{engine} = P_{engine\ to\ ring} + P_{engine\ to\ sun} \Rightarrow T_p \omega_p = \frac{r_r \omega_r}{r_r + r_s} T_p + \frac{r_s \omega_s}{r_r + r_s} T_p \quad (1)$$

The directions of rotation shown in Figure 1 for the three PPDD gears associated with the three drive components are assumed to be a positive direction of rotation.

1.1 Mode of operation with EM (low speeds, reversing, battery charging)

In this mode, the internal combustion engine is switched off and the wire is stationary, ie, $\omega = 0$. The generator that performs the function and the starter rotate freely in idle conditions in the opposite direction. The speed relationship between EG and EM is given by an expression (2):

$$r_r \omega_r = -r_s \omega_s \quad (2)$$

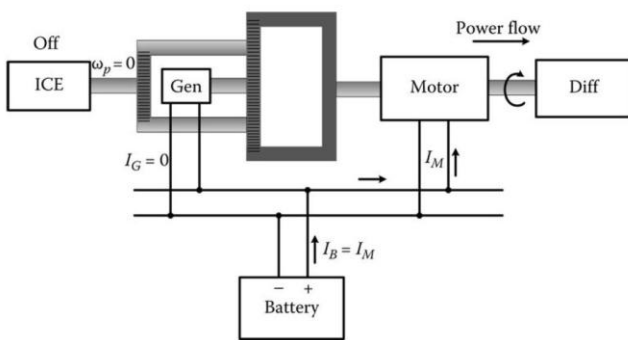


Fig.2. Electric mode of operation.[6]

The electric drive driven by the SB energy provides the traction force of the drive wheels as shown in Figure 2. No power is transmitted through the PPDD. The accelerator pedal position (set by the driver) and the vehicle speed determine the set current value of the EM (3):

$$I_{motor} \omega_{motor} = \frac{P_{motor}}{\omega_r} \quad (3)$$

The SB can be recharged using regenerative braking control strategy, with the EM operating in EG mode when HEV is running in inertia or stops while the ICE is off.

1.2 Starting the ICE and low speeds

To run an internal combustion engine it is necessary to work in the engine (starter) mode. The starter mode is activated by a command from the driver, where EG rotates in the opposite direction and draws power from the SB for the purpose of running the ICE. The starting of the HEV can be accomplished with the power provided by the EM. The energy source during the start of the ICE and the start of the HEV is SB.

1.3 Parallel Mode (Peak Acceleration)

The drive operates in parallel peak acceleration mode, which may be required during acceleration of the HEV. Simultaneously the ICE, EG and EM participate in this short-term process. The power flow in the parallel mode is shown in Figure 3.

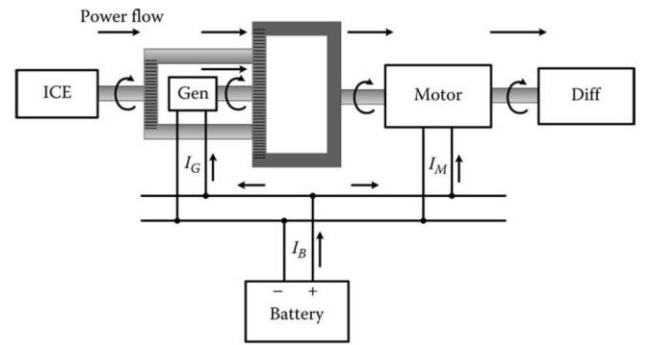


Fig.3. Parallel operation of electrical and mechanical components from power transmission[6]

The power of EG, using equation (1), is obtained from:

$$P_{sun\ to\ ring} = \frac{r_s \omega_s}{r_r + r_s} T_p, \quad \omega_s < 0 \quad (4)$$

The sun wheel rotates in the opposite direction, i. in an anti-clockwise direction viewed from the shaft of EG, that is, $\omega_s \leq 0$. The reverse rotation of the solar wheel increases the torque of the internal combustion engine, allowing EG to produce the power for the EM, which is transmitted to the final drive. The input of EG in this case is an SB power supply.

1.4 Power distribution mode (smooth running, low acceleration)

In this mode, the internal combustion engine power is divided between EG and EM, as shown in Figure 4. ICE assists the EM by adding more torque to the differential input shaft of the final drive. At the same time, some power of the EM can be diverted to the solar gear to bring EG into the generator mode to charge SB. EG rotates forward.

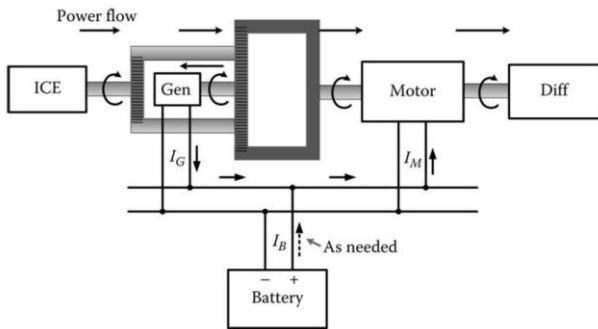


Fig.4. Power distribution mode [6]

The power flow of the ICE to EG, and hence to the SB, is regulated by controlling the engine speed, since the percentage of the torque of the EM shifted to EG is mechanically fixed. The required power of AB determines the current of EG, and hence its torque (5).

$$I_{gen} \rightarrow T_s = \frac{r_s}{r_r + r_s} T_p \quad (5)$$

This torque on the sun wheel of the PPDD, in turn, fixes the torque T of the EM; therefore, ICE must be speed controlled.

1.5 Engine Brake Mode

In this mode, an ICE runs idle and draws some energy. EM rotates freely ($I = 0$). EG rotates in the opposite direction and generates electrical energy. The power flow in this mode is shown in Figure 5

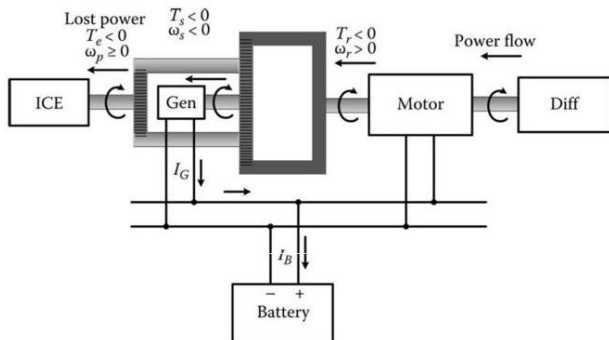


Fig.5. Engine Brake Mode [6]

1.6 Regenerative braking mode (SB charging)

In this mode, the shaft of EG rotates freely ($I = 0$). EM is driven by the kinetic energy of HEV and restores (recharges) SB. The power flow in this mode is shown in Figure 6.

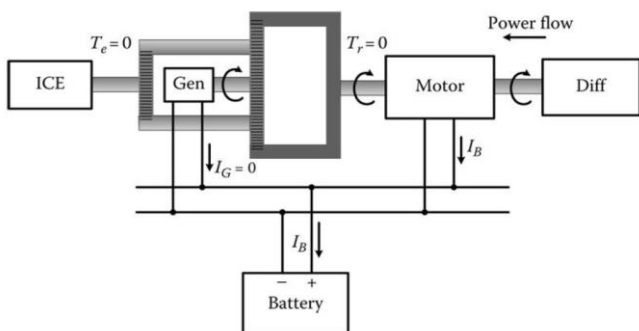


Fig.6. Regenerative braking mode [6]

3. Modal control strategies

Modal control algorithms use driver commands and system feedback inputs to meet the requirements, while optimizing drive efficiency and minimizing emissions. SOC of the SB is also maintained in a predefined range to meet performance requirements without damaging the system.

The control algorithms within the modal control strategy define the best reference points for the energy converters and the best transmission ratio for the transmission. Management algorithms can be generated based on an optimization algorithm, where the cost function, which is fuel economy, emissions, efficiency, or SB resource, is minimized. Global optimization to achieve the best fuel efficiency depends on the prior knowledge of energy consumption and driving conditions, which is only possible in simulation. Global optimization based on fixed driving cycles can be used to define real-time flow management rules. In real-life scenarios, a management strategy based on real-time optimization can be developed [10,11].

For this, an instantaneous cost function, defined as real-time variables, applicable to such an optimization strategy is used. Drive subsystems place limits on maximum continuous and peak power that can be provided in individual operating modes.

However, the modal control algorithms share general calculations to determine the maximum power that the ICE, EM, and EG can provide. The calculations are based on the maximum load values of transmission devices, temperature, current of the current bus, the velocity of the HEV and other parameters that determine the operating point limits for each subsystem. For example, the power limitation of the EM can be achieved as a function of the reduction of the bus voltage. The voltage of the bus depends on the stored energy in the SB. The purpose of reducing the DC power for reduced voltages is to ensure acceptable control by eliminating the sudden reduction of acceleration if the EM enters the shutdown mode when the SB is depleted. The power limitation for the EM also depends on the temperature. The nominal voltage values of the EM are reduced for the increased operating temperatures.

Conclusion

Single, parallel, and mixed HEV modes require different management algorithms. Optimization methods, if used, for different modal control strategies are also different. It should be noted that the modal control strategies discussed in this article are just examples; there may be various other ways to implement a modal control strategy depending on the size of the available components of the power aggregates and the desired optimization strategy.

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CO₂ EMISSIONS OF E-MOBILITY

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Abstract: E-mobility is generally regarded as a zero emission. This sentence can only be true in a very small scope, as only in relation to selected parameters and in a very limited its dimension. An example of this is the measurement of CO₂ emissions from BEV (battery electric vehicle), which is known to be zero. The situation can change radically if it will be take into account the emissions in the production of electricity that is necessary for the movement of this type of vehicles. This paper presents this problem, taking into account the energy mix in various countries of the European Union. Simulation studies show that there are already countries in the EU in which the operation of electric vehicles makes sense. Especially when it concerns CO₂ emissions. Emissions below the standards for 2025 can be obtained there. Unfortunately, in most EU countries, the operation of BEV is associated with an increase (in relation to today) of CO₂ emissions. Without the change of energy policy, and in particular the energy mix, the introduction of e-mobility is problematic.

Keywords: E-MOBILITY, EMISSIONS, CO₂

1. Introduction

E-mobility is treated as emission-free. Generally, this sentence can only be true in a very small range. Namely, about selected parameters and in a very limited using area. An example of this is the measurement of CO₂ emissions in the immediate vicinity of BEV (battery electric vehicle). The situation can change dramatically if you take into account the emissions in the energy production necessary for car traffic. This work presents this issue taking into account the energy mix in the various countries of the European Union.

In Figure 1 is the energy by sources in EU countries given.

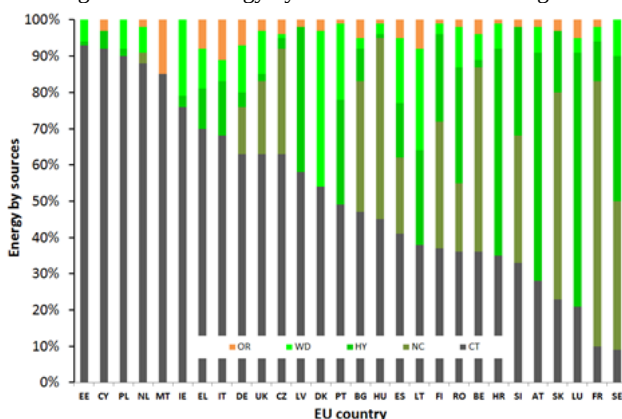


Fig. 1 Energy by sources in some countries in Europe. (CT – conventional thermal, NC – nuclear, HY – hydro, WD – wind, OR- other resources, based on [1])

As can be seen in the European Union there is a strong diversification of sources of electricity. In some countries the dominant role is played by conventional sources, while in others the acquisition of electricity from renewable resources is definitely more important.

But nowhere has such a state of affairs been achieved that all electricity comes from renewable resources.

Today's electricity production covers today's needs. E-mobility is "new" in energy demand. Hence the question arises from which energy sources e-mobility will be powered, and in particular how it will affect emissions.

When discussing emissions, the most common issues are global emissions such as CO₂ emissions. However, from the point of view of people, also important are the emissions of PM – solid particles (e.g. from grated tires or roadways), NO_x – nitrogen oxides, SO_x – sulfur oxides or HC – hydrocarbons.

Generally, emissions are also divided into so-called low emissions (smog) and high emissions.

Such a division may perhaps make sense, but each emission has a negative impact on people and the environment, and unfortunately there is no exception.

The problem of emission assessment is therefore multifaceted. This work is devoted to the global approach to emission issues by assessing CO₂ emissions during the operation of electric vehicles. It goes without saying that with the emission of CO₂, the emission of the above compounds will follow. These emissions are not linearly correlated. This will have to be subjected to a deeper analysis, for which it is also necessary to develop appropriate methods, and this publication is also devoted this issue to.

The issue of emissions from e-mobility can be considered in static terms (thus analyzing what is happening at a given moment) or in dynamic terms, thus as a function of time (for example including the increase in the number of electric vehicles).

In this work the issue was treated statically. But even in this case there are issues that cannot be omitted.

Such issue is, for example, the issue of energy import and export between countries. In one country, more "pure" energy can be produced and this energy is exported to a country that produces "dirty" energy. Then, in the importing country, "more pure" energy is used. Of course, the opposite is also possible. This undoubtedly affects energy LCA in individual countries.

An important factor affecting energy LCA is also the use of electricity, by BEVs, in individual countries. The issue here is a way of assessing the use of electricity during the natural exploitation of vehicles.

These issues are (somewhat) more accurately presented in this publication.

2. Well-to-Wheels methodology

The methodology presented here as chapter 2, 3 and 4 are on basis of [2] The methodology considered in this article is Well-To-Wheel (WTW) detailed in version 4a of the [3]

This approach allows quantifying the amount of energy required for greenhouse gas emissions resulting from the production, transport and distribution of conventional and alternative fuels for road transport (Well-To-Tank, WTT), as well as for quantifying the performance of various drive units (Tank- To-Wheels, TTW).

Compared to the Comprehensive Attribution Life Cycle Assessment (LCA) approach, WTW considers part of the LCA impact category "energy consumption" and "greenhouse gas emissions".

In the WTW approach, emissions related to the construction of equipment, maintenance and decommissioning of fuel and vehicle production plants, including material cycles, are not taken into account. Water pollution requirements or emissions are not taken into account if they do not affect GHG emissions. GHG included is carbon dioxide, methane and dinitrogen monoxide. The WTW methodology can be seen as a simplified LCA, designed to assess only energy consumption and greenhouse gas emissions from the use of road transport fuels.

3. CI – Carbon intensity of electricity

Carbon intensity of electricity can be defined as the GHG emitted for producing or using a certain amount of electricity as shown in equation (1):

$$CI = \text{GHG emissions/electricity amount} \quad (1)$$

Since GHG emissions are expressed in grams [g] of CO₂ equivalent and the electricity (e.g. produced or using) is expressed in [kWh] the consequent carbon intensity (CI) is usually expressed in [gCO₂eq/kWh].

In this paper it will be report the carbon intensities for all the following stages of the electricity pathway: gross production, net production, electricity traded, supply post-trade, consumed at high voltage after transmission, consumed at medium voltage after distribution and consumed (by the most of users) at low voltage.

The JEC WTW analysis considers GHG emissions occurring in two main steps, that is: combustion emissions occurring when fuels are burnt and upstream emissions.

The upstream emissions are caused by the extraction, refining and transport of the fuels to the power plants. For other fuels and renewables such as peat, municipal and industrial wastes, hydro-power, geothermal, solar, wind and tidal power the upstream emission factors were considered equal to zero.

For nuclear power plants the approach in use by main international statistical bodies (IEA, EUROSTAT, IAEA) has been adopted. Converting the electric energy produced from nuclear or renewables into an equivalent primary energy have a average thermal efficiency (e.g. IAEA, 2007) equal 33%.

4. Electricity trade and carbon intensity

The carbon intensity of the electricity consumed in a country depends also on the CI and amount of electricity

traded with other countries. Logically, electricity imported in a country embeds also the GHG necessary for its production, so a WTW (or LCA) calculation aiming at realistically representing the carbon intensity of electricity consumed, should also consider the trade aspect, especially for countries having high electricity imports.

The electricity supplied (EIS) to a national network, considering the trade, is defined by the IEA with the equation (2):

$$EIS = EI_{\text{net production}} - EI_{\text{pumping}} + EI_{\text{Imports}} - EI_{\text{Exports}} \quad (2)$$

For all these terms presented in equation (2) it can be used the IEA statistical data.

In order to calculate the CI of the electricity supplied (post trade) in a country it is possible to use equation (1), considering in the denominator the result of equation (2), and in the numerator the value of total GHG emissions embedded in the electricity supplied, calculated according to equation (3):

$$GHG_{\text{Total}} = GHG_{\text{Combustion}} + GHG_{\text{Upstream}} - GHG_{\text{Exported}} + GHG_{\text{Imported}} \quad (3)$$

Combustion and upstream GHG emissions are the same values used to calculate the CI of electricity produced in each country, the exported GHG is simply the product between the CI of electricity traded multiplied by the Upstream and combustion emissions

Imported GHG emissions can be treated as

$$GHG_{\text{Import}} = S(GHG_{\text{Import from i-th Country}} \times CI_{\text{El production in i-th Country}}) \quad (4)$$

where for each country it is necessary to consider the sum-product of all the amount of electricity traded (EI. Import from Country "i") and the respective Carbon Intensities (CI El traded Country "i").

Table 1 shows the results of calculations for the different values of carbon intensity, calculated for each EU country (for the year 2013).

The order of the countries listed in Table 1 is the same as shown in Figure 1. Countries were presented according to the decreasing share of non-renewable sources in the generation of electricity.

Interesting are the results presented in Figure 2. The results from Table 1 have been added to the results presented in Figure 1. The percentage of electricity from combustion processes (in individual EU countries) are compared as well with the CO₂ mass emissions (per kilowatt-hour) by electricity production and its use (together with import) in every country.

The data primarily indicate that centralized electricity generation and distribution systems cause large losses in energy transmission - which means a significant increase in specific CO₂ emissions (in g_{eq}/kWh).

Electricity imports (especially if this energy is produced in the exporter's country from non-renewable resources), can lead to a

significant increase in CO₂ emissions "in the country that imports" electricity.

Table 1 Carbon intensity (CI) in EU countries in several steps of production trading and supplied

Country	CI of gross electricity production (combustion only) [g/kWh]	CI of gross electricity production (with upstream) [g/kWh]	CI of net electricity production with upstream emissions [g/kWh]	CI of electricity traded (with upstream) [g/kWh]	CI of electricity supplied (with upstream) [g/kWh]	Variation of CI after trade [%]	CI of electricity consumed at HV (with upstream) [g/kWh]	CI of electricity consumed at MV (with upstream) [g/kWh]	CI of electricity consumed at LV (combustion only) [g/kWh]	CI of electricity consumed at LV (with upstream) [g/kWh]
Austria	123	151	156	170	315	0.85	322	325	305	334
Belgium	188	224	233	239	257	0.08	261	262	224	267
Bulgaria	507	532	585	601	589	-0.02	618	628	636	669
Croatia	231	273	282	285	465	0.63	487	494	463	524
Cyprus	646	737	773	773	773	0.00	787	792	710	810
Czech Republic	518	545	587	596	640	0.07	657	663	643	685
Denmark	316	368	386	386	356	-0.08	364	367	328	377
Estonia	1000	1022	1152	1152	840	-0.27	878	891	951	944
Finland	171	200	209	209	204	-0.02	207	207	181	211
France	66	88	92	92	97	0.04	100	101	80	105
Germany	485	534	567	574	588	0.02	599	602	558	615
Greece	655	695	755	757	712	-0.06	732	739	723	767
Hungary	310	340	368	368	369	0.00	383	388	365	407
Ireland	459	533	555	568	570	0.00	588	594	530	617
Italy	358	427	444	448	402	-0.10	413	417	362	431
Latvia	134	173	185	185	1075	4.82	1110	1122	1140	1168
Lithuania	204	246	262	315	358	0.14	370	374	331	390
Luxembourg	236	283	283	585	505	-0.14	508	509	467	513
Malta	731	831	868	868	910	0.05	954	970	908	1032
Netherlands	479	559	582	582	547	-0.06	555	558	494	569
Poland	770	847	929	934	911	-0.03	937	946	890	980
Portugal	295	346	355	365	357	-0.02	372	378	340	400
Romania	356	379	413	416	425	0.02	449	457	460	492
Slovakia	173	199	211	215	407	0.90	412	414	383	420
Slovenia	315	329	351	361	302	-0.16	309	312	291	321
Spain	248	295	305	312	309	-0.01	321	325	287	341
Sweden	16	24	25	25	44	0.74	45	46	36	47
United Kingdom	469	555	584	591	576	-0.03	593	599	526	623
EU 28 average	340	387	407	413	417	0.01	428	432	393	447

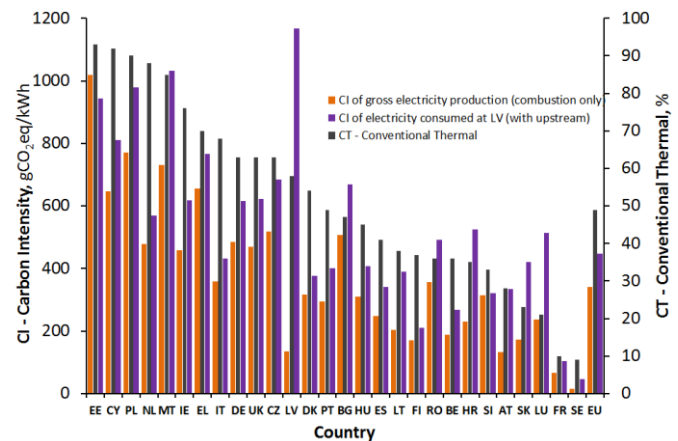


Fig. 2 Carbon intensity by production and use of electricity in EU countries

5. Electricity use by BEV's operation

For the correct emission assessment related to the production and use of energy in e-mobility, it is necessary to know the electricity demand of electric vehicles (BEVs)

Based on the assumption that the emission related to the supply of electricity to the vehicle's charging point is known (Table 1), it is necessary to assess how much of this energy must be used to drive at a particular section of road.

The necessary data can be obtained from the appropriate tests (in the EU previously NEDC test and currently WLTP [4]) but it is known that the test results do not coincide with the data from natural exploitation [11]

Therefore, it is crucial to assess the operational energy "consumption" in the natural exploitation of vehicles (energy cannot be consumed - possible is the change of its form only - but as parallel to the historical term "fuel consumption" in following will be the term "energy consumption" used).

It seems that for assessing the energy consumption in natural exploitation of BEVs in particular is the theory of cumulative energy consumption useful.

The theory of cumulative energy consumption was originally developed (as author work) to assess the cumulative consumption of fuel in the natural exploitation of ICE vehicles [5].

The usefulness of the theory has been repeatedly confirmed, also when powering the engines with various fuels [6, 7, 8, 9]. The main applications of the theory have been found in assessing the fuel consumption of urban bus fleets. Special software has been created for proper data collection (for obvious reasons, it will not be described here).

The energy consumption of a car in its natural exploitation is a random process. Energy is consumed in the "quantum" model. Energy quanta have a random size. Also, the time between the quantum of energy consumed is random.

Total amount of quanta of energy supplied to the car engine in its operating period is called as cumulative energy consumption.

Energy quantum summation leads to determining the cumulative energy consumption. Energy consumption caused by the time t of the engine work, can be designated as

$$CFCc(t_d) = \sum_{i=1}^{n(t_d)} q_i = n(t_d) \cdot \bar{q}(t_d) \quad (5)$$

wherein:

$CFCc(t_d)$ - the cumulative energy consumption to the mileage t_d

t_d - mileage

q_i - i -th quantum of energy

$\bar{q}(t_d)$ - the average size of the quantum of energy used to the mileage t_d

$n(t_d)$ - number of the energy quantum used to the mileage t_d

To know the cumulative energy consumption to the mileage t_d should be familiar with the average size of the quanta and the number of quantum of consumed energy to that mileage.

The way to reach these values has been presented in [1].

These publications also provide a way to obtain a mathematical model describing the cumulative energy consumption as a function of the vehicle's mileage.

The model has a form

$$CFCc(t_d) = \sum_{i=1}^{n(t_d)} q_i = n(t_d) \cdot \bar{q}(t_d) = ct_d^{(a+1)} \quad (6)$$

The intensity of energy consumption is a mathematical derivative from equation (6), so it has a form

$$CFC'c = ICFCc(t_d) = \frac{dCFCc}{dt} = c(a+1)t_d^a \quad (7)$$

wherein:

$ICFCc(t_d)$ - the intensity of cumulative energy consumption to the mileage t_d .

c, a - coefficients

Constants " c " and " a " equations (6) can be derived from data obtained from the use of vehicles in natural operation. Such data are collected by various institutions and individuals. One of a good database is from the website *spritmonitor.de* [11]. The advantage of this database is not only the large amount of data collected there, but also their widespread (and easy) availability. Data from this database will be used in further consideration.

Figure 3 presents operation data of the SMART Fortwo car No 641784. To determine the coefficients " c " and " a ", data from the operation are necessary and sufficient.

After calculations, the following results are obtained

$$c = 0.201467, a = -0.017827 \quad (8)$$

and accordingly

$$CFCc(t_d) = ct_d^{(a+1)} = 0,201467t_d^{0,982173} \quad (9)$$

And

$$ICFCc = c(a+1)t_d^a = 0.197874t_d^{-0.017827} \quad (10)$$

Six decimal places of coefficient values look a bit shocking. They were, however, deliberately entered. The author's experience shows that the more accurately the value of coefficients is given, the mathematical model is more adequate. On the other hand, in today's computing calculations, the accuracy of calculations results from the use of values with a much larger number of decimal places. These values are stored in the computer's memory and it does not matter how they are displayed on the screen.

Similarly, the results of the analysis but in the case of a TESLA S85 car (No. 733036) lead to data

$$c = 0.212467 \text{ and } a = -0.003939 \quad (11)$$

The models adequacy assessment (6) was carried out using the analysis of variance. The results are as follows (Table 2).

Table 2. Results of the analysis of variance to determine the adequacy of the model (6).

	SMART Fortwo (729182)	TESLA S85 (733036)
Multiple R	0.999884	0.999922
Rsquare	0.999768	0.999844
Matched Rsquare	0.999766	0.999839
Standard error	0.010254	0.013717
Observations	83	35

The observations number is in this case the same as the charging number.

The results are amazingly good. It was not expected that the correlation coefficients will be so high (it is worth recalling here that the maximum theoretical value of, for example, the R square (R^2) coefficient is $R^2 = 1$).

It is hardly surprising that the correlation coefficient has such a high value since the "measuring" points lie almost perfectly on the curve of the model.

A graphic illustration of the results obtained is shown in Figures 4 and 5. In this form presented results can be treated as a kind of energy footprint of the defined vehicle.

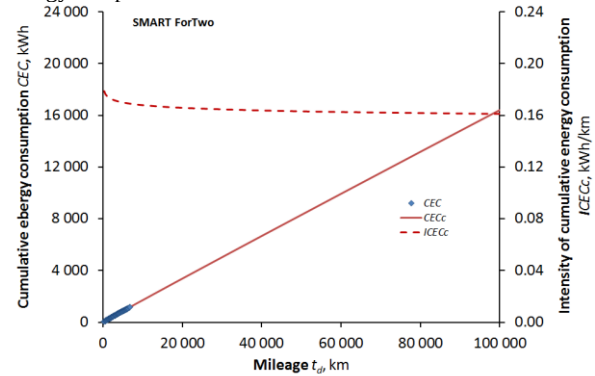


Fig. 3. Energy footprint of SMART Fortwo car No. 729182

Both curves ($CFCc$ and $ICFCc$) give the impression that they are straight lines. However, when analyzing values of coefficients, it must be clearly stated that they are curves, and only in some cases (as presented here) quasi straight-lines.

Both drawings show that the average intensity of cumulated electricity consumption ($ICECc$) can be reported relative to one kilometer of the car's mileage. As you can see, the intensity of cumulative energy consumption is not constant - therefore, for example, the average value should be assumed as representative for a particular car.

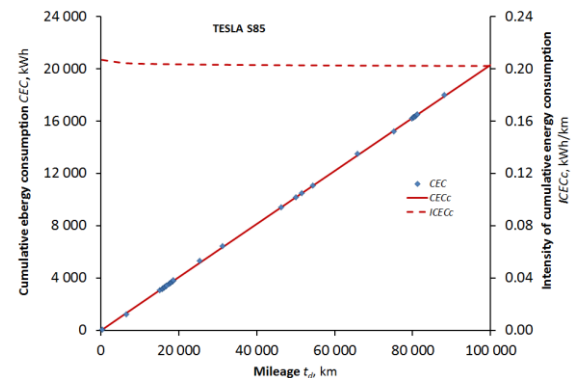


Fig. 4 Energy footprint of TESLA S car No. 733036

If the data on the $ICECc$ for more cars are known, then can be achieve the values for a given type of car. The relevant data are shown in Table 4.

Table 3 Intensity of cumulative energy consumption data for analyzed cars types

Statistical parameter	SMART Fortwo (729182)	TESLA S85 (733036)
Average	0.1647	0.2083
Standard error	0.0039	0.0039
Median	0.1624	0.2093
Dominant	0.1554	0.2111
Standard deviation	0.0233	0.0315
The variance of the sample	0.0005	0.0010
Kurtosis	0.7362	3.1771
Slant	0.8955	0.4176
Range	0.1023	0.2177
Minimum	0.1250	0.1109
Maximum	0.2273	0.3286
Sum	5.9294	13.5366
Counter	36	65
Confidence level for the average (95.0%)	0.0079	0.0078

With the data from tables 1 and 3 is possible to achieve of CO₂ emission in each country of EU. The calculations results are here in the Figure 5 given.

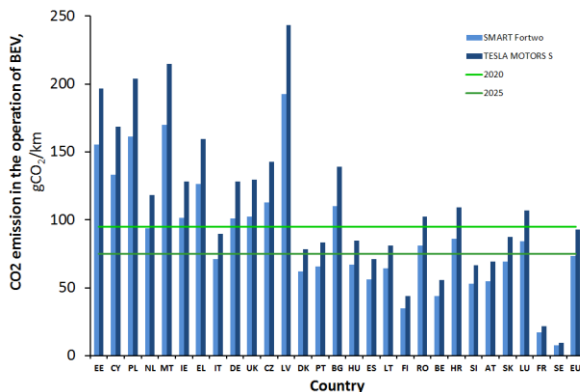


Fig. 5 CO₂ emission in the operation of BEV's in countries of EU and also average for EU

For the comparison in Figure 5 are the maximum emission of CO₂ for car fleets in EU for next year's showing. These values are correct for NEDC but for the WLTP test they are only slightly lower.

The results of the calculations proved to be in line with expectations. On average, in the European Union it is already worthwhile to use electro vehicles (BEV's) because CO₂ emissions are within the limits of the adopted standards for 2020. The use of small BEV's already allows to meet the standards for 2025 today.

Figure 5 shows that in some countries, in order to get closer to the standards for 2020, it would be necessary to reduce CO₂ emissions by at least a half. This means that although any action is aimed at reducing energy consumption of vehicles have a sense, then the main burden of change should concern the change in energy production and distribution.

6. Conclusions

This paper presents two important methods for assessing the emission of electric vehicles

- an emission assessment method for generating and supplying electricity to battery charging points,
- a method of assessing energy consumption in the natural use of vehicles.

Both methods are shown in a static application - although there are no contraindications to use them together in dynamic applications, including emission forecasting.

The method of using both methods is presented on the example of CO₂ emission assessment resulting from the operation of battery electric vehicles.

Simulation research shows that there are already countries in the EU where the operation of electric vehicles makes sense. Especially when it concerns CO₂ emissions. Emissions below the standards for 2025 can be obtained there. Unfortunately, in many EU countries,

the operation of BEV is associated with increased (in relation to present day) CO₂ emissions.

Because the high emission, in the first place, corresponds to the use of energy coming from non-renewable resources, together with excessive CO₂ emissions probably occur excessive emissions of nitrogen and sulfur oxides and a number of others, as well as heavy and radioactive metals. Even if the plants are equipped with appropriate exhaust gas treatment systems, there are no systems operating with 100% efficiency - therefore emissions cannot be avoided.

Without changing the energy policy, and in particular the energy mix, introducing e-mobility is problematic.

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ENVIRONMENTAL IMPACT OF ELECTRIC VEHICLES

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Abstract: The development of strategies for mitigating negative environmental impacts has been developed for a long period of time and it is actually now also. At the European level, the DIRECTIVE 2014/94/EU of the European Parliament and of the Council has been adopted. This the Directive has been in force since 2014. The main objective of the Directive is to reduce the use of oil and the adverse effects caused by traffic, respectively the transition to alternative fuels. The idea of electric vehicles and their advantages is popularized because that. This work will highlight the need for the use of electric vehicles, as well as the development of strategies for their use. Many of the leading European and world countries already have a great deal of successful practice in sustainable development and can boast of positive results. These countries emphasize the need of using natural resources and transforming them into energy that can be used, while minimizing negative effects. Also, various innovations that influence the improvement of the quality of life and the possibilities of using electric vehicles are being developed and projected. How and to what extent electric cars and the use of alternative fuel can contribute to a better and cleaner environment has not yet been established, but it is certain that they can have a positive effect on the future.

Keywords: SUSTAINABLE MOBILITY, ELECTRIC CARS, CHARGING INFRASTRUCTURE

1. Introduction

A mobility of people and goods is necessary for a quality life, business competitiveness, economic and social development, both for developed and developing countries. On the other hand, increase of mobility caused increase of motorization, development of new transport infrastructure instead of green areas, increased traffic load, increased pollution, increased noise, and creation of many other negative effects on human society. Over time, negative effects were increasing to such an extent that it was necessary find ways to mitigate them. The idea of sustainable mobility which essentially emphasized the importance of transport as an economic activity, has developed at the global level. This idea was emphasizing that traffic safety, environmental protection, better and economically more profitable transport should be addressed. Many countries began to develop strategies and offer different solutions with this goal in the 20th century. One of the solutions, in an aspiration of sustainable development, was transition to alternative fuel, because use of oil began to exceed limits of supply capability. As a result, the idea of electric vehicles and advantages it offers is popularized. Electric vehicles are a mode of transport that can be considered sustainable and which is get an increasing role within strategies developed by many European and world countries. Electric vehicles offer great potential to dramatically reduce local air pollution, greenhouse gas emissions and resulting climate change impacts, and oil use from the transport sector [1].

2. Sustainable development

Generally, sustainable development is a broad term that is promoted in all segments of life, with a special emphasis on providing safe, environmentally friendly and economically justified services and activities. The World Commission on Environment and Development (Brundtland Commission) established by the United Nations in 1983 provided the following intergenerational definition of sustainability: "Sustainable development is development that meets the needs of the present without compromising the ability of future generations to meet their own needs" [2].

Consequently, the concept of sustainability has become present in all segments, as well as in the context of mobility, or transport. Today, there are a lot of talk about the concept of sustainable mobility. The transport is a key driver in attempts to increase the degree of sustainability in our societies. It has a direct effect on all the negative impacts that can be measured environmental impacts, social impacts, economic impacts, etc. Sustainable transport, or sustainable mobility, essentially implies a future vision of a society that will enable economic development and normal functioning of society, but in sustainable and acceptable frameworks.

In recent years, various strategies have been adopted with aim of identifying and reducing harmful causative agents in air, soil and water, and adjustments and harmonization of legislative policy have been made, both at national and international level. The modes of transport are potentiating who have equally positive influence on a living space and possibility of providing efficient service. Special emphasis is placed on reducing the use of conventional fuel and promoting renewable energy sources. Such a policy also involves encouraging and improving production of new vehicles that will use biofuels or some other less harmful energy sources.

3.1. Basic recommendations at the EU level

The negative consequences of mobility, that society faces, are most prominent in urban areas. Emission of harmful gases, energy consumption, communal noise, taking up space in favor of traffic infrastructure, etc. are just some of the consequences, which may be most often highlighted as adverse effects of traffic.

The emission of harmful gases is increasing every year, especially the amount of CO₂. The main source of CO₂ nascency is burning of fossil fuels and it is in principle contributes to greenhouse effect. According to the EU statistical data from 2011, traffic activities resulted in approximately 20% of total greenhouse gas emissions as a result of all activities (Figure 1). More than 70% of CO₂ is derived from road motor vehicles, observed in relation to the total amount of CO₂ generated from transport activities in EU countries. [3]

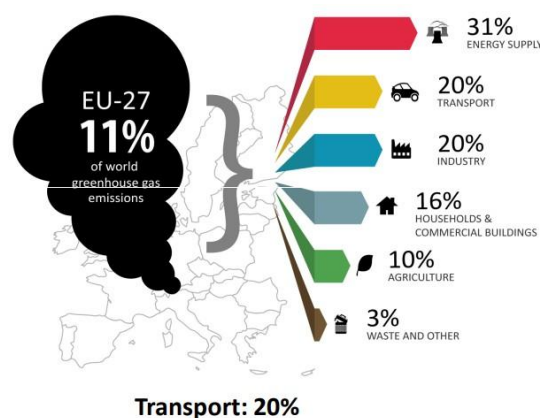


Fig. 1 CO₂ transport emissions, as a result of different activities in EU, 2011 [3].

Expressing concerns about overuse of oil and its diminishing reserves, but also due to decarbonisation and combusting fuels

harmful to environment as well, the EU has adopted a Directive that seeks to encourage its members towards sustainable mobility and healthier life. Better known as Directive 2014/94 / EU of the European Parliament and of the Council of 2014, this document provides guidance and suggests the use of alternative fuels and setting up of an infrastructure that will enable the supply of vehicles to alternative fuels.

EU Member States were obliged to adopt infrastructure construction plans for alternative fuels vehicles, where completion of construction is planned for 2020 and 2025 respectively, all depending on vehicles technologies. Within this strategy, electromobility has also an important place with all its specific recommendations are given regarding the development of charging infrastructure, promotion of technological innovations in this field, use of intelligent metering systems in order to contribute to stability of the electricity system by recharging batteries from the grid at times of low general electricity demand, etc. [4]

The European Commission also dealt with the reduction of pollution within the White Paper. They have introduced a strategy that generally predicted reduction in European dependence on oil imports and reduction in carbon emissions in the transport sector for 60%, by 2050. In addition, use of cleaner cars and cleaner fuels is envisaged for transport in urban areas. There is the plan that 50% of cars with conventional fuel are replaced by cleaner cars by 2030, and their complete abolishment is done by 2050 [5]. Within the White Paper are presented construction infrastructure network guidelines, financing through various funds and other sources, adoption of new technologies (new technologies of traffic control, new technologies for filling vehicles - new charging stations), etc. During 2012, the European Commission has published a strategy for clean transport systems, with specific details on measures to encourage and facilitate introduction of clean vehicles and development of standards across the EU for the application of clean vehicles, with particular emphasis on electric vehicles.

CIVITAS Initiative, financed by EU, also plays a significant role in promoting and supporting cities which are introducing or considering introduction of a strategic policy for sustainable urban mobility. The Initiative started its work in 2002 launching the CIVITAS I project, which included 19 cities. Development of following projects also increased the number of participating cities, so today this number reached a figure of 60 cities [6]. Among other things, cities involved in the CIVITAS Initiative promote clean fuels and vehicles using alternative fuels, including electric vehicles.

As can be seen, previous experience shows that in Europe, and of course at the world level, different strategies are developed that result from today's conditions and today's real picture of state of the environment. Most of strategies are based on preserving natural environment, then maintaining human health and safety, meeting needs of population for travel, supporting a good and efficient economy, minimizing transport and infrastructure costs, maintaining energy security and ensuring long-term sustainability of the transport system. Within framework of strategies, measures are proposed that offer solutions and improvement of situation. Different directives and regulations have been adopted in the framework of international and national regulations, all with unique goal of promoting the sustainable mobility and the sustainable transport.

3. Experience of individual countries

All developed world countries are constantly working on developing strategies for the use of electric vehicles in accordance with their capabilities and policies. Countries are developing partnerships with companies involved in production of electric vehicles and development of their filling infrastructure, striving always with various innovations and improvements. Reviving concept of sustainable mobility through the development of electric

vehicles and their infrastructure, is basically a costly investment. However, many years of experience and practice, cooperation with a clearly defined policy of functioning, can lead to fantastic results that are useful and profitable for producers, governments and consumers, and at same time there is a healthier environment.

United Kingdom

When it comes to electric vehicles and their infrastructure in the United Kingdom, it can be said that the British with great care and investment have dedicated themselves to this topic. There are approximately 212000 electric vehicles registered in the UK, from which 60000 were registered last year [7]. Research in the UK shows that all monthly electric vehicle related costs are approximate to costs required by conventional vehicles. Certain types of subsidies and tax deductions for electric vehicles are certainly contributed to this. The electric vehicles in the UK are free of toll payments. In the UK, most of the charging electric vehicles is done at home, with the government paying 75% of installation costs [8]. 11837 electric vehicle chargers were registered on 4237 public locations, of which 2173 were super fast chargers during 2017 [9].

The Highways England, the government organisation responsible for road infrastructure maintenance, develops a project that would allow enable to electric vehicles to be supplied with electricity during their movement. Need for this project has arisen due to lack of filling stations on highways, but also in order to maintain continuity in driving. The aim of the project is a select number of cars will be fitted with requisite wireless charging technology, and a test road will be built to show how smaller sub-stations, AC/AC converters, and power transfer loops can provide inductive charging built into the road itself [10]. The UK Government has provided a great deal of money to try this technology with aim to create a more sustainable road network for England.

Another of the most interesting innovations the British have patented is electric busses. The testing of project was carried out in the city of Milton Keynes, on bus line 7. The length of the line is 25 km. Fleet of 8 electric vehicles was inserted on the line 7 and their testing is scheduled for the end of 2019. Since movement of vehicles on a public transport line is organized so that buses operate in a determined order of driving, it is very important to adjust filling of vehicle to their movement on the line. It is therefore necessary to use every little longer of their standing, which is usually at final terminals. The bus timetable is not disturbed by this way of charging which is an advantage of wireless charging.

Such a project has come up with positive reviews and there are intentions to expand and promote it in the future. Financial incentives for 11 new electric bus and charging infrastructure have been approved [11].



Fig. 2 Wireless charging of electric buses [12].

Germany

Germany is considered the leading country in production of cars. Many major manufacturers come from this country. However, the beginnings of development of idea about electric vehicles were not optimistic, especially since the Government declared that they would not provide subsidies. The Government has recognized many positive things about the use of electric vehicles by time, and they began to take part more and more in the promotion of electric vehicles. 129246 electric vehicles were registered in Germany, in 2017. Targets are targeted towards 2020, when hopes are made to increase the number of electrical vehicles to as much as one million. The charging infrastructure is still in the process of development and progress. Germany owned 4800 public charging stations in 2014. All projects related to the development of the charging station network were realized on basis of partnership relations between car manufacturers and utility companies [13].

One of the main problems facing larger cities in Germany and other countries is problem with an electricity network that is not sufficiently equipped to support the development of electric vehicles. Electric vehicles require the use of electricity whose network is designed to meet conditions required by each city, but not overloading caused by the charging of electric vehicles. This automatically leads to the need to reconstruct the network in line with increase in the number of cars in order to avoid collapse and loss of electricity. Research in Germany has found that as much as 80% of electric vehicles are charged at home or at work, which represents a large energy consumption [14]. It is necessary to consider all possibilities and find the most adequate solution, since overall idea about the development of electric vehicles is the best option for the future. In Germany, the solution is sought through common cooperation between industry, government and society, in search of alternative sources of supply, such as solar energy.

Similar to the UK, in Germany, the city of Mannheim developed the idea of electric buses and their use in city traffic. A pilot project was carried out in 2013. The project involved introduction of two electric buses on line 63 in the Mannheim which can charging by wireless network on bus stops. This project was implemented for 12 months, and similar ideas occurring in other cities [15].

Norway

Norway is a country that stands out as a special example of electric vehicles. It is the first country in which every electric car was registered for every 100 passenger cars. The number of these vehicles is the highest per capita in the world, and Oslo is considered head of the city of electric vehicles. Figure 3 shows the number of registered electric vehicles in Norway for period from 2004 to 2018 [16].

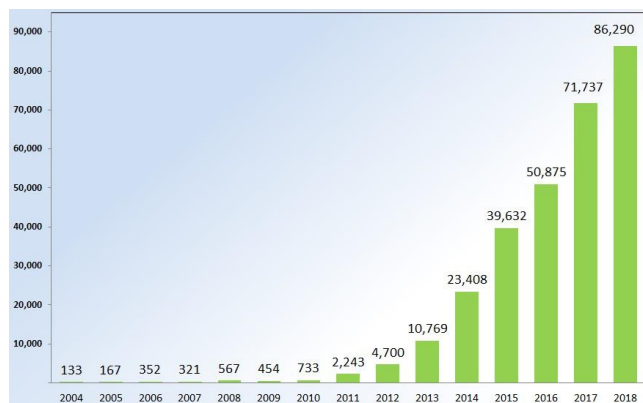


Fig. 3 Registration electric vehicles in Norway by year 2004-2018 [16].

Electric vehicles in Norway are considered the cleanest, as even 98% of the electricity used as a plant comes from hydropower. The production and expansion of electric vehicles in this country has influenced the Government to awaken awareness of welfare of electric vehicles through a certain stimulus. This incentive consisted in release of electric vehicles from all non-refundable charges, including purchase taxes and 25% of VAT during purchase. Local authorities have been given option of deciding whether electric vehicles can be parked free of charge. All of these facilitation and successful policies of Norway have led to accelerated growth of electric vehicles on roads.

China

One of the largest and most populous countries in the world also faced the problem of environmental pollution. China was the world's largest car and fuel consumer in 2009. They imported large quantities of oil that were consumed in the same amount as well. For all of that, the Chinese government has understood this as a serious invitation to do something in the field of reducing emissions of harmful gases and oil imports. Their plans were aimed at two goals: to reduce CO₂, and to increase the use of electric vehicles. The use and production of electric vehicles first came to life in the major cities of China, where six cities were selected through a single project to implement and subsidize the development of electric vehicles, with a commitment to invest \$ 9000 per vehicle. A large number of manufacturers came in and presented their models of electric vehicles and announced their mass production. Plans to build the necessary infrastructure are also made. A concept was developed to build 1700 charging stations and 3 million charging points in 2015 [17]. Sales of electric vehicles in China increased by 53%, according to the data from 2017, and their tendencies are aimed at selling 2 million electric vehicles annually by 2020, as well as to completely prohibit the use of engines with internal combustion [18].

The Chinese authorities saw three important benefits through the expansion and promotion of electric vehicles:

1. Economic Opportunities
2. Energy security
3. Pure air [19].

4. Conclusion

Although the views regarding application of electric vehicles are different and very often in complete mutual opposition, increasingly massive use of electric vehicles in the future is realistic. The development of infrastructure and the use of alternative fuel vehicles has seen significant growth in recent years. Technological innovations invested in significant investments and pilot projects carried out within individual countries contribute to accomplishment that the European Commission has set as a goal - complete abolition of conventional vehicles by 2050. Many cities encouraged by EU policies have implemented a number of measures that have resulted in a reduction in dependence on conventional fuel. Since the development and application of renewable energy is becoming more and more current, it is necessary to use this fact and work on co-ordination and creation of common benefits in these areas at all national, European and world levels. It is necessary to create such conditions in which despite the many shortcomings prevailing advantages of using electric vehicles. Disadvantages are time-consuming, studied, and strive to minimize them.

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MODEL FOR ASSESSMENT OF POLLUTANT EMISSIONS FROM ROAD TRANSPORT ON NATIONAL ROADS OF THE REPUBLIC OF SERBIA

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Abstract: *Determination the annual quantities of pollutant emissions in road transport emitted into the atmosphere, with the timely delivery of reliable information to all interested parties, conditions are created for raising the level of public awareness of environmental protection. Determining the amount of pollutants emitted facilitates monitoring of trends in order to lower the level of risk from their negative effect. This paper presents the results of calculating the amount of emitted pollutant emissions from road motor vehicles and determining emissions of pollutants on state roads I and II in the Republic of Serbia for the period 2013 to 2015 using the current version of COPERT 5 software. On the basis of the calculated emission of pollutants by shares and the belonging of the sections to the corresponding squares, the spatial distribution according to the squares of the European Monitoring and Evaluation Program (EMEP) network is shown.*

Keywords: ATMOSPHERIC POLLUTANT, COPERT 5, ROAD SECTION, EMEP NETWORK

1. Introduction

Determining emissions of pollutants in road transport is very complex and requires the modeling of input parameters. In addition to the pollution forecast, models and their results are used to make decisions when creating strategies in order to reduce the negative impact on the environment. With the help of the model, the effects of the applied measures are evaluated. In order to apply the concept of sustainable development to the road transport sector, it is necessary to know the participation of road transport in air pollution, which is provided by models for estimating emissions from road transport. By determining the annual quantities of pollutants from road transport in the atmosphere, with the timely delivery of reliable information to all interested parties, conditions for raising the level of public awareness of environmental protection are created. Determining the amount of pollutants emitted also facilitates the monitoring of trends in order to lower the level of risk from their negative effect. All variables that affect the amount of pollutant emissions in road transport is necessary to accurately determine or evaluate in order to enable analysis of the effects of stimulating and restrictive measures (cost-benefit analysis, intangible effects, etc.) in order to achieve sustainability of road transport. The assessment method presented in this paper provides a good basis for assessing the feasibility of fiscal measures to reduce emissions from road transport, or to increase its sustainability, as well as to estimate pollutant emission generated by vehicles on state roads I and II category. The subject of this paper is to calculate the emissions of pollutants from road vehicles and to determine emissions of pollutants on state roads I and II category using the current version of COPERT 5 software for the period from 2013 to 2015. The subject of research is also determining the influence of the dominant exploitation conditions on the emission of pollutants. On the basis of the estimated distance traveled, the prevailing conditions of exploitation and the level of pollutant emission standards of vehicles, it is determined the technical condition of vehicles and the final value of vehicle emissions on roads. For all sections of state roads I and II category based on data from automatic counters or weighted data on average annual daily traffic (AADT), structure of vehicle fleet, section length and average speed on a section (measured or expertly assessed), the emissions of a set of pollutants for individual sections by category of vehicle are calculated. Based on the calculated emissions of pollutants per road section and the affiliation of the section with the corresponding squares, the spatial distribution is made according to the squares of the European Monitoring and Evaluation Programme (EMEP) network.

2. Model for assessment of pollutants emissions

In order to quantify the emission of gaseous pollutants derived from road transport in this paper, the results obtained using the COPERT 5 software tool (April, 2017) are presented. COPERT (Computer Program to calculate Emissions from Road Transport) is one of the European tools for calculating emissions according to the Convention on Long-Range Transboundary Air Pollution (CLRTAP), in accordance with the requirements set by the Cooperation Program for monitoring and evaluation of the EMEP and the European Environment Agency (EEA), which financed the development of COPERT within the activities of the European Topic Center for Environmental Protection air and climate change [1, 2].

In order to carry out the assessment of emissions from road transport by using the COPERT 5 software tool, it is necessary to collect extensive input data. Prior to any evaluation or use of the software, it was necessary to collect data on:

- weather (climatic) conditions during the year,
- specific characteristics of all types of fuel in sales,
- total (annual) consumption of all types of fuel,
- a vehicle fleet classified according to the required categories, subcategories and vehicle emission technologies (number of vehicles)
- the average distance traveled for each category of vehicle (based on a special survey),
- average speeds of vehicles by categories of vehicles and roads,
- participation of the mileage by categories of vehicles and roads (urban, rural and highway) in percentages.

Input data for the Republic of Serbia, which were available in official records or statistics of state institutions and bodies, were collected from the Statistical Office of the Republic of Serbia (data on sold / spent fuel in traffic and transport, data on border traffic of passenger and freight vehicles, etc. .) and the Republic Hydrometeorological Institute of Serbia (data on dominant weather - hydrometeorological conditions). After analyzing the data, the method of their correction, ie bringing in the form required by the COPERT 5 model, has been determined.

Determination of the structure of the vehicle fleet on the first and second road categories was done by adopting the relevant national vehicle fleet structure, and according to the average annual daily traffic (AADT) by category of vehicle.

The only relevant source of data on hydrometeorological (weather) conditions in the Republic of Serbia is the Meteorological Yearbook issued by the Republic Hydrometeorological Service of Serbia (RHSS). RHSS disposes of so-called "Climatological" data from 1949 to 2015 with the exception of the period from 1980 to 1989. These reports contain data on average monthly minimum and maximum temperatures, average monthly air pressure and relative humidity.

Climatological data required for the calculation are:

- mean maximum monthly temperature (°C),
- mean minimum monthly temperature (°C),
- air pressure (kPa) and
- relative humidity (%).

These input data are necessary to obtain the average monthly conditions in which vehicles are used. They are used to assess the impact of a cold start on vehicle emissions, as well as air conditioners, both for the purpose of cooling during the summer (warmer months), as well as heating during winter, as well as reducing air humidity (over the whole year).

Consumption or amount of spent fuel is one of the indicators of transport activities. It is used as a control indicator for determining and possibly correcting the average annual traveled route of certain vehicle categories. Average fuel consumption is a measure of the efficiency of fuel utilization as the ratio between the distance traveled and the amount of fuel consumed. Given that spent fuel is an important factor in air pollution, a large number of countries have introduced strict fuel consumption related restrictions.

The COPERT 5 software tool calculates energy consumption rather than the fuel consumption to facilitate the calculation of energy consumption for new types of vehicles (hybrid vehicles - plug-in vehicles with gasoline and hybrid vehicles powered by diesel; electric vehicles drive - batteries and electricity, fuel cells (N2) and electric drive).

Access to the COPERT 5 model implies that the following information are entered for the vehicle: vehicle type, vehicle speed (km / h), primary fuel consumption (TJ), primary fuel content (MJ / kg), fuel mixture used, in a mixture of fuel (%). The COPERT 5 model compares the statistical and calculated energy consumption, modifies the input data (for example, the traveled vehicle distance) and repeats the procedure for calculating the amount of emitted pollutants.

The source of data for determining size of the national vehicle fleet is data on all national vehicles (excluding fleet of military and police) located in the base, ie, records of registered vehicles. In order to be able to use the data from registered vehicle records for the calculation according to the COPERT 5 model, it is necessary to adapt the existing vehicle classification to the categorization of the vehicle defined in this model.

Sources that have been processed for the purpose of collecting data on vehicle activities in the survey are as follows:

- passenger car user survey conducted in 2017;
- regular survey conducted in 2013 and 2016 in transport companies for the transport of passengers (urban and intercity buses) and for the transport of goods (delivery and cargo vehicles);
- average annual daily traffic on the roads of the first and second category of the Republic of Serbia in the period 2013-2015.

All of the aforementioned and available data were used in terms of obtaining the most reliable estimation, in the first place, the number of vehicles on the road network of the Republic of Serbia, and then the realized route of those vehicles. Values of certain input

data, for which there is no record, or not obtained through research, were adopted according to the project recommendations [1]. According to this project the value of the average length of travel should be in the range of 8 to 15 km, but in the absence of data, the value is 12.4 km, which represents the average length of travel in the EU Member States.

3. Emission of the national vehicle fleet

The total emissions of pollutants of the national vehicle fleet are shown in Fig. 1 and Fig. 2. Passenger vehicles mostly affect CO, CO₂, SO₂ and Pb emissions, while commercial vehicles have the largest share in NO_x, PM_{2.5} and PM₁₀ emissions (Fig. 3 - Fig. 5).

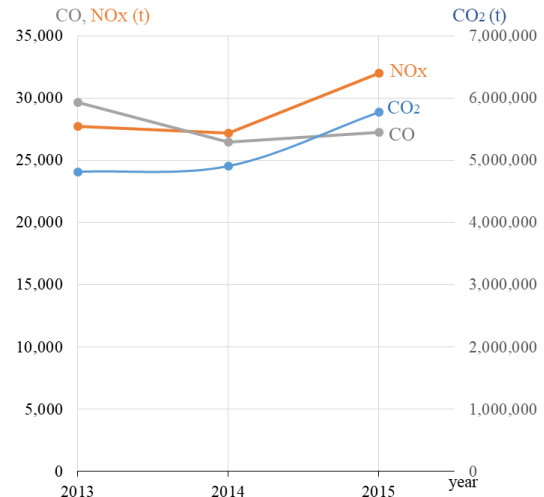


Fig. 1 The total emissions of carbon monoxide (CO), nitrogen oxides (NO_x) and carbon dioxide (CO₂), 2013-2015 year [t]

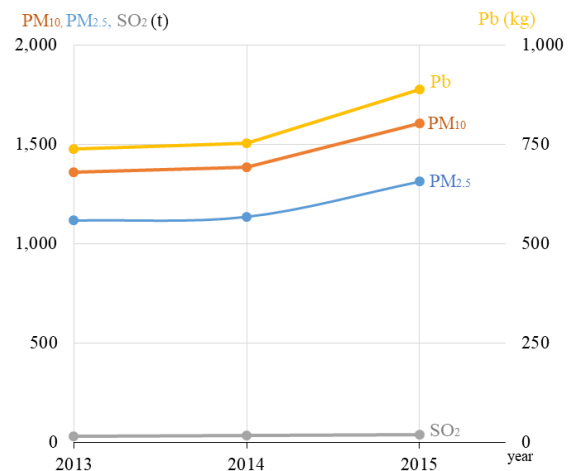


Fig. 2 The total emission of suspended particles (PM_{2.5}, PM₁₀), sulphur dioxide (SO₂) and lead (Pb), 2013-2015 year [t]

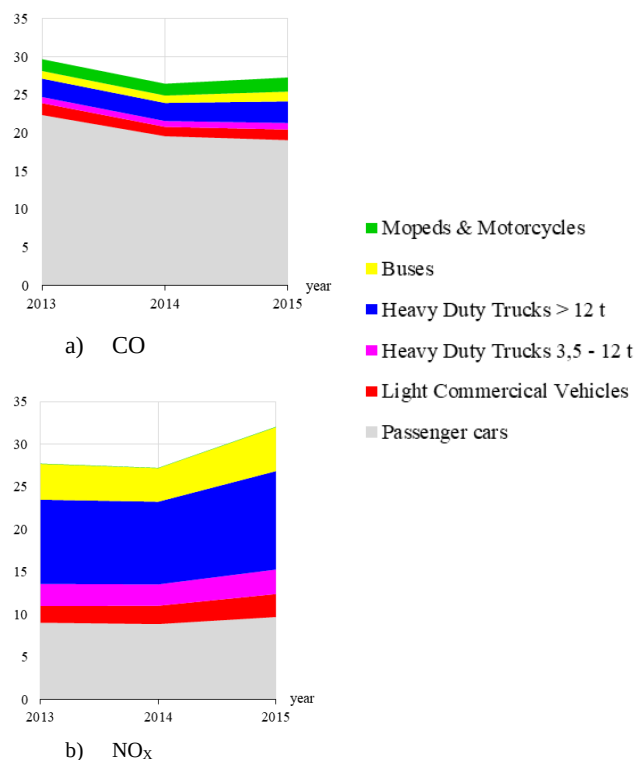


Fig. 3 Cumulative emissions by category of vehicles 2013-2015 year: a) carbon - monoxide (CO) [10^3 t] and b) nitrogen oxides (NO_x) [10^3 t]

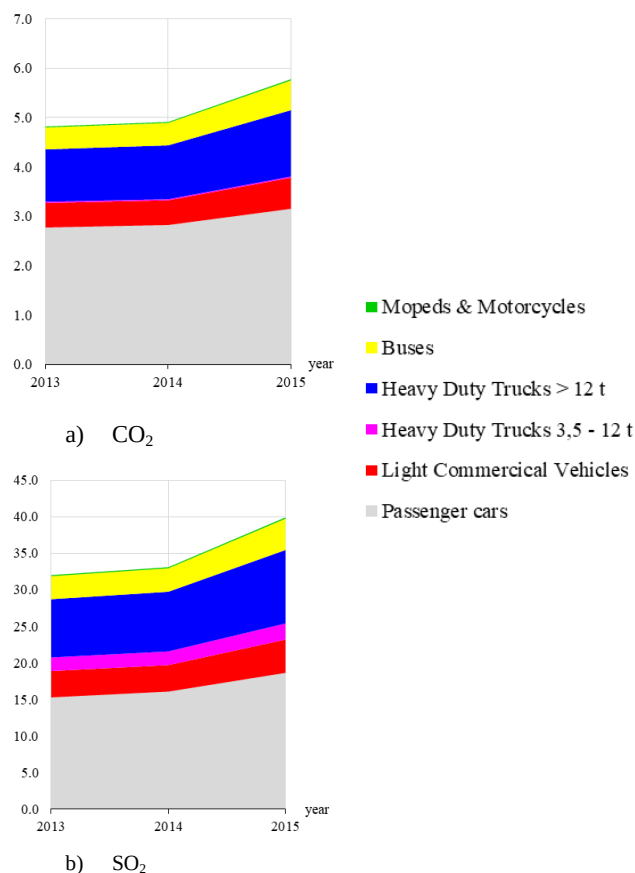


Fig.4 Cumulative emissions by category of vehicles 2013-2015 year: a) carbon-dioxide (CO₂) [10^6 t] and b) sulfur-dioxide (SO₂) [kg]

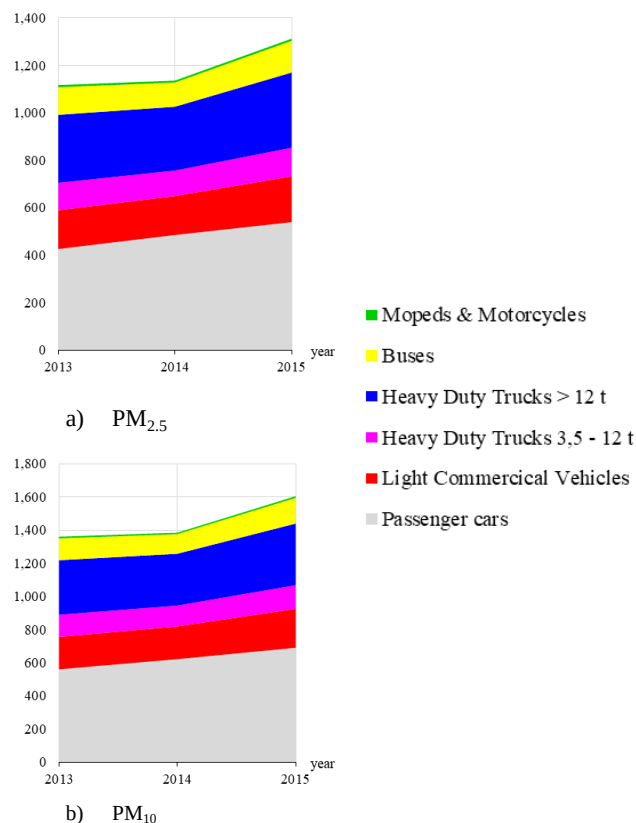


Fig. 5 Cumulative emissions by category of vehicles 2013-2015 year: a) particulate matters up to 2,5 μ m (PM_{2.5}) [t] and b) particulate matters up to 10 μ m (PM₁₀) [t]

4. Emissions of pollutants on road sections of the I and II category of the national roads

This paper presents the results of the Study on estimation of emissions of pollutants in the atmosphere from transport on state roads I and II category for the period from 2013 to 2015 [3].

The data on the vehicle fleet of the Republic of Serbia and the emission factors from the COPERT 5 software tool have been used for the calculation of the emissions of exhaust gases.

For all state roads (over 100 roads) and sections (over 1,000), for each year of the observed period, 2013, 2014 and 2015, the amount of pollutants emitted is calculated.

The following data were used for the calculation:

- average annual daily traffic per vehicle category by road section,
- length of road section,
- average speed of vehicles on road section and
- emission of pollutants by vehicle category (g/km).

Based on the available data on the lengths of the road sections and the average annual daily traffic, the total mileage traveled by road categories (in autocilometers) and road sections was determined. The average speed of the vehicle on the sections are calculated based on the available time travel speeds of the vehicles read on the traffic counters. The unit emission of pollutants is expressed in grams per autocilometer by category of vehicle (passenger car, bus, light duty vehicle, medium freight vehicle, heavy duty vehicle, articulated vehicle). In order to determine the unit's emissions, the software tool COPERT 5 and the structure of the fleet of the Republic of Serbia were used in 2013, 2014 and 2015.

The total emission of pollutants on the road section during the year is the product of the unit emission in the calculated autokilometer and the total number of autokilometers per vehicle category.

Total emissions of pollutants on state roads I and II category, by category of vehicles, in the period from 2013 to 2015 is shown in Table 1.

Table 1: Total emission of pollutants on state roads I and II category in the period 2013-2015

		2013	%	2014	%	2015	%
CO (t)	CAR	15,494.05	87.43	13,257.21	86.50	14,932.66	86.16
	BUS	303.86	1.71	261.43	1.71	364.89	2.11
	LDV	150.74	0.85	124.93	0.82	160.44	0.93
	MHV	286.49	1.62	248.09	1.62	296.92	1.71
	HDV	251.88	1.42	210.10	1.37	299.76	1.73
	AV	1,234.05	6.96	1,224.39	7.99	1,276.54	7.37
	Total	17,721.07	100	15,326.15	100	17,331.20	100
NO _x (t)	CAR	7,992.67	46.19	7,090.09	45.11	8,282.76	45.42
	BUS	1,441.15	8.33	1,177.36	7.49	1,646.63	9.03
	LDV	167.90	0.97	173.42	1.10	242.82	1.33
	MHV	1,143.68	6.61	997.13	6.34	1,204.59	6.61
	HDV	1,102.39	6.37	915.20	5.82	1,309.50	7.18
	AV	5,454.68	31.53	5,365.39	34.13	5,548.09	30.43
	Total	17,302.48	100	15,718.59	100	18,234.38	100
PM _{2.5} (t)	CAR	276.09	48.56	256.49	49.30	310.85	50.71
	BUS	40.11	7.05	31.46	6.05	44.15	7.20
	LDV	18.65	3.28	18.17	3.49	23.44	3.82
	MHV	42.59	7.49	36.10	6.94	43.01	7.02
	HDV	33.58	5.91	27.22	5.23	37.98	6.20
	AV	157.56	27.71	150.80	28.99	153.56	25.05
	Total	568.58	100	520.24	100	612.98	100
PM ₁₀ (t)	CAR	336.66	50.94	310.98	51.40	342.11	52.22
	BUS	44.31	6.70	35.13	5.81	40.17	6.13
	LDV	20.38	3.08	19.79	3.27	22.48	3.43
	MHV	47.59	7.20	40.53	6.70	43.38	6.62
	HDV	37.03	5.60	30.18	4.99	33.52	5.12
	AV	174.98	26.47	168.39	27.83	173.47	26.48
	Total	660.94	100	605.01	100	655.13	100
CO ₂ (t)	CAR	1,536,634.20	61.13	1,449,798.53	60.29	1,769,202.49	60.77
	BUS	152,594.27	6.07	137,812.73	5.73	194,754.07	6.69
	LDV	41,559.61	1.65	40,582.44	1.69	57,112.42	1.96
	MHV	99,082.13	3.94	90,113.47	3.75	111,522.66	3.83
	HDV	100,869.11	4.01	87,841.10	3.65	131,738.71	4.52
	AV	583,000.46	23.19	598,699.95	24.90	647,201.86	22.23
	Total	2,513,739.78	100	2,404,848.22	100	2,911,532.21	100
SO ₂ (t)	CAR	0.009	56.80	0.009	56.18	0.011	56.65
	BUS	0.001	6.67	0.001	6.24	0.001	7.75
	LDV	0.000	1.86	0.000	1.87	0.000	2.15
	MHV	0.001	4.39	0.001	4.14	0.001	4.19
	HDV	0.001	4.47	0.001	4.04	0.001	4.95
	AV	0.004	25.82	0.004	27.52	0.005	24.30
	Total	0.016	100	0.016	100	0.019	100
Pb (kg)	CAR	163.22	65.64	144.59	64.47	175.58	64.18
	BUS	12.97	5.22	11.21	5.00	15.85	5.79
	LDV	4.61	1.86	4.27	1.90	6.04	2.21
	MHV	16.05	6.45	14.14	6.30	17.50	6.40
	HDV	10.75	4.32	9.16	4.09	13.98	5.11
	AV	41.05	16.51	40.89	18.23	44.63	16.31
	Total	248.65	100	224.27	100	273.57	100

5. Spatial distribution by squares of the EMEP network

On the basis of the calculated emission of pollutants by road sections and the belonging of the sections to the corresponding squares, the spatial distribution according to the squares of the Program of European Monitoring and Evaluation (EMEP) is made.

The emission level of the three selected pollutants according to the EMEP network squares in 2015 are shown in the following figures (Fig. 6 - Fig. 8). The highest emission of pollutants is in the squares where the length of the road network is large and the high value of the PGDS (squares 12.2, 12.1, 12.7, 12.8, etc.)

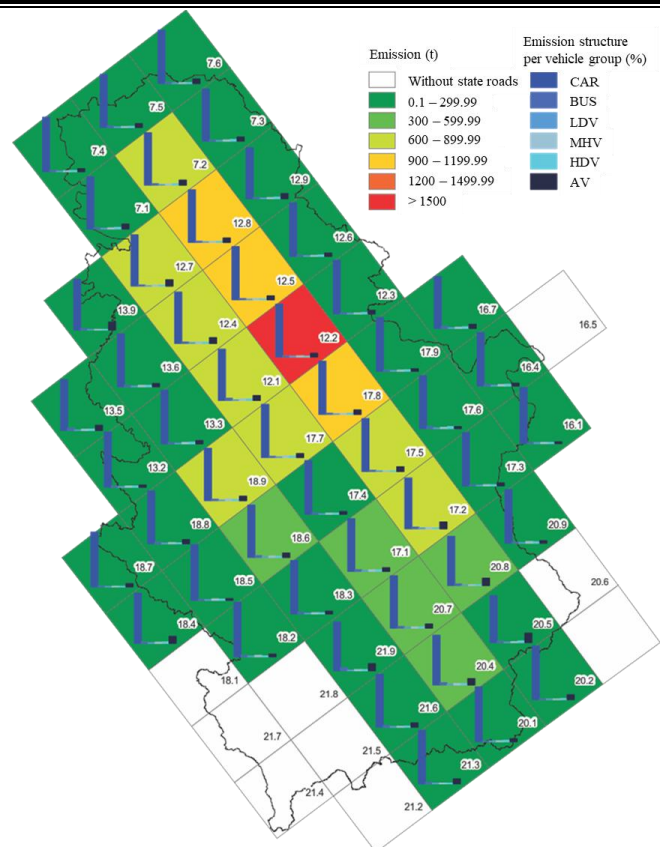


Fig. 6 Emission of CO per network squares, year 2015

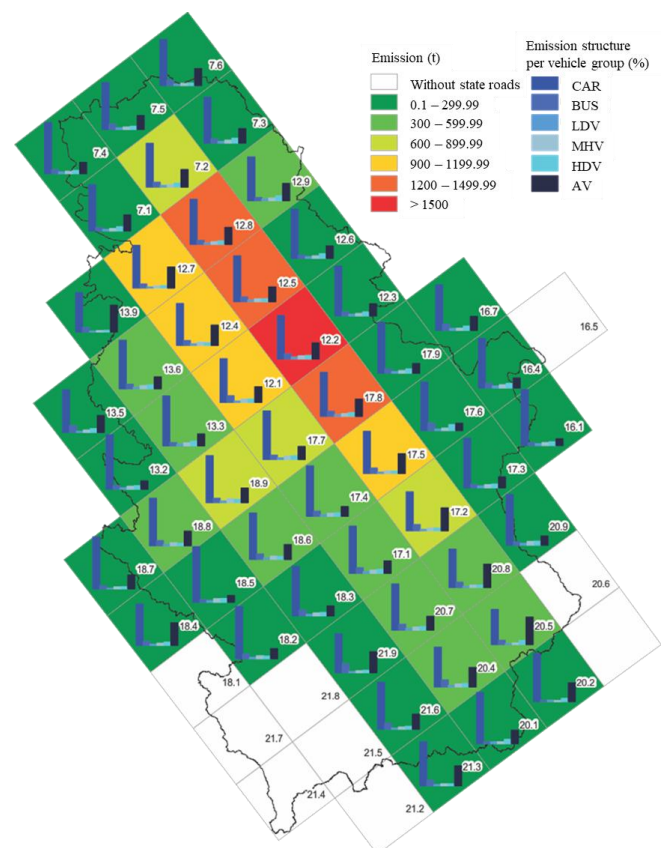


Fig. 7 Emission of NO_x per network square, 2015 year

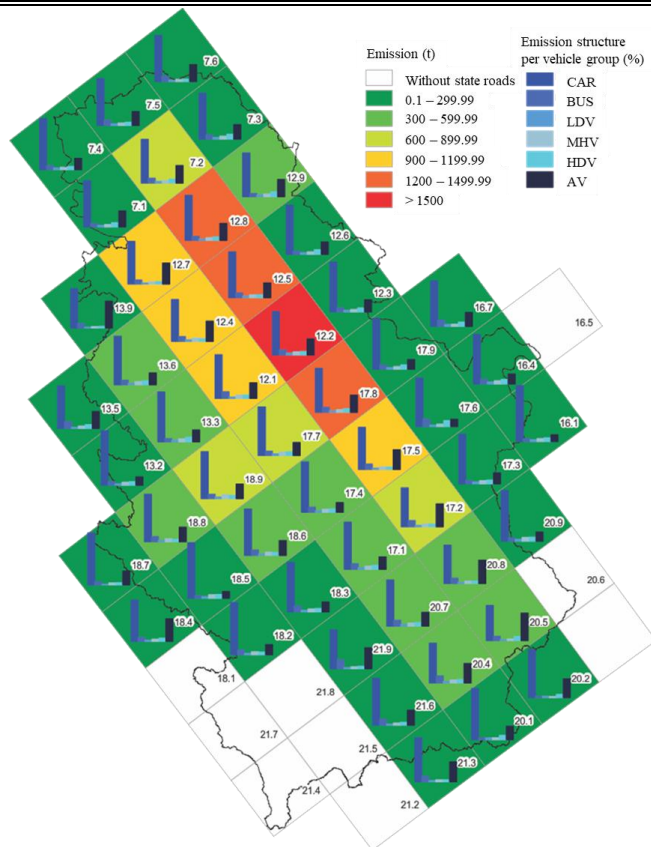


Fig. 8 Emission of CO₂ per network square, 2015 year

6. Conclusion

In order to calculate the amount of pollutants emitted in this study, the model and software tool of the European Environment Agency - COPERT 5 was used.

For the purpose of the calculation of emissions, systematized data on the fleet, mileage of the vehicle, climatological data and other elements necessary for the calculation were collected. For the observed period, the structure of the vehicle fleet was presented and the average annual mileage by category of vehicles was presented. Finally, as a result of using the COPERT 5 model, the quantities of emitted pollutants from road transport at the national level for the period from 2013 to 2015, as well as the quantities of emitted pollutants on the first and second roads in 2013, 2014 and 2015, as shown in the EMEP squares.

Depending on the quality and precision of the input data, depends the level of quality of the results of the calculation. The results of the calculation can serve as a basis for modeling different scenarios of changing the structure of the vehicle fleet, transport policy, ways of using roads and vehicles and the effects of these changes on the environment and the impact of these changes on the policy of taxation of the possession and use of roads and vehicles, both at national and at the local level.

The basic effect of applying the results of this study should be the creation of conditions for reducing the amount of pollutants emitted for the realization of a certain amount of transport work in order to reduce the adverse impact of vehicles on the environment.

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USER INTERFACE OF AN INNOVATIVE EXTERNAL BAGGAGE STORAGE SYSTEM FOR PUBLIC TRANSPORTATIONS

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Abstract: An innovative external baggage storage system for public transportation has been developed to ensure the ergonomic requirements. This paper proposes, for this system, a user interface that increases the level of comfort and security for train passengers. The interaction between the storage system and the final user it's based on a complex scenario which includes the analysis of train stops time frames, type of luggage, train station configuration and the user's age..

Keywords: PUBLIC TRANSPORTATION, STORAGE SYSTEM, ERGONOMIC, USER INTERFACE

1. Introduction

The purpose of this study is to analyze the current state of comfort and accessibility in public transport by rail and how they interfere with passenger transport options and their comfort when using these services. This study is based on surveys conducted in Europe by various companies specialized in this field and on statistical data recorded during simulations of passenger behavior and time tables on various train routes in Romania in the last 3 years by studying [1].

The study shows that there are various situations in Europe in terms of passenger comfort, accessibility and security, and areas requiring improvements in rail transport services.

These surveys concluded that the major difficulties are embarkation in train, finding the reserved place, acces to storage spaces, reduced mobility inside trains, uncomfortable chairs and the lack of security system.

The research is focused on the study of elderly people, people with disabilities and tourists. The results of this work will be relevant to future development and design, in terms of ergonomics, accessibility and comfort, in the public transport area. This study is aiming to optimize the flow between the passenger and luggage module by using the same user interface.

A major concern in rail passenger services is to find and assess the level of customer satisfaction. This level of satisfaction is largely influenced by the following factors: comfort, accessibility and security. Although these factors have been improved over the past 20 years, there are still major problems that require resolution and situations requiring improvement (figure 1), according to the information presented in the following study.

The impact of passenger dissatisfaction with rail transport services can lead to operational and financial costs. Also, this can impact environment in terms of people preferring to use personal transportation (greater pollution and more congested roads) [2].

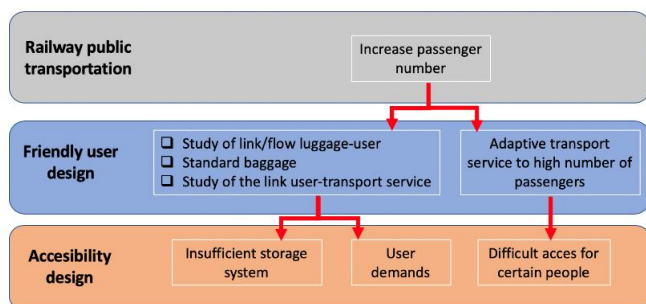


Fig. 1 Global increasing of passenger using public transportation *Грешка! Източникът на препратката не е намерен.*

In this study, the time required for different types of passengers to embark and disembark from the train is measured. Passengers aged between 15 to 70 years with heavy or light luggage are considered. Data was also collected during several train journeys,

with a large baggage experimenting with the storage solutions offered inside the train [3].

2. Ergonomic environment *Грешка! Източникът на препратката не е намерен.*

The comfort or discomfort of train passengers vary according to the purpose of the journey, the age of the passengers, the type of the wagon and the length of the journey. The influence of these factors increases when agglomeration exceeds a certain level, due to inadequate baggage storage or exceeding the normal journey capacity.

Human behavior has a special role in a properly constructed ergonomic environment. Psychological, behavioral and physical factors are needed to be analyzed in order to determine their influence on passenger comfort. Ethnographic methods can also be used to understand passengers behavior so that the user does not feel constrained in any way when traveling.

The constant changing technology can be used to inform, influence and direct passengers to make better use of the solutions offered for travel. Besides that, it is very important how the design impacts passenger behavior.

To determine the efficiency of accessibility and ergonomics offered by the train's characteristics in relation to human behavior, the time required for different passengers for boarding and disembarking from the train was measured [4]. The time measurement process was carried out during various hours of the day, including peak hours. By analyzing these times, adjustments can be made to the access routes and inside the train to achieve a better flow of passengers during the embarkation and disembarkation process.

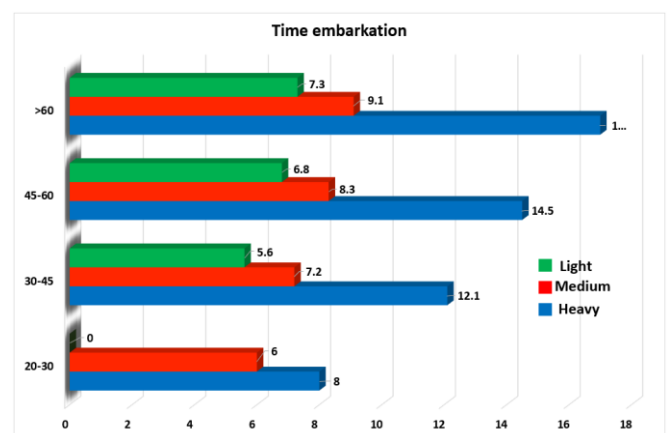


Fig. 2 Time analysis for embarkation *Грешка! Източникът на препратката не е намерен.*

A wide range of metal powders (from light alloys through steels to super-alloys and composites) is currently available for DMLS

process and other new materials are under development. Table 1 lists mechanical properties of selected powder materials.

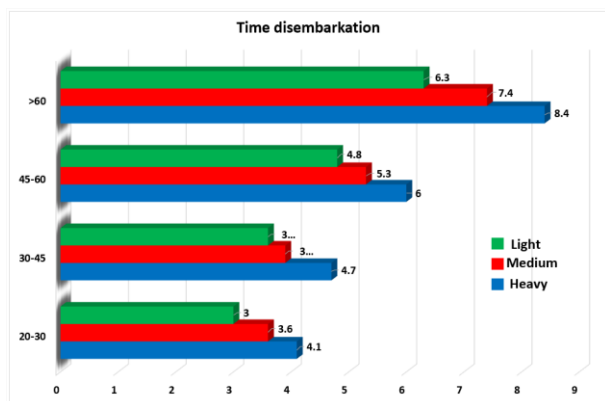


Fig. 3 Time analysis for disembarkation *Грешка! Източникът на препратката не е намерен.*

Thus, in case of medium and large luggage, the average disembarkation time for people aged from 20 to 35 was 4.54 seconds and for embarkation was 4.91 seconds. For the same type of luggage the average time at disembarkation for people between 35-70 years was 8, 4 seconds, and 8.8 seconds for embarkation. For younger people, boarding or disembarking time was about 2.5 seconds and for the elderly, between 7 and 15 seconds, depending on their luggage.,

Figure 2 and 3 shows disembarkation and boarding times in function of luggage volume for people of different ages was analysed considering stationary times at different stops. An increase in average time can be observed (highlighted in blue) for boarding and disembarking in case of people with large luggage and the elderly (respective of the size of their luggage).

3. User interface

The interaction between the user and the module is based on a complex scenario. The module is mounted on a train wagon and there is a live communication interface with the railway service provider. The scenario takes into account stationary times, the type of baggage and user age.

The user has access to a deposit space in the moment of buying the ticket. This will probably require an additional cost (figure 4).

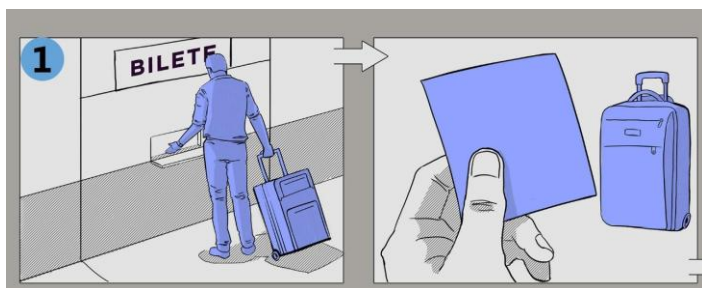


Fig. 4 Scenario: First step- Purchasing the ticket for deposit space *Грешка! Източникът на препратката не е намерен.*

The allocation of a deposit space it is done by a software. This software process the availability of spaces and destination stations. Boundaries are put in place, to avoid overloading a module, using methods to uniform the distributing of the seats for the entire train wagon.

Access to the deposit space is possible by scanning the barcode printed on the ticket at the time of purchase (figure 5). The ticket scan sends a command to the module to select the allocated deposit space [5], bringing it to the level of the user (figure 6).

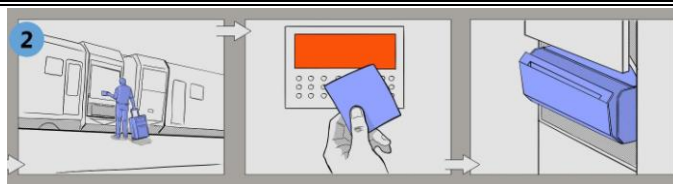


Fig. 5 Scenario: Second step- Automatically assignment of deposit space *Грешка! Източникът на препратката не е намерен.*

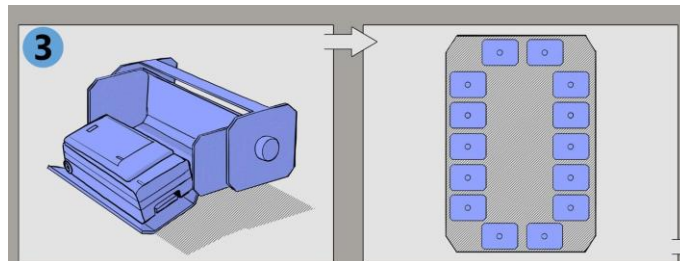


Fig. 6 Scenario: Third step- System pick up of the luggage.

The system takes the capsule with the luggage in, then prepares another capsule for the next user (figure 6).

To access the baggage at the destination station, the user has to scan the ticket on a device located inside the wagon in the immediate vicinity of the access door (figure 7). The location of the scanning device, is based on the intention of organizing and fluidizing access to the module. The time required for pick up the luggage from the deposit space is equivalent with the time needed for the passenger to scan the ticket, disembark the train and arrive in front of the module.

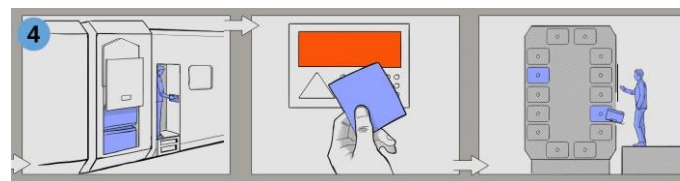


Fig. 7 Scenario: Fourth step- Pick up the luggage at destination.

4. Conclusions

The external baggage storage system presented in this paper brings an increase in comfort and security for railway transportation users. The system offers adequate storage for luggage and easy access.

The storage dimensions are in total concordance with the existing type of baggage. The module dimensions permit the internal design, to be modified in case of changing the international standards.

Implementation of this system doesn't require administrative staff and has a friendly user interface. Also, the system pick up mechanism it's easy to use, by elderly and people with disabilities.

From a security point of view, the system can be improved, by adding special scanning device in the moment of the pick up.

The proposed concept represent a viable solution which can partially resolve some of the current shortcomings in public transportation.

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SOCIAL DEVELOPMENT MANAGEMENT OF AIRLINES IN UKRAINE

УПРАВЛЕНИЕ СОЦИАЛЬНЫМ РАЗВИТИЕМ АВИАКОМПАНИЙ В УКРАИНЕ

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Annotation. The purpose of this study is to determine the importance of influencing the effectiveness of social development management of airlines in Ukraine on the economic indicators of their economic activity. The study was conducted on the example of 10 Ukrainian airlines, whose financial statements are officially available during the analysed period of 2007-2017. The results of applying the statistical analysis method showed that spending on social activities, as an indicator of social development is the largest by volume and the best in the positive dynamics of the market leader, the UIA airline. However, the use of the method of analytical alignment to analyze the impact of spending on social activities of the analyzed Ukrainian airlines on the profitability of their sales showed that the strongest impact of the results of social development management on the efficiency of economic activity are in such airlines as Constanta, Artem-Avia, Kharkiv Airlines and Dniproavia. Consequently, the main hypothesis of the study on the average importance of the impact of spending on social activities as an indicator of the effectiveness of social development management on the economic performance of airlines in Ukraine was confirmed.

KEYWORDS: AIRLINE, MANAGEMENT, SOCIAL DEVELOPMENT, PROFITABILITY OF SALES, SPENDING ON SOCIAL ACTIVITIES.

1. Introduction

The research of problems and prospects of the development of the air transport market in Ukraine was carried out by the authors in the previous publication (G. Zhavoronkova, V. Zhavoronkov, M. Volvach, 2018). However, the social security of this development has not received adequate attention. Indeed, modern trends in world development require airlines to be socially responsible actors of societies in which they operate, and to use social results as factors of their further economic growth. This has become particularly relevant during the times of the socioeconomic crisis that is taking place in Ukraine.

In our view, the practical management of Ukrainian airlines underestimates the priority of social goals and often has a stereotypical view of social issues as an object of exclusive management of state bodies. However, today the harmonization of social and economic goals is very important for the strategic management of human capital of airlines in Ukraine, since the components of the social-commercialization activity of the reflexive-knowledge paradigm have the greatest impact on their socio-economic development (Shkoda, 2018). Applied aspects of managing the social development of airlines in Ukraine need further research.

The purpose of this research is to determine the importance of influencing the effectiveness of social development management of airlines in Ukraine on the economic indicators of their economic activity.

The main hypothesis of the research is that the importance of influencing the spending on social activities as an indicator of the effectiveness of social development management on the economic performance of airlines in Ukraine is average.

2. Literature review

Problems of social development of enterprises and their management are researched in the works of the following scientists: A. Babenko (2015), A. Kolot (2008), O. Martyakova (2011), T. Nadтока and G. Kakunina (2011), O. Novikova (2018), L. Semenova (2016), N. Sychova (2015), etc.

In their study, T. Nadтока and G. Kakunina (2011) note that the key feature of the social development of the enterprise is a certain type of change, which leads to a qualitatively new state of all social processes and relations in the enterprise. N. Sychova (2015) interprets the social development of the enterprise as "progressive quantitative, qualitative and structural organizational changes aimed at improving the social environment of the enterprise and the sphere of social relations with the groups of those interested in the activity of the enterprise such as owners, personnel, consumers, public, business partners on principles of social partnership and participatory approach in management". This author also links social development with changes, and takes into account the impact of the social environment and relationships with stakeholders.

In our opinion, the social environment in Ukraine does not contribute to the rapid social development of domestic airlines. Unpopular social reforms, absence of Social Code, unconsciousness of the priority of social goals solution by airlines delay practical and theoretical understanding of social development. For the transformation of the modern situation, changes are needed both in applied and in the theoretical way. Ensuring appropriate changes requires the development of a methodology for creating a favourable internal and external social environment.

Social development covers a wide range of aspects that are factors of the close social environment of the organization (Shkoda, 2012): organization potential, social infrastructure, working conditions, occupational safety, leisure, material remuneration, socio-psychological climate, social security. All these factors have a full effect on the social development of airlines. For example, according to O. Novikova and L. Logachova (2018), the reform of the Ukrainian labour protection management system in Ukrainian enterprises needs to improve the scientific and methodological support for the analysis and evaluation of industrial safety and occupational risk, the modernization of the system of benefits and compensations under labour conditions on the basis of a risk-oriented approach.

Thus, the social development of the airline can be characterized as noticeable changes in the air transport company, determined by the transition of all social relations and processes to a qualitatively new state under the influence of factors of the internal

and external environment. The social development of the airline's employees as human capital carriers is a consequence of both the targeted activity of the people who are the subjects of this process and the indirect effect of production on the social groups of the enterprise, the population of the region, and the consumers of the air transport company's services.

According to N. Sychova (2015), the social development management of the enterprise is a process of improving the internal social environment and conditions for the implementation of labour activities of the personnel, which allows enterprises to achieve high results of economic activity. Agreeing in general with this viewpoint, we consider it useful to add that in order to successfully manage the social development of the airline it is necessary to identify clearly the real goals of social development, the ways of achieving which must be prescribed in the social policy of the air transport enterprise and provided with the necessary resources. Of course, the implementation of the developed social measures is essential.

According to the authors' point of view, the social policy of the airlines represents the goals and measures related to the provision of additional social benefits, services and benefits to workers, which ensure the involvement of airline employees. At most, enterprises, along with mandatory social programs, a large number of voluntary programs are being implemented. Implementation of compulsory and voluntary social programs is the implementation of the social function of the airline.

According to L. Semenova & A. Shapoval (2016), A. Babenko & A. Holodna (2015), the social policy of the enterprise should be considered in conjunction with the social policy of the state, since the activities of the enterprise in the social sphere are determined by social policy and oriented on, it general laws and contributes to the achievement of the main goals. In view of this, the authors believe that the social policy of the enterprise and the social policy of the state are influenced by the trends of world development, which, in our opinion, should be supplemented with the main components and presented in Table 1.

Table 1 Trends and the main components of global development that affect social development of the enterprise

Main components	Trends		
	Generally civilizational	Economic	Social
New technologies	The development of the Internet, nanotechnology and biotechnology (in general, NBICS technologies)	E-business, automation and robotics	Social innovations, mass communications
Organizational structures	Adaptive, flexible and network organizational structures	Virtual (digital) economy	The emergence of the doctrine of "social cohesion" Socially responsible business
Results	Desynchronization Internationalization	Globalization and ecologization of the world economy	Mass consumer individualization Changing the demoseconomic characteristics of human capital

Source: composed by the authors on the basis of (A. Kolot, 2008; O. Martynakova, V. Zubenko, 2011)

Indeed, it is evident that the economic realities and social development of the country, and therefore the enterprises, correlate with each other, the transformation of social and labour relations and social expectations of airline employees and the airlines themselves as employers is taking place.

At the large enterprise, social development management is implemented by the social unit of the personnel management department, while in the medium or small enterprise, the specified functions are performed by individual employees of the personnel

management department or employer. The tasks and functions of these employees have their own specifics. In the process of carrying out work on social development of personnel, they must, by means of justified provision of additional payments and benefits, encourage the employees to their further development.

3. Research methodology

The research of determining the importance of influencing the effectiveness of management of the social development of airlines in Ukraine on the economic indicators of their economic activity was conducted on the basis of available official data of the Stock Market infrastructure development agency of Ukraine (SMIDA, 2019) for 2007-2017 for 10 airlines in Ukraine.

In the process of the research, statistical methods were used to analyse the dynamics of spending on social activities in Ukrainian airlines as a significant indicator of social development.

To analyse the impact of spending on social activities of Ukrainian airlines on the profitability of sales, the method of analytical alignment was applied by the authors. The trend model is considered to be adequate to the process being studied and reflects the tendency of its development in time, when the provided values of R^2 are close to 1.

An important problem that was solved with the application of the method of analytical alignment was the selection of a mathematical function for which the theoretical levels of a row are calculated. The trend model, in which the determination coefficient had the highest value, became the most adequate for each estimated dependence.

Also, the correlation coefficient was determined, which made it possible to measure the statistical dependence (the level of influence of the argument x (spending on social activities of Ukrainian airlines) on the function y (profitability of sales)). It is taken into account that the correlation coefficient can range from -1 to +1. Therefore, based on the value of the calculated coefficient of correlation on the Chaddock scale, the conclusion was reached on the presence or absence of stochastic dependence: 1) from 0 till $\pm 0,3$ – absent; 2) from $\pm 0,3$ till $\pm 0,5$ – weak; 3) from $\pm 0,5$ till $\pm 0,7$ – moderate (average); 4) from $\pm 0,7$ till ± 1 – strong.

4. Research results

The success of measures to improve the social development of airlines was analysed by assessing their spending on social activities and analysing their impact on profitability of sales of Ukrainian airlines for the period 2007-2017.

The results of the analysis of the dynamics of spending on social activities for Ukrainian airlines are shown in Figure 1. It was also used in the calculations the projected spending on social activities of airlines in Ukraine for 2018-2019, as the official statistical reporting for 2018 at the time of the research was not available.

On the basis of the analysis of the obtained results (Fig. 1), it is noted that in the social development of air transport enterprises, several trends are outlined:

growth of rates of increase of spending on social activities of the leader of the air transportation market, Ukrainian International Airlines (UIA);

slight increase for airlines URGA and Ukrainian Helicopters; a certain deceleration in the rate of increase of spending on social activities for airlines Bukovina, Dniproavia;

saving at the same level for airlines Artem-Avia, Kharkiv Airlines, Constanta, Spets-Avia, and Ukraine-Aeroalliance.

The increase in spending on social activities enables the airline UIA: to increase the flexibility of social programs, to strengthen the individual approach, to enrich the content of social programs, due to the need to meet new social needs and problems. All this confirms that the social function of this airline is developing and strengthening, which contributes to the development of its personnel, the formation of partnerships and increased efficiency of work.

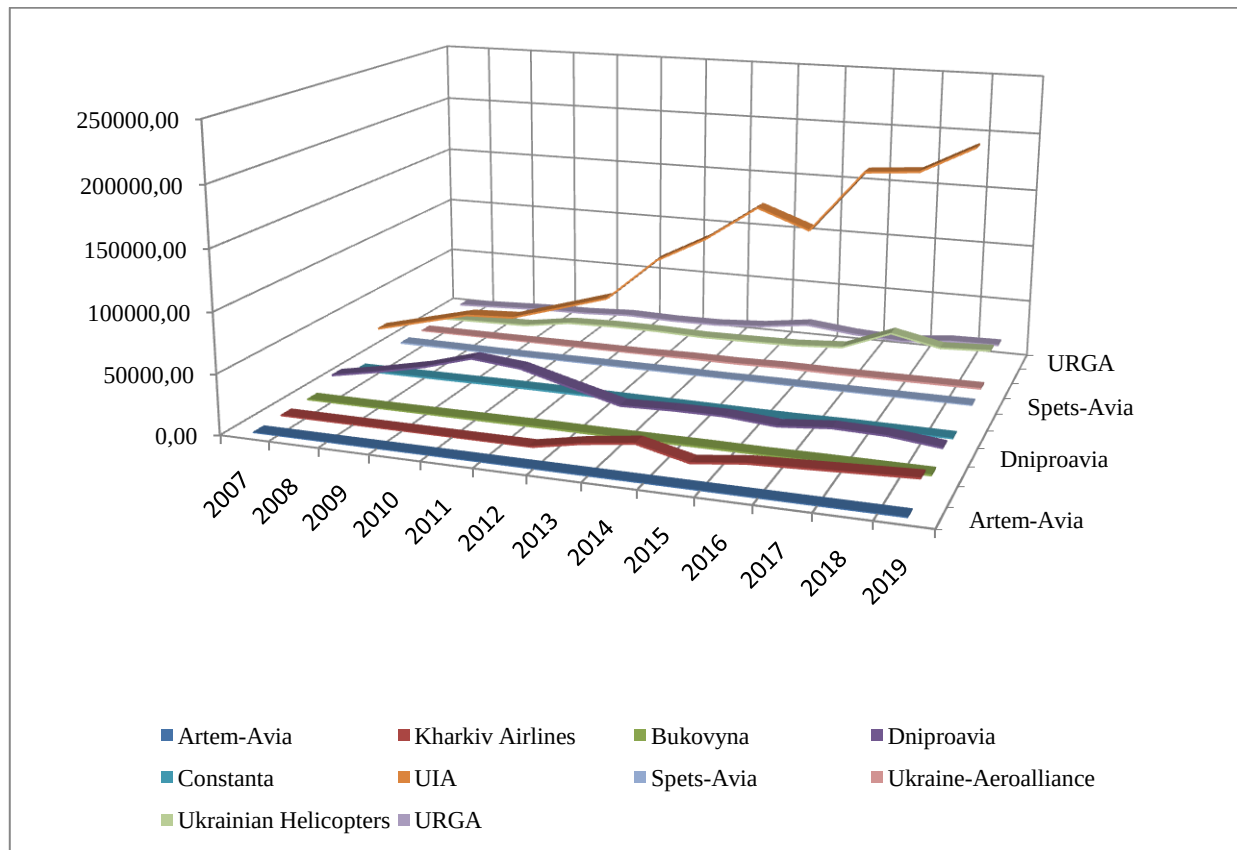


Fig.1. Dynamics of spending on social activities for Ukrainian airlines, thousand UAH, 2007-2017 years

Source: calculated by the authors on the basis of (SMIDA, 2019)

The results of analytical alignment for spending on social activities of airlines are presented in Table 2.

As a mathematical model of the trend for all Ukrainian airlines analysed, the second-order polynomial is chosen, since the determination coefficient R^2 has the highest value among the proposed by the program Microsoft Excel.

Most of the existing polynomial dependencies indicate the relative stability of the impact of the dynamics of costs on the social measures of Ukrainian airlines on the profitability of sales with a steady slight slowing down of their growth rates, as evidenced by the small negative value of the coefficients a_2 (Table 2).

Table 2 Impact of spending on social activities of Ukrainian airlines (x) on profitability of sales (y), 2007-2017 years

Airline	Economic-mathematical model	Determination coefficient (R^2)	Correlation coefficient (R)	Student's t-criterion
Artem-Avia	$y = 0,0002x^2 - 0,0261x + 0,7881$	0,2843	0,5332	1,7827
Kharkiv Airlines	$y = -2E-08x^2 + 0,0004x - 2,3803$	0,2846	0,5335	1,7840
Bukovina	$y = 2E-05x^2 - 0,0271x + 7,4101$	0,1668	0,4084	1,2655
Dniproavia	$y = 3E-09x^2 - 7E-05x - 0,9873$	0,2791	0,5283	1,7599
Constanta	$y = -2E-06x^2 + 0,0054x - 3,1131$	0,8038	0,8965	5,7249
UIA	$y = 1E-11x^2 - 3E-06x + 0,0819$	0,1556	0,3945	1,2142
Spets-Avia	$y = -1E-05x^2 + 0,0098x - 2,1016$	0,0889	0,2982	0,8835
Ukraine-Aeroalliance	$y = -6E-08x^2 + 9E-05x + 0,0185$	0,0715	0,2674	0,7849
Ukrainian Helicopters	$y = 2E-10x^2 - 7E-06x + 0,0309$	0,0555	0,2356	0,6856
URGA	$y = 3E-10x^2 - 1E-05x + 0,1371$	0,1278	0,3575	1,0827

Source: calculated by the authors on the basis of (SMIDA, 2019)

The calculated correlation coefficient R (Table 2) indicates the strong stochastic dependence of the profitability of sales of the airline Constanta on the factor indicator of spending on social activities for the relevant period. This means that in this airline, social development has a significant impact on the economic performance. Also, the influence of the factor character x on the resulting indicator y should be taken into account in the social development management of the analysed airline.

The moderate (average) value of the correlation coefficient R occurs in the airlines Artem-Avia, Kharkiv Airlines and Dniproavia. This also points to the very significant dependence of the profitability of sales on the spending on social activities of these airlines.

For the airlines of Bukovina, UIA, Spets-Avia, Ukraine-Aeroalliance, Ukrainian Helicopters and URGA, no significant stochastic dependence of the profitability of sales (y) on the factor characteristic of deductions on social measures (x) was found during the relevant period.

The evaluation of the constructed regressive economic and mathematical models based on Student's t -criterion (Table 2) confirms their adequacy under the following conditions (to define critical values the appropriate statistical tables were used (Vitlinskyj, 2008)):

Constanta – $t''_{critic.value}(\sigma/2; k) = 2,306$ at the level of significance $\alpha = 0,05$ and degrees of freedom $k = n - m - 1 = 8$,
 $t'_{critic.value}(\sigma/2; k) = -t''_{critic.value}(\sigma/2; k) = -2,306$;

Artem-Avia, Kharkiv Airlines and Dniproavia – $t''_{critic.value}(\sigma/2; k) = 1,397$ at the level of significance $\alpha = 0,2$ and degrees of freedom $k = n - m - 1 = 8$, moreover $t'_{critic.value}(\sigma/2; k) = -t''_{critic.value}(\sigma/2; k) = -1,397$;

Bukovina – $t''_{critic.value}(\sigma/2; k) = 1,108$ at the level of significance $\alpha = 0,3$ and degrees of freedom $k = n - m - 1 = 8$, moreover $t'_{critic.value}(\sigma/2; k) = -t''_{critic.value}(\sigma/2; k) = -1,108$;

URGA – $t''_{critic.value}(\sigma/2; k) = 0,889$ at the level of significance $\alpha = 0,4$ and degrees of freedom $k = n - m - 1 = 8$, moreover $t'_{critic.value}(\sigma/2; k) = -t''_{critic.value}(\sigma/2; k) = -0,889$;

UIA, Spets-Avia, Ukraine-Aeroalliance – $t''_{critic.value}(\sigma/2; k) = 0,706$ at the level of significance $\alpha = 0,5$ and degrees of freedom $k = n - m - 1 = 8$, moreover $t'_{critic.value}(\sigma/2; k) = -t''_{critic.value}(\sigma/2; k) = -0,706$;

Ukrainian Helicopters – $t''_{critic.value}(\sigma/2; k) = 0,546$ at the level of significance $\alpha = 0,6$ and degrees of freedom $k = n - m - 1 = 8$, moreover $t'_{critic.value}(\sigma/2; k) = -t''_{critic.value}(\sigma/2; k) = -0,546$.

These obtained results also confirm the main hypothesis of this research as the regressive economic and mathematical models with strong and average values of the correlation coefficient have the confirms their adequacy under the highest level of significance.

5. Conclusions

The results of applying the statistical analysis method showed that spending on social activities as an indicator of social development is the largest by volume and the best in the positive dynamics of the market leader, the UIA airline. However, the use of the method of analytical alignment to analyze the impact of spending on social activities of the analyzed Ukrainian airlines on the profitability of their sale showed that the most significant impact of the results of social development management on the efficiency of economic activity are in the airlines Constanta, Artem-Avia, Kharkiv Airlines and Dniproavia. Consequently, the main hypothesis of the research was confirmed on the average importance of influencing the spending on social activities as an indicator of the effectiveness of social development management on the economic performance of airlines in Ukraine.

It is significant that the majority of airlines, whose spending on social activities were stable during the analyzed period of 2007-2017, also have the strong (airline Constanta) or the average (airlines Artem-Avia, Kharkiv Airlines) importance of the impact of this factor on the profitability of their sale.

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GENERATING MANAGEMENT PROGRAM OF THE TEST BENCH SKAD-1 FOR COMPUTER CONTROL OF AUTOMOTIVE GASOLINE INJECTION ENGINE

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Abstract: The new requirements of modern automobiles become more stringent corresponding to power, torque, fuel economy and ecology legislations [2]. The main factor in this area is the automotive engine fuel system, which is controlled by the electronic control unit (ECU). The electronic control of the Spark Ignition Engines (SI engines), as well as the Direct Ignition Engines (DI engines) is based on the certain sensors signals, program maps and management algorithms. The advanced automotive scientific research centres and automotive manufacturers design and develop a specialized laboratory, stationary and movable test benches and train complex for researching and testing of automotive sensors and actuators, automotive prototypes and series, and automotive units. The test benches for internal combustion engine (ICE) management are the equipment, which are used for ICE development, specification and testing. These test benches allow the engine to work at different work modes and states and ensured measurement of the engine physical work parameters. The design of the engine management test benches enable easy access to the ICE certain systems, units and details. This paper includes results of the generating a control program using the Flowcode 7.0 software of test bench SKAD-1 for computer management of automotive gasoline injection engine, with ability to programming input parameters and measuring the output results.

Keywords: TEST BENCH, MANAGEMENT, GASOLINE INJECTION

1. Introduction

The automotive industry is one of the important sectors of the economy also undergo unceasing updating, in looking for competitive advantages even in small things, and more so using breakthrough technology [4]. Electronics, computers and sensors have become an integral part of any modern car.

In this connection, it is extremely important to study, design and develop management programs of automotive components and processes.

The structure of a test bench SKAD-1 for computer control of automotive ICE with petrol injection is presented in Fig.1

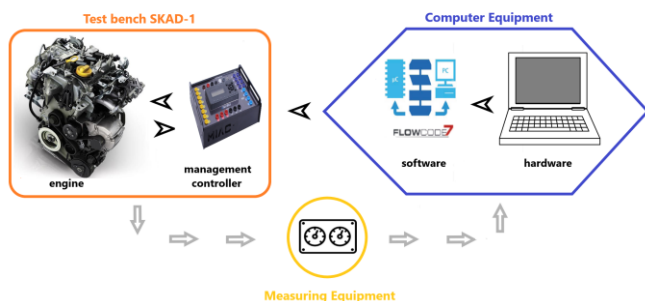


Fig.1. Schematic diagram of a test bench SKAD-1 for computer management of automotive ICE with petrol injection [5, 6, 8]

As a base of the test bench SKAD-1 is chosen automotive gasoline injected ICE brand Renault, Kangoo (98-09), engine capacity 1149 cm³, power 44kW (60 hp) / 5250 min⁻¹, torque 105 Nm / 3500 rpm, cylinder diameter 69 mm, piston stroke 76.8 mm, compression ratio 9.6. The engine of the test bench SKAD-1 is equipped with its own electronic control unit brand name "Marelli".

The management controller of the engine ECU is Matrix MI0245, developed by Matrix Technology Solutions Limited, England [8]. With the MI0245 controller, the SKAD-1 engine is started and stopped, and in the future it is possible to design and reproduce individual engine operating points as part of the engine output characteristics.

Computer control of the test bench engine is carried out with computer equipment using the program product Flowcode7 [7], which is used to program and set up the management controller, which may be according to the purpose of the respective task or study.

The results of the programming, tuning and control of the test bench SKAD-1 are reported using the measuring equipment. For this purpose, a control panel is built on the test bench, which gives access to all signals of the sensors and actuators. An oscilloscope holder for measuring and recording real-time signals is provided. A gas analyzer can be connected to the test bench to measure the amount of exhaust emissions.

Measurement results serve as a benchmark and prerequisites for making adjustments to the management program and the operation of the test bench.

The test bench layout is designed with the perspective of being able to connect in the future to a dynamometer equipment to capture the full set of ICE characteristics of the test bench and to fully evaluate the management programming and setup parameters. The common view of the test bench SKAD-1 is represented in Fig.2.



Fig.2. Overview of the test bench SKAD-1: 1-test bench; 2- computer equipment; 3-measuring equipment

To the technological possibilities of the test bench SKAD-1 can be noted:

- 1) Computer control via programmable controller MI0245;
- 2) Automatic control via the OEM electronic control unit Marelli;
- 3) Development of management programs with Flowcode7 software;

- 4) Oscilloscope measurement of input and output signals from sensors and actuators;
- 5) Exhaust emission measurement by exhaust gas analyzer;
- 6) Diagnostics via diagnostic interface;
- 7) Ability to join to a dynamometer equipment.

The three-dimensional appearance of the developed test bench SKAD-1 is shown in Fig. 3.

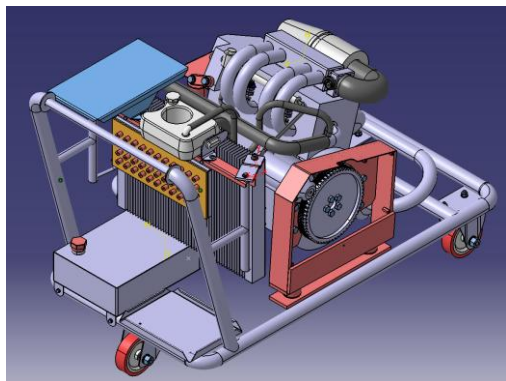


Fig. 3. Three-dimensional model of the test bench SKAD-1

2. Structure

The development of the management program of a SKAD-1 test bench for computer control of automotive ICE with gasoline injection was carried out with the software product Flowcode, a modern integrated development environment (IDE) for development of electronic and electromechanical systems [1, 3, 7]. The development of the SKAD-1 test bench management program consists of four stages.

The first stage of the analysis consists in choosing a corresponding process to be managed. By default, this is the process of starting, running, and stopping an ICE of the test bench. As a control system, a fuel injection system is selected as part of an ICE of the SKAD-1 test bench. In the analysis of the fuel injection system the following components are specified as well as the respective connections between them:

- 1) Sensors – buttons for access, start, run and stop of SKAD-1 test bench;
- 2) Actuators – SKAD-1 engine main relay, a fuel pump relay, a starter relay, a fuel pump, fuel injectors;
- 3) Electronic control unit – controller MI0245 and SKAD-1 control board;
- 4) Sequence of work – access level 1, access level 2, ON, START, RUN, OFF;
- 5) ON / OFF conditions – switching ON the main relay in ON mode, switching ON the fuel pump and the starter in START mode, automatic shut-OFF of the starter after 1 s, normal operation in RUN mode, switching OFF the main relay and the fuel pump relay in OFF mode;
- 6) ON / OFF times – according to the control program, which may vary depending on the mode of operation;
- 7) ON / OFF state – depending on the position of the control buttons;
- 8) Forbidden operating modes – in OFF and FAILED modes;
- 9) Allowed modes of operation – in ON" and RUN modes.

The second stage (design stage) consists in generating the management program, which is related to the determination of macros for operating modes, parameters and function of the components and variables for the operating states.

The macros for operating modes are:

- 1) Master macro Main (main program);
- 2) GetCode access macro;
- 3) ON macro;
- 4) START macro.

3. Management Program

The algorithm of the SKAD-1 management program is shown in Fig. 4 to Fig. 9.

At the start (1) of the management program (fig.4), the MIAC controller screen is initialized (2) and the instruction label "Test bench SKAD1" (3) is made. Then follows positioning the cursor on the screen (4) and printing "ENTER CODE" (5). The value of the variable "ignition" (6) is initialized.

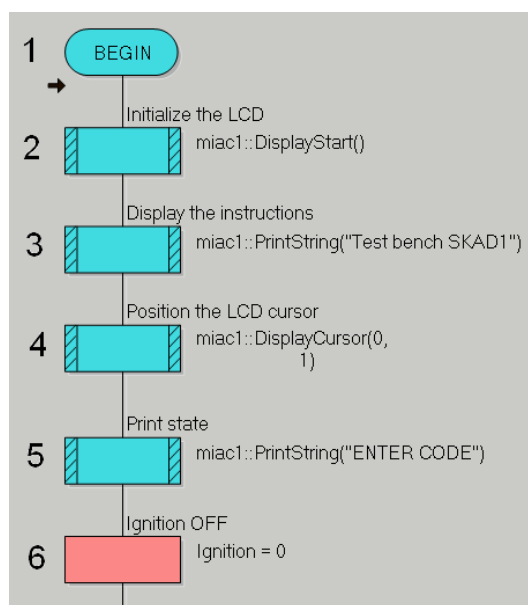


Fig. 4. Initialization

Since it is necessary to periodically repeat the following instructions (fig.5), the loop function (7) is used. In the cycle, the access codes for accessing the first level are checked in the macro GetCode (8), where the variable "Passcode1" is checking [9]. The checking proceeds after the setting a combination for the first code.

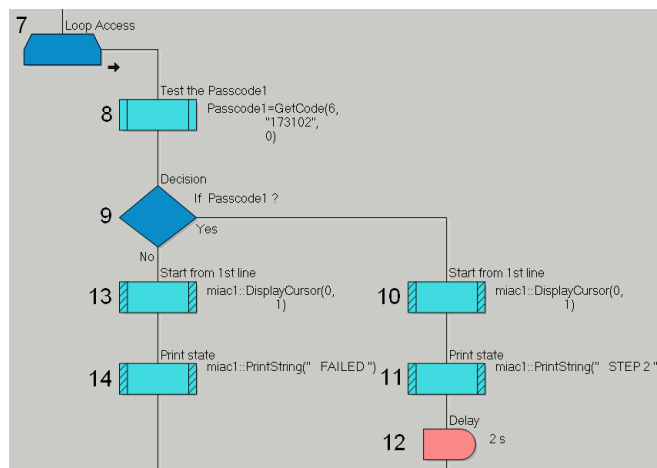


Fig. 5. Accessing the first level

The decision function (Decision) (8) - fig. 5 is used after the introduction of the first code for verification of its correctness. If the entered combination is wrong, the screen cursor (13) activates and "FAILED" message (14) is printed, the cycle ends and the program returns to begin 1 (fig.4). When the entered combination is correct, the cursor (10) activates and the message "STEP 2" (11) is printed on the controller display. The Delay function (12) increases the time interval from the message inscription until it is hidden.

Then the access codes for accessing the second level (fig.6) are checked in the same macro GetCode (15), where the variable "Passcode2" is checking.

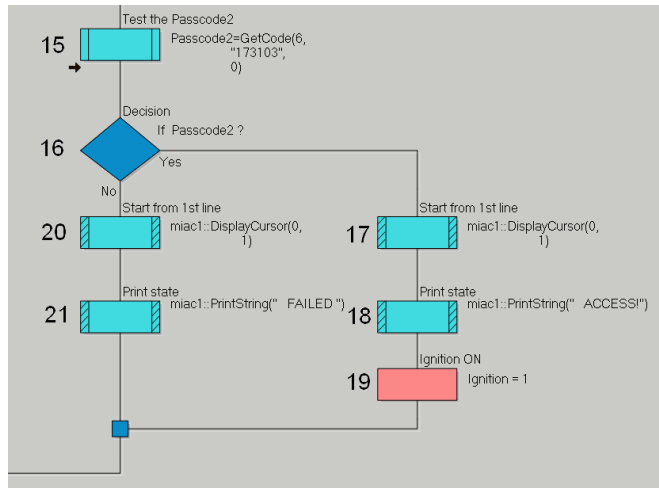


Fig. 6. Accessing the second level

The checking proceed after the set a combination for the second code. The decision (16) is used again after the introduction of the second code for verification of its correctness. If the entered combination is wrong, the screen cursor (20) activates and "FAILED" message (21) is printed, the cycle ends and the program returns to begin 1 (fig.4). When the entered combination is correct, the cursor (17) activates and the message "ACCESS!" (18) is printed on the controller display. The value of the variable "ignition" (19) is changed, allowing access to the "ON" and "START" macros - fig.7.

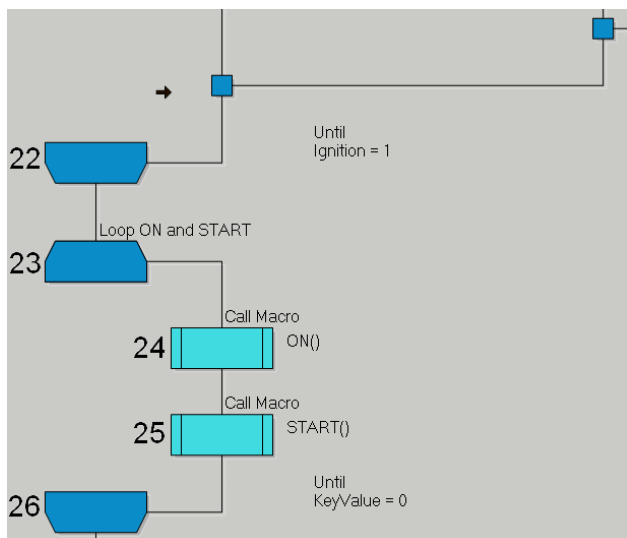


Fig. 7. Implementing the loop for ON and START macro

The program exits from the code verification loop (22) and introduces a new cycle entry (23) command. It runs the macro "ON" (24) and the macro "START" (25). If the variable "keyvalue", which is set by the controller keypad is equal to zero the cycle (26) ends (fig.8).

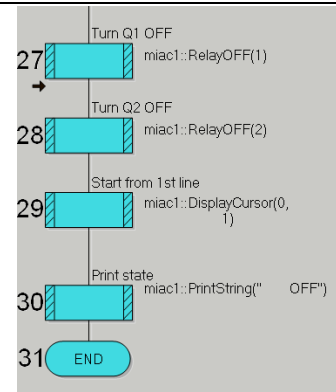


Fig. 8. End of management program

Then the output "Q1" of the controller, which is used to control the main relay, is switched OFF (27) and the main relay is turned OFF. Switching OFF the output "Q2" (28) via which the fuel pump relay is supplied leads to turn the fuel pump OFF. The cursor (29) activates and the controller display shows "OFF" (30). The program goes in end (31). Program goes to begin by the controller reset.

4. Management program macros

The management program macros are an ON macro to turn ON the SKAD-1 main engine relay and a START macro to start the SKAD-1 engine.

ON macro algorithm for switching ON the SKAD-1 main engine relay is shown in fig. 9.

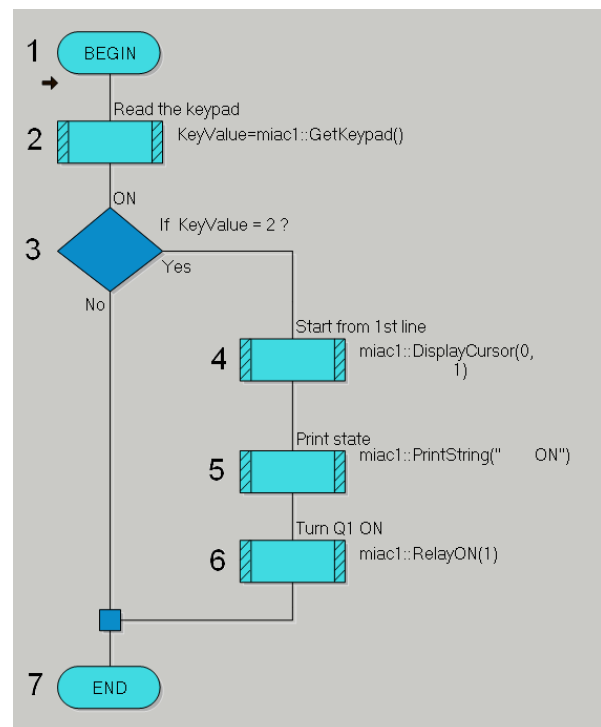


Fig. 9. ON macro

After the begin (1) the controller keypad (2) is read. The decision (3) compares the different keypad values. If the set value of the "keyvalue" variable is equal to two then the cursor (4) activates, and "ON" is printed on the display (5). The output "Q1" (6) is switched ON which turns the SKAD-1 main engine relay ON. With different set value or unpressed button, the macro goes to end (7) and because of the loop (fig.7) goes again to begin (1).

The algorithm of the START macro to start the SKAD-1 engine is shown in fig. 10.

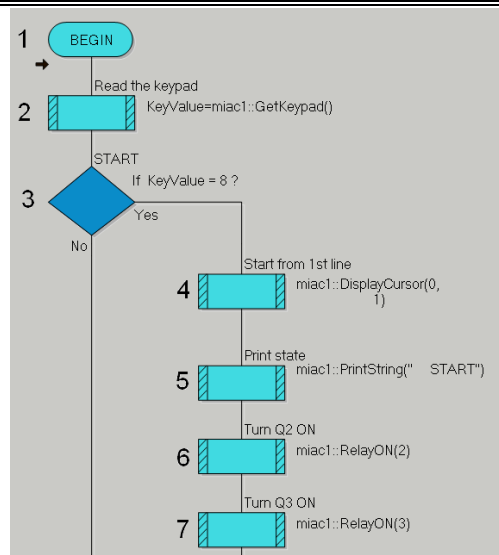


Fig. 10. START macro-first part

After the begin (1) the controller keypad (2) is read. The decision (3) compares the different keypad values. If the set value of the "keyvalue" variable is equal to eight then the cursor (4) activates, and "START" is printed on the display (5). The output "Q2" (6) is switched ON, which turns the fuel pump relay ON. The output "Q3" (7) is also switched ON, which turns the starter relay ON.

A delay of one second (8) is set (fig.11) during which the SKAD-1 engine is starting. After 1 s the output "Q3" (9) is turned OFF. The cursor (10) activates and the display (11) of the controller prints "RUN". The controller keypad (12) continues to be read.

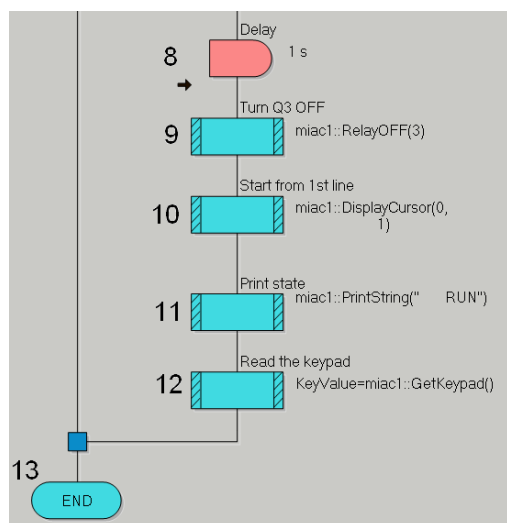


Fig. 11. START macro-second part

With different set value or unpressed button, the macro goes to end (13) and because of the loop (fig.7) goes again to begin (1).

During the RUN mode the SKAD-1 engine is running and sensors and actuators signals can be measured, such as the intake air temperature sensor, the manifold air pressure sensor, the throttle position sensor, the knock sensor, the engine coolant temperature sensor, the oxygen sensor (lambda-probe), the ignition coil, the electromagnetic injectors, auxiliary air device (idling), etc.

The third stage of program implementation consists in transferring the generated management program (hex file) and its execution using the MI245 controller and the SKAD-1 control panel.

The fourth stage of program development continues with adjustments and changes of the parameters in the management program, reproduction of the program and analysis of the results obtained.

5. Conclusion

The developed management program covers the process of switching ON, starting and switching OFF the SKAD-1 test bench. This can be used as the basis for future development of management programs to design work points from the ICE operating regime and its self-management via the controller MI0245.

The management program can be used as a successful basis for further programming of the test bench, according to the interests and creativity of students and researchers in the researching of the processes in automotive technique.

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NORMS AND LEGAL REGULATIONS TO LIMIT TOXIC EMISSIONS FROM INTERNAL COMBUSTION ENGINES WHEN USING ALTERNATIVE FUELS AS ENVIRONMENTALLY ELIGIBLE IN RELATION OF CONVENTIONAL FUELS

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Abstract: During the decades-long development of internal combustion engines, the main criteria for optimality were the increased power, the low fuel consumption and the adjustment of the working process under non-stationary operating conditions. Even when the air quality in some settlements was significantly worsening, due to the high degree of motorization, special attention has been paid to polluting the atmosphere with exhaust gases from the engines. Problems that are created due to the increased environmental pollution significantly influence the choice of providing minimal environmental conditions, they receive priority, especially in urban areas. As toxic components are considered CO, CnNm, NOx, solid particles, etc. So if we know the conditions in which they are created then they can be the criterion for optimality. The requirements also affect their reduction within certain permitted limits.

Keywords: norms, legal regulations, internal combustion engines, environmental criteria.

1. Introduction

The adoption of the legal regulations for limiting the emissions of toxic components from the exhaust gases of internal combustion engines initiated many extensive examinations mainly in the interior of the engine and the additional treatment of exhaust gases through thermal and catalytic reactors, contributed to the reduction of toxic emissions.

The day-to-day development of internal combustion engines is aimed at reducing the toxic emissions of exhaust gases at the barrier level and reducing fuel consumption, while maintaining the good engine characteristics.

Environmental pollution is a permanent process and it is a complex phenomenon that is relatively slowly being explored and the legitimacy of these are completely not defined. For many occurrences, there are only hypotheses and assumptions, such as the warming of the atmosphere in global proportions.

The biological existence of a human is inextricably linked to the biosphere that is the main ecosystem of the country, which, with the help of natural self-regulatory processes, is in the state of dynamic equilibrium. Until the beginning of the rapid development of industrialization, urbanization and motorization, which took place in different countries at different times, it was considered that pure air and water were in unlimited quantities, and the pollution that occurred as a result of human activity was easily assimilated and removed, as a result of the great power of self-awareness of these media. Alongside with the increase in human activity in various spheres, the first signs of degradation of the environment.

The more the man wanted to change the environment, the more he burdened the country of the ball with various degradation problems, seeking the most urgent solution. The degradation of the environment gradually slowed down all over the environment in which the human being lives, so it is difficult to determine its dimensions and the consequences that it causes.

2. The efficiency of the internal combustion motors in the aggregate pollution of the atmosphere

Due to the huge economy, the favorable specific power and the favorable dimensions, the engines are accepted as the most suitable source of thermal mechanical energy in many areas of application. In road transport, they represent an exceptional means of propulsion.

With combustion of 1 (t) fuel in the engine, depending on the type of engine, the operating mode and regulation, can occur in the exhaust gases: 150 – 800 kg CO, 7,5 – 40 kg NO_x and 30 – 100 kg C_nH_m.

Table 1. Air pollution in the US on an annual level

SOURCES	Harmful substance (10 ⁶ t)				
	CO	Particles	CO ₂	C _n H _m	NO _x
Transport	110.9	0.8	1.0	19.5	11.7
Combustion in stationary installations	0.8	6.0	21.5	0.6	9.4
Industry	11.4	13.3	6.4	5.5	0.2
Combustion of waste	7.2	1.4	0.1	2.0	0.4
Rest	18.3	4.0	0.2	7.3	0.5
SUMMARY	148.6	25.5	29.2	34.9	22.2

The data for the participation of internal combustion engines as aeronautics are very diverse. These data are in some ways one of the main indicators for industrial development. In addition, the most developed countries are the largest aerospace producers.

Observing the impact of internal combustion engines as aeronautics, in Central Europe, was noted that their share in the CO emission is 65%, the NO_x emission is 55%, C_nH_m is 40%, and the SO₂ is 3%. The estimated impact of the main air pollutants in relation to the emissions of wastes in R. of North Macedonia for the end of the twentieth century is shown in the impact assessment. Table 2 shows that the largest part of all emissions originated from the combustion processes. The traffic is the largest emitter of carbon monoxide, hydrogen peroxide and nitrogen oxides. On the other hand, the largest part of the emitted sulfur originates from the stationary power stations of the electric power station and from the local and general consumption. This structure of issuers and emissions is also valid for other countries, depending on their degree of industrialization, urbanization and motorization

Table 2. The estimated impact of the main air pollutants in relation to the emissions of wastes in R. of North Macedonia for the end of the twentieth century is shown in the impact assessment.

POLLUTANTS	HARMFUL SUBSTANCE (%)				
	CO	C _n H _m	NO _x	CO ₂	Solid particles
Electricity distribution	1	1	28	43	27
Industrial	13	22	13	28	20

pitches					
Individual pitches	21	28	4	20	33
Traffic	65	39	54	3	13
Total combustion processes	100	90	99	94	93
Other industrial process	0	10	1	6	7
In total	100	100	100	100	100

Engines with internal combustion, regardless of the degree of combustion, emitted emissions which pose a potential danger to the environment, while at the same time impairing the safety in traffic.

It was noted that when combining 1 l. petrol is obtained from about 10 (m³) gas gases. Out of the total produced amount of lead (which is about 2 million annual losses of about 50 thousand tons), about 10% is spent on antidetonator additives, which the exhaust gases are grounded in the environment.

The SO emission is most likely to emerge from the traffic and, for example, in the past 1982.

In terms of SO₂ emission, industrial facilities have a far-reaching role, thermal power installations and the heaters (installations in which the fuel oil is oil and coal). From these pollutants it is assumed that SO₂ plays, a decisive role in the creation of the so-called "acid rains" that destroy the plants across the length of the main roads in Europe.

The given data clearly indicate the gradual acceleration of the pollution of the atmosphere on the planet's surface. The distribution of the pollution is not uniform across the entire planet's surface, so the pollutant has recorded more pollution (93% of the total pollution) of the atmosphere relative to the southern hemisphere. This is due to the uneven development of the industry, because the developed industrial countries are located on the northern hemisphere. About 90% of these pollutants pollute 8 - 10% of the surface of the planet's surface (parts of Europe, North America and Japan), or 3% of the total surface of the planets.

On this basis, an orientation assessment can be given for the needs of the air for combustion of the planet's fuel. In 2000, they amount to 22.1012 (m³ / year), which is 0.01% of the total mass of the atmosphere.

For the calculation of the maximum terrestrial concentration of harmful substances from conventional fuels as sources of pollution, the known equation of Voeikov is used to calculate the maximum ground concentration from precise sources of pollution, where:

- A - coefficient of temperature stratification of the atmosphere, which depends on the meteorological conditions;
- E_{s,p} (g/s) – emissions of sulfur and nitrogen dioxide, or solid particles from all vehicles at the intersection;
- F_f – without a dimensional coefficient that takes into account the speed of road charges, which depends on the level of clearance and in this case it can be taken F_f = 3;
- min – without dimensional coefficients which take into account the exhaust outlet conditions and are calculated according to the following expressions;

$$m = \frac{1}{0,67 + 0,1\sqrt{f} + 0,34\sqrt[3]{f}}$$

f – parameter that is calculated:

$$f = \frac{10^3 W_g^2 d^u}{H_0^2 \Delta T}$$

d_o (m) – the diameter of the exhaust pipe light;

w_g (m/s) – the speed of the combustion products of the exhaust pipe, which can be calculated according to the following level;

$$W_g = 1,27 \frac{V_g}{d_0^2} (m/s)$$

To compile, to calculate the coefficient "n", it is necessary to pre-calculate the V_m parameter:

$$V_m = 0,65 \sqrt{\frac{V_g \Delta T}{H_0}}$$

at:

$$V_m \leq 0,3 \quad n = 0,3$$

$$0,3 < V_m \leq 2,0$$

$$n = 3 - \sqrt{(V_m - 0,3)(4,36 - V_m)}$$

$$V_m \leq 2,0 \quad n = 1,0$$

V_g (m³/s) – volume flow of combustion products reduced to a condition that governs the exit of the exhaust pipe;

ΔT = t_g – t_{r,v} (°C) - the temperature difference between the temperatures of the products of combustion (exhaust gases) on the exit of the exhaust pipe and the medium temperature of the air.

The exhaust gas temperature of the exhaust pipe is different for vehicles with internal combustion (t_{gB}) and diesel motors (t_{gD}), so because of that in this case, work with medium temperature of the combustion products:

$$t_g = \frac{t_{gB} + t_{gD}}{2} \text{ } ^\circ\text{C}$$

An important magnitude that is penetrated in the calculation is the diameter of the adopted exhaust pipe which in this case is:

$$d_o = n_e d_{ic}$$

n_e – number of vehicles at the intersection

d_{ic} (m) - diameter of the exhaust pipe of one vehicle (equivalent vehicle).

The concentration of harmful substances in urban areas is influenced by several factors:

- Influence of meteorological factors
 - Impact on the speed of air movement (wind);
 - Impact on the temperature of the outdoor air;
 - Impact on the direction of air movement (wind),
- the impact of the factor taking into account the geographic position of the urban environment;
- impact of the factors that depend on the thermal power plants in the urban environment.

Pi (%) – percentage representation of vehicles with internal combustion and diesel engines (for internal combustion motors much more in relation to Diesel engines), at intersections,

n_{ei} – total number of vehicles on the intersection

The volume flow of the combustion products (exhaust gases) under normal conditions is calculated according to the expression:

$$V_{gi}^0 = 0,2778 n_{ei} B_i V_{igi} \text{ (m/s)}$$

$i = B, D$

B_i (t/h) – fuel / diesel consumption

V_{igi} – volume of the products of the consumption during consumption fuel or diesel

n_{ei} - number of equivalent vehicles with internal combustion and diesel motors).

The volume flow of combustion products is reduced to the conditions that the control of the exhaust pipe from the exhaust pipe is calculated according to the expression:

t_g (C) - temperature of the products of combustion of the exhaust from the exhaust pipe for the Otto or Diesel engine, which varies, but is usually less than 100 (°C). By measuring the t_g of several vehicles idling on the engine, the following values were obtained:

- for internal combustion motors $t_g = 70(^{\circ}\text{C})$ or $343(K)$
- for diesel motors $t_g = 60(^{\circ}\text{C})$ or $333(K)$

Measured temperatures are in accordance with the temperatures of the combustion products in the cylinder at the end of the extraction process, which move in the following borders:

- for internal combustion motors $t_p = 800 - 1100 (K)$
- for diesel motors $t_p = 700 - 900 (K)$

The total volume flow of the combustion products is the sum of the volume flows of the combustion products from internal combustion and diesel motor respectively:

$$V_g = \sum V_{gi} = V_{gB} + V_{gD} \text{ (m}^3/\text{s)}$$

CO₂ emission from vehicle with internal combustion or diesel motor is calculated with the following expression:

$$E_{SO_2i} = 5,556 B_i S_i (1 - n_{SO_2}) (1 - n_{SO_2})$$

$i=B$ (petrol), D (diesel)

B_i (t/h) – petrol or diesel fuel consumption

S_i (%) – content of petrol or diesel fuel

n_{SO_2} – coefficient that takes into account the percentage of SO₂ retention in the exhaust part of the engine and runs for liquid fuels (petrol and diesel) within the limits (0,0 – 0,2)

$n_{SO_2} = 0$ - a coefficient that takes into account the percentage of SO₂ in the purifier of solid particles and in the vehicle is zero at all under the condition that there is no purifier of the combustion products

The total SO₂ emission of all vehicles at the intersection is calculated according to the following expression:

$$E_{SO_2} = \sum_i n_{ei} \sum SO_{2i} = n_{eB} E_{SO_2B} + n_{eD} E_{SO_2D} \text{ (g/s)}$$

n_{eB}, n_{eD} – number of vehicles with internal combustion or diesel motors at the intersection.

The NO₂ emission from the vehicle with the internal combustion and diesel engine is calculated according to the expression:

$D_{ei} = \sqrt{\frac{4A_{ci}}{\pi}}$ (m) – the equivalent diameter of the combustion area for internal combustion and diesel motor

$A_{ci} = \frac{\pi D_{ci}^2}{4} n_{ci}$ (m²) – cross section of the cylinder for internal combustion and diesel motor

S_i – piston path for internal combustion and diesel motor

D_{ci} – the diameter of the cylinder for internal combustion and diesel motor

For internal combustion motor $S_B = 1,1 \rightarrow 1,3$

$$\frac{S_B}{D_{cB}} = 0,8 \Rightarrow S_B = 0,8 D_{cB}$$

For diesel motor $S_D = 1,3 \rightarrow 1,7$

$$\frac{S_D}{D_{cD}} = 1,3 \Rightarrow S_D = 1,3 D_{cD}$$

$$V_{cD} = \frac{\pi D_{cD}^2}{4} 1,3 D_{cD} = 0,325 \pi D_{cD}^3$$

$$D_{cB} = \sqrt[3]{\frac{V_{cB}}{0,2\pi}} \text{ (cm)}$$

$$D_{cD} = \sqrt[3]{\frac{V_{cD}}{0,32\pi}} \text{ (cm)}$$

We will get the values for V_{ci} from the cylinder displacement:

$$V_{ci} = \frac{V_i}{n_{ci}} \text{ (cm}^3\text{)}$$

n_{ci} – number of cylinders at internal combustion and diesel motors

The total NO₂ emissions from all vehicles at the intersection are calculated according to the following expression:

$$E_{NO_2} = \sum_i n_{ei} E_{NO_2i} = n_{eB} E_{NO_2B} + n_{eD} E_{NO_2D} \left(\frac{g}{s}\right)$$

n_{ei}, n_{eB}, n_{eD} – number of vehicles with internal combustion or diesel motors at the intersection.

The emission of solid particles from a vehicle with internal combustion or diesel engine is calculated according to the expression:

$$E_{pi} = 277,778 B_i \left[\left(1 - \frac{U_4}{100}\right) A_i a_g + \frac{U_4}{100} \right] \text{ (g/s)}$$

A_i – ash content in petrol or diesel fuel

U_4 % - heat loss due to chemically incomplete combustion, in the vehicle with internal combustion or diesel engine that moves:

$$U_4 = 0,5 \rightarrow 0,7$$

a_g – part of the ash, which comes out with the products of combustion that the vehicles are carrying

$$a_g = 0 \rightarrow 0,1$$

The total emission of solid particles from all vehicles at the intersection is calculated according to the following expression:

$$E_p = \sum_i n_{ei} E_{pi} = n_{eB} E_{pB} + n_{eD} E_{pD} \text{ (g/s)}$$

$n_{ei}(n_{eB}, n_{eD})$ – number of vehicles with internal combustion and diesel motors at the intersection

The CO emissions from vehicles with internal combustion or diesel engine are calculated according to the expression:

$$E_{COi} = \frac{12,5U_4Hd_iBiV_{CO_2i}}{3,6(23544,235C_i - U_4Hd_i)} (g/s)$$

Bi (t/h) – consumption of petrol i.e. diesel fuel

U_4 (%) – heat loss due to chemically incomplete combustion, in the vehicle with internal combustion or diesel engine that moves:

$$U_4 = 0,5 \rightarrow 0,7$$

Hd_i (kJ/kg) – lower thermal power on petrol or diesel fuel

V_{CO_2i} (m³) – volume of the CO₂ combustion products at internal combustion and diesel motors

$$V_{CO_2i} = \frac{M_{CO_2i}}{\rho_{CO_2i}} (m^3)$$

T_{gi} (K) – temperature of the combustion products on the exit of the exhaust pipe for internal combustion and diesel motors, usually lower than 100 °C.

- internal combustion motor $T_{gb} = 70^\circ\text{C} = 343\text{ K}$
- diesel motor $T_{gd} = 60^\circ\text{C} = 333\text{ K}$

M_{CO_2i} – weight of CO₂ in combustion products

ρ_{CO_2i} – density CO₂ of in combustion products at petrol and diesel fuel

$$\rho_{CO_2} = \frac{100000}{1000R_{CO_2i}(T_{gi} + 273,5)} (kg/m^3)$$

R_{CO_2i} – gas constant for CO₂ at internal combustion and diesel motor

The total CO emissions from all vehicles on the intersection are calculated according to the expression:

$$E_{CO} = \sum_i n_{ei}E_{COi} = n_{eB}E_{COB} + n_{eD}E_{COD} (g/s)$$

$n_{ei}(n_{eB}, n_{eD})$ – number of vehicles with internal combustion and diesel motor.

3. Alternative fuels and their ecological qualities in relation to conventional fuels

Since it has been established that the utilized energy potential of the Earth has been completed, the term "energy crisis" is emerging. The energy crisis and knowledge of the limitations of natural reserves for the production of conventional fuels, gasoline and diesel fuel are increasingly given to them the significance of fuels that can be produced from raw materials that are available in practically unlimited quantities.

Resolving environmental problems also leads to research focused on the selection of appropriate fuel as an alternative fuel, which would be a worthwhile replacement of the used white derivatives - gasoline and diesel fuel for internal combustion engines.

In order to be able to be replaced accordingly, alternative fuels are set to meet the requirements to be fulfilled. They should be easily transported, maintained in the long-term storage, not polluting the environment more than the existing fuels with the exhaust emission gases, to be profitable and competitive.

Alternative fuels that could be alternatives to existing fuels would be: different liquid hydrocarbons, methanol, ethanol, natural gas, liquefied petroleum gas, water, etc.

Today, the most suitable source of energy in many areas, especially in road transport, is internal combustion engines fueled with petrol or diesel fuel. Accordingly to the researches of these engines, they do not have a bright future ahead.

- Methanol – one kind of alternative fuel

Methanol (methyl alcohol - CH₃OH) is a colorless, transparent, low-viscosity liquid characterized by an alcoholic scent. It is made of stone, coal, natural gas, purifier, organic waste or as a by-product in the organic – chemical industry. Physical – chemical characteristics of methanol, differ from commonly used fuels and have a significant impact on the course of combustion and emission of exhaust gases.

The following conclusions are important:

- Viscosity, density, as well as the heat in the mixture of petrol and methanol, differ significantly.
- The presence of chemical oxygen in the alcohols reduces the heat of combustion. That's why methanol has an enlarged specific consumption.
- The optimum pre-ignition angle of the engine with methanol is less often used when working with gasoline, which indicates a change in the combustion engine, the second and the faster progress of the combustion process.
- The effective degree of usefulness - when working with methanol is higher because of the low heat losses and the lower exhaust gas temperature.
- Methanol has a higher octane number, which is the reason for increasing the compression ratio $\varepsilon = 12 \div 14$: 1, and thus increasing the effective power of the engine.
- When working with methanol, the limits of the flammability of the mixture, especially in the context of its impotence, are being sprayed.
- In the field of rich mixture in ($\lambda < 1$) when working with methanol, the CO is significantly reduced in the exhaust gases. The drive with methanol showed favorable emissions of uncombusted gases. The methanol drive showed a favorable emissions of both carbon dioxide CH₄, in the whole field of interest in the high-air coefficient. The values of the total quantities of undamaged hydrofoils shown in the diagram are measured using a flame - ionizing FID analyzer. Measured on FID - Regulations showed confidence in the analysis of the products of combustion. The sensitivity of FID alcohol analyzers is considerably smaller than the usual components contained in normal fuels: paraffins, olefins and aromatics. In this way, a large part of the combusted hydrocarbons can not be registered with the current common method of measurement.
- The environmental indicators of the engine while working on methanol are virtually identical and significantly improved as they work on gasoline. The low pressure of the saturated steam of the methanol impairs the initial engine qualities, as it will be necessary to add to the wood-volatile hydrocarbons. In winter conditions, electric heating is necessary.
- Methanol mixing in any proportion with water is successful, but the mixture of methanol and water causes corrosion of the engine parts.
- The disadvantage of methanol as motor fuel is that there is a large amount of aldehydes in the exhaust gases.
- Methanol vapors are often more harmful to human health than petrol's.

An interesting variant of the drive is the operation of the internal combustion engine with a mixture of gasoline and methanol. The conversion of 20% methanol in the fuel is achieved, without any changes in the engine, the oscillation of the mixture by 8.8% and that is so called M20 fuel. In this way, the composition of the exhaust gases is significantly

improved. Such a reduction was achieved by 75% SO, 30% for HC and 22% for NO. Secondary problems are not recorded.

Conclusion

The day-to-day development of internal combustion engines is aimed at reducing the toxic emissions of exhaust gases at the barrier level and reducing fuel consumption, while maintaining the good engine characteristics.

Engines with internal combustion, regardless of the degree of combustion, emitted emissions which pose a potential danger to the environment, while at the same time impairing the safety in traffic.

Resolving environmental problems leads to research focused on the selection of appropriate fuel as an alternative fuel, which would be a worthwhile replacement of the used white derivatives – gasoline and diesel fuel for internal combustion engines.

Methanol is one kind of alternative fuel that is alternative to existing fuels, it is a colorless, transparent, low-viscosity liquid characterized by an alcoholic scent. The effective degree of usefulness - when working with methanol is higher because of the low heat losses and the lower exhaust gas temperature.

Methanol and other alternative fuels will be the new fuels which are going to be use for motors with internal combustion.

Alternative fuels are healthier for the environment, cheaper for the consumers and with better combustion than standard fuels.

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NUMERICAL ANALYSIS OF IN-CYLINDER PRESSURE AND TEMPERATURE CHANGE FOR NATURALLY ASPIRATED AND UPGRADED GASOLINE ENGINE

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Abstract: The paper presents numerical analysis of in-cylinder pressure and temperature change for naturally aspirated gasoline engine and two of its upgrades - upgrade with turbocharger only and upgrade with turbocharger along with air cooler. Numerical analysis was performed with 0D (zero-dimensional) numerical model. In-cylinder temperatures, for each engine rotational speed, are the highest for engine upgraded only with the turbocharger. The highest observed in-cylinder temperature of turbocharged engine was obtained at 5000 rpm and amounts 2542.4 °C. In-cylinder pressures are the highest for engine upgraded with turbocharger and air cooler for all rotational speeds except the highest one. The highest observed in-cylinder pressure of a turbocharged engine with air cooler was obtained at 5000 rpm and amounts 129.7 bars. Presented analysis showed that the selected air cooler can be improved at highest engine rotational speed.

KEYWORDS: NUMERICAL SIMULATION, IN-CYLINDER PROCESS, GASOLINE ENGINE, ENGINE UPGRADE

1. Introduction

Gasoline engines with spark ignition are one of the known types of internal combustion engines [1]. Its characteristics and specifications are dependable on many parameters.

Researchers are currently investigating various elements related to gasoline engines. Kilicarslan and Qatu [2] performed an exhaust gas analysis of gasoline engine based on engine speed. Elsemary et al. [3] investigated spark timing influence on the performance of a gasoline engine fueled with a mixture of hydrogen-gasoline.

Control and regulation systems are essential elements of any gasoline engine, which ensures engine proper operation. Yar et al. [4] developed and presented first principle based control oriented model of a gasoline engine which includes multi-cylinder dynamics. Nonlinear constrained torque control system for a gasoline engine developed Kang et al. [5].

Alternative fuels for gasoline engines are investigated by many authors. Elfasakhany [6] performed gasoline engines performance evaluation and pollutant emissions analysis by using ternary bio-ethanol-iso-butanol-gasoline blends. Effect of addition of hydrogen and exhaust gas recirculation on characteristics of hydrogen gasoline engine investigated Du et al. [7].

Turbocharging process which uses the energy of engine exhaust gases is one of the best methods for improving naturally aspirated engine operating parameters and characteristics. Modeling and control of the air system for a turbocharged gasoline engine investigated Moulin and Chauvin [8]. An upgrade of turbocharging process involves air cooler after charger, in order to perform proper cooling of air which enters into the engine cylinders [9]. Air cooling allows an increase of engine volumetric efficiency and decrease of maximum in-cylinder temperature when compared to the engine which has only the turbocharger.

In this paper is presented numerical analysis of in-cylinder pressure and temperature change for naturally aspirated gasoline engine and two of its upgrades - upgrade only with turbocharger and upgrade with turbocharger along with air cooler. Numerical analysis was performed with 0D (zero-dimensional) numerical model. It was obtained that in-cylinder temperatures, for each engine rotational speed, are the highest for engine upgraded only with the turbocharger. In-cylinder pressures are the highest for engine upgraded with turbocharger and air cooler for all rotational speeds except the highest one. Presented analysis showed that air cooler, selected in this analysis, can and should be improved at highest engine rotational speed.

2. Numerical model equations for in-cylinder temperature and pressure change calculation

Numerical model used for simulations is 0D (zero-dimensional) model presented by Medica [10]. 0D model is basically developed for simulation of diesel engines and after a while is upgraded on QD (quasi-dimensional) model [11] which results are presented in [12] and [13] for high-speed four-stroke diesel engine and in [14] for slow-speed two-stroke diesel engine.

To be able to simulate the operating parameters of a gasoline engine with the mentioned 0D model, the numerical model is modified in necessary elements which present differences in operating characteristics between gasoline and diesel engines. The modified 0D model is tested on several gasoline engines. For all analyzed gasoline engines and for its operating parameters were obtained deviations between producer specifications and numerical model results in the range of $\pm 3\%$.

Engine cylinder is presented as a separate control volume with periodical change of the volume. The shape is determined by the volume walls (cylinder, head and piston face). The differential equation for the temperature change related to the crank angle is:

$$\frac{dT_c}{d\varphi} = \frac{1}{m_c \left(\frac{\partial u}{\partial T} \right)_c} \left[\sum_i \frac{dQ_{c,i}}{d\varphi} - p_c \frac{dV_c}{d\varphi} + \sum_j \left(h \frac{dm}{d\varphi} \right)_{c,j} - \left[-u_c \frac{dm_c}{d\varphi} - m_c \left(\frac{\partial u}{\partial \lambda} \right)_c \frac{d\lambda_c}{d\varphi} \right] \right] \quad (1)$$

All indicated members of the equation (1) are related to the state in the cylinder. The work transmitted to the piston, as pressure forces to the moving boundary is:

$$\frac{dW_c}{d\varphi} = p_c \frac{dV_c}{d\varphi} \quad (2)$$

The heat exchange over cylinder boundaries (except the sensitive heat admitted by mass exchange) has the members in the heat of fuel combustion Q_f and heat transferred to cylinder walls $Q_{c,w}$ [15]:

$$\sum_i \frac{dQ_{c,i}}{d\varphi} = \frac{dQ_f}{d\varphi} + \frac{dQ_{c,w}}{d\varphi} \quad (3)$$

The cylinder pressure is determined from the gas state equation:

$$p_c = \frac{m_c R_c T_c}{V_c} \quad (4)$$

The heat exchange between the working fluid and the cylinder walls was calculated by using an equation:

$$\frac{dQ_{c,w}}{d\varphi} = \sum_i \alpha_c A_{w,c,i} (T_{w,i} - T_c) \frac{dt}{d\varphi} \quad (5)$$

where the mean heat transfer coefficient α_c is calculated by an empirical equation presented by Woschni [16].

The combustion process is described by the heat release rate:

$$\frac{dQ_f}{d\varphi} = \frac{dx_f}{d\varphi} \cdot m_{f,1pr} \cdot H_d \cdot \eta_{comb} \quad (6)$$

where the relative amount of combusted fuel increment $dx_f/d\varphi$ is calculated by equation presented by Vibe [17].

In the above equations, used symbols are: T = temperature, φ = engine crankshaft angle, m = operating medium mass, u = operating

medium specific internal energy, Q = heat amount, V = operating area volume, p = operating medium pressure, h = operating medium specific enthalpy, λ = excess air ratio, W = work, R = operating medium gas constant, A = control volume surface, t = time, x = relative amount of combusted fuel, H_d = fuel lower heating value, η_{comb} = efficiency of the combustion process, 1pr = per one engine process, f = index for fuel, w = index for cylinder walls, c = index for engine cylinder. Calorific gas properties (u , h , $\partial u/\partial \lambda$, $\partial u/\partial T$) are modeled from the analytical expressions relating the temperature and gas composition [18], [19]. To make the simulation as fast as possible, it is assumed that in each engine cylinder happens the same change of pressure and temperature (phase-shifted).

3. Characteristics and specifications of base engine and both engine upgrades

The base engine is a four stroke, high speed, naturally aspirated gasoline engine with direct fuel injection. The engine is designed for the usage in automotive applications. Base engine does not have any upgrades. Main operating characteristics and parameters of the base, naturally aspirated engine are presented in Table 1.

In Table 1 are also presented used cylinder materials and fuel basic specifications. Those data were the baseline for the correct heat exchange calculations in the engine cylinder.

Table 1. Analyzed naturally aspirated engine main operating characteristics

Fuel	Gasoline
Fuel lower calorific value	43 MJ/kg
Fuel density	0.75 kg/l
Number of cylinders	4
Ignition order	1-3-4-2
Compression ratio	11
Cylinder bore	84 mm
Stroke	86 mm
Cylinder clearance volume	0.0477 l
Engine cooling	Water
Materials:	
Cylinder head	Aluminum
Piston	Aluminum
Cylinder liner	Cast Iron

Numerical simulation was firstly performed for the base, naturally aspirated engine. For base engine, along with other operating parameters, was obtained curves of change in cylinder temperature and pressure.

After simulation of base engine, it is performed the first base engine upgrade - inclusion of the turbocharger. Turbine and charger operating maps were described by polynomials and included in numerical simulation as a new subroutine along with equations for operating parameters calculation. During the engine upgrade with turbocharger engine base operating and geometrical characteristics remain unchanged, because one of the intentions was to investigate the possibility of engine proper operation with selected turbocharger without any base engine modifications. The main geometrical characteristics of selected turbocharger KKK 30.60/13.21 are presented in Table 2. Turbine and charger operating maps are obtained from the turbocharger producer.

Table 2. Geometry parameters of selected turbocharger KKK 30.60/13.21 [20]

Charger inlet diameter	0.0457 m
Charger outlet diameter	0.0762 m
Intake turbine flowing surface	0.0013 m ²

Numerical simulation of engine with included turbocharger was performed and again, along with other operating parameters, was obtained curves of change in cylinder temperature and pressure.

Second and final base engine upgrade was including air cooler after charger into engine simulation. Air cooler is air-air heat exchanger. In such heat exchanger numerical description, it is necessary to define heat exchanger cooling medium (air) mass flow, pressure loss and overall efficiency. For selected, standard charging

air cooler, according to producer specifications [21], air pressure loss and cooler overall efficiency were presented in relation to cooling air mass flow, Fig. 1.

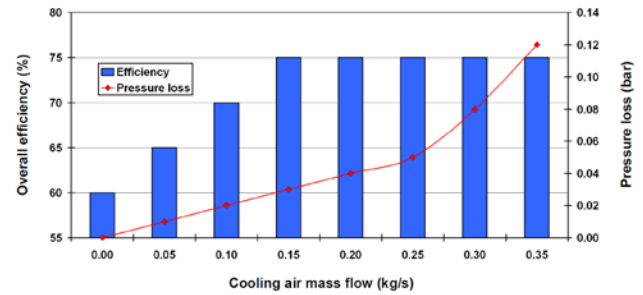


Fig. 1. Air cooler pressure loss and overall efficiency in relation to cooling air mass flow

Final, third simulation was performed and along with other operating parameters, was obtained curves of change in cylinder temperature and pressure for the engine with both upgrades (turbocharger + air cooler).

4. Results of in-cylinder pressure and temperature change with discussion

Numerical model results of in-cylinder pressure and temperature change for all three simulated gasoline engine variants (base engine and two upgrades) are presented. Differences of analyzed engine variants are the most notable in high pressure and high temperature parts of in-cylinder process. In all the figures (from Fig. 2 to Fig. 7) it is presented the high temperature and high pressure part of in-cylinder process in relation to engine crank angle.

4.1. Cylinder temperature change for all simulated engine variants at different engine rotational speeds

At engine rotational speed of 3000 rpm, gasoline engine upgraded only with a turbocharger (without air cooler) gives the highest in-cylinder temperatures, with a peak value of 2491.2 °C. Engine upgraded with a turbocharger and air cooler at 3000 rpm gives lower in-cylinder temperatures than engine upgraded only with a turbocharger, but cylinder temperatures for engine with both upgrades are higher in comparison with a naturally aspirated engine. Peak in-cylinder temperature at 3000 rpm for the gasoline engine upgraded with a turbocharger and air cooler amounts 2471.8 °C. It can be concluded that air cooler causes notable decrease in cylinder temperature when compared to engine upgraded only with a turbocharger, Fig. 2. The lowest in-cylinder temperatures at 3000 rpm are achieved, as expected, for naturally aspirated engine. Peak in-cylinder temperature for naturally aspirated engine amounts 2443.8 °C at 3000 rpm.

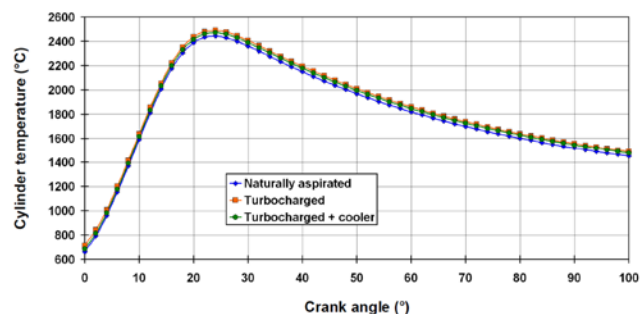


Fig. 2. Cylinder temperature change for the analyzed engine at rotational speed of 3000 rpm

At engine rotational speed of 5000 rpm can be noticed significant differences in change of engine cylinder temperature for three simulated engine variants, Fig. 3. As before at 3000 rpm, at 5000 rpm the highest in-cylinder temperatures are obtained for the gasoline engine upgraded only with a turbocharger. Peak temperature value for engine upgraded with a turbocharger (without

air cooler) at 5000 rpm amounts 2542.4 °C. Engine upgraded with a turbocharger and air cooler at 5000 rpm gives lower in-cylinder temperatures than engine upgraded only with a turbocharger, while at the same time in-cylinder temperatures for engine with both upgrades are higher in comparison with a naturally aspirated engine. Peak in-cylinder temperature at 5000 rpm for the engine upgraded with a turbocharger and air cooler amounts 2461.4 °C. Air cooler significantly decreases in-cylinder temperatures at 5000 rpm, because maximum in-cylinder temperature for the engine with two upgrades is lower at 5000 rpm than at 3000 rpm, Fig. 3.

Again, as before, at 5000 rpm the lowest in-cylinder temperatures were achieved for naturally aspirated engine while temperature peak amounts 2431.1 °C, lower than at 3000 rpm.

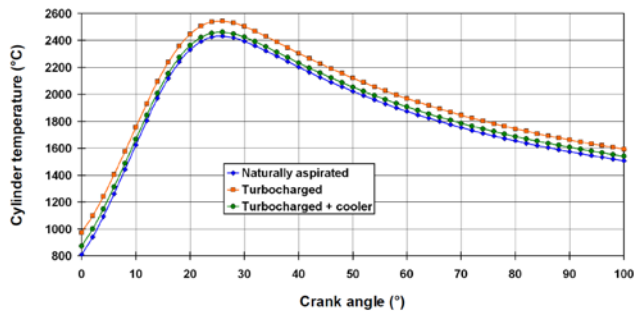


Fig. 3. Cylinder temperature change for the analyzed engine at rotational speed of 5000 rpm

At the highest engine rotational speed (6000 rpm), some conclusions about engine in-cylinder temperature change for three simulated engine variants differ in comparison with the lower engine rotational speeds. The same conclusion as before can be seen for engine upgraded only with a turbocharger, which at 6000 rpm again gives the highest in-cylinder temperatures and the peak temperature amounts 2505.6 °C, Fig. 4.

For the lower engine rotational speeds were valid a conclusion that engine with turbocharger and air cooler gives in-cylinder temperatures higher than naturally aspirated engine. At the highest engine rotational speed of 6000 rpm, in some parts on in-cylinder process, temperatures for engine with two upgrades are lower in comparison with a naturally aspirated engine. This conclusion leads to the fact that on the highest engine rotational speed, air cooler has the highest cooling medium mass flow and efficiency, so the temperature of air which enters into engine cylinders is much lower than on the lower rotational speeds.

At the 6000 rpm peak in-cylinder temperature for the engine with turbocharger and air cooler amounts 2401.6 °C, while for naturally aspirated engine peak in-cylinder temperature amounts 2415.1 °C.

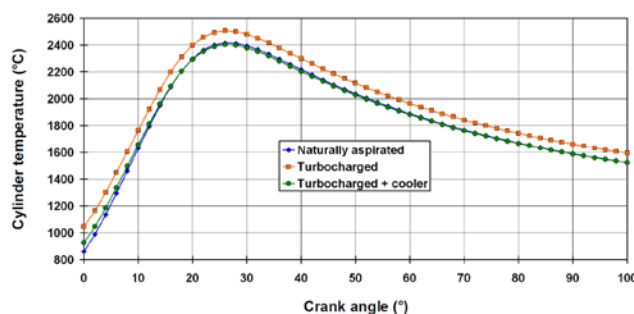


Fig. 4. Cylinder temperature change for the analyzed engine at rotational speed of 6000 rpm

4.2. Cylinder pressure change for all simulated engine variants at different engine rotational speeds

Naturally aspirated engine at 3000 rpm has significantly lower in-cylinder pressures when compared to engine with turbocharger or to an engine with turbocharger and air cooler, Fig. 5. Peak in-cylinder pressure for a naturally aspirated engine, at 3000 rpm, amounts 63.2 bars. Again, the highest values of in-cylinder pressures at 3000 rpm

has an engine with both upgrades and peak value of in-cylinder pressure for this engine variant amount 81.7 bars. An engine which is upgraded only with a turbocharger at 3000 rpm has in-cylinder pressure values slightly lower when compared to engine with both upgrades, while when this engine is compared with naturally aspirated one in-cylinder pressures are significantly higher. At the engine rotational speed of 3000 rpm, engine upgraded only with a turbocharger has peak in-cylinder pressure value equal to 77.4 bars.

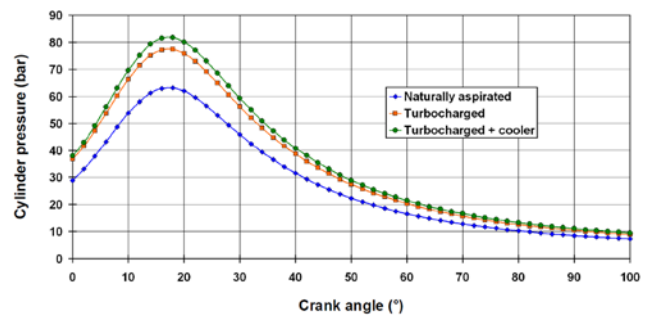


Fig. 5. Cylinder pressure change for the analyzed engine at rotational speed of 3000 rpm

In general, the same conclusions for in-cylinder pressure change for all three simulated engine variants, which are valid for engine rotational speeds of 3000 rpm, are also valid for engine rotational speed of 5000 rpm. The only difference can be seen in Fig. 6 - engine with turbocharger or an engine with turbocharger and air cooler has much higher in-cylinder pressures in comparison to naturally aspirated engine at 5000 rpm.

So, it can be concluded that turbocharging process causes a significant increase in engine in-cylinder pressure values especially at high engine rotational speeds. At the same high engine rotational speeds, with turbocharger and air cooler will be obtained the highest in-cylinder pressure values.

At 5000 rpm, peak value of in-cylinder pressure for engine upgraded with turbocharger and air cooler amounts 129.7 bars, for engine upgraded only with a turbocharger it amounts 122.1 bars and for naturally aspirated engine amounts 72.3 bars.

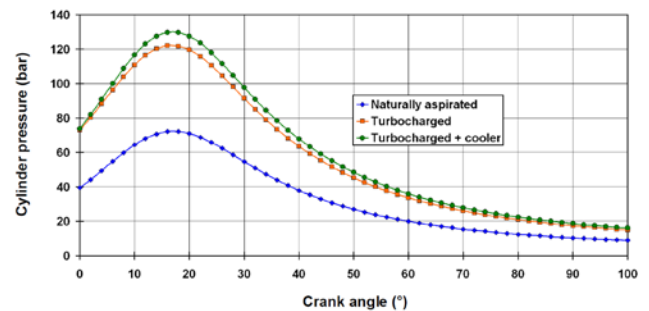


Fig. 6. Cylinder pressure change for the analyzed engine at rotational speed of 5000 rpm

At the highest engine rotational speed (6000 rpm) engine with turbocharger or an engine with turbocharger and air cooler also has significant higher in-cylinder pressures in comparison with a naturally aspirated engine, Fig. 7. The only difference which occurs at the highest engine rotational speed (in comparison to lower rotational speeds) is that the highest in-cylinder pressures are obtained for the engine only with a turbocharger, not as before for the engine with a turbocharger and air cooler. The reason of this occurrence can be found in Fig. 4. Decrease in in-cylinder temperature at 6000 rpm caused by air cooler after the turbocharger is significant, therefore simultaneously with an in-cylinder temperature decrease occurs decrease of in-cylinder pressure. So, only at 6000 rpm, the highest values of in-cylinder pressure will be obtained with engine upgraded only with a turbocharger.

This fact leads to conclusion that selected air cooler is not the best option for a simulated engine at the highest engine rotational speed. One of the future research directions of this engine and its

upgrades will surely be to find or design a new air cooler, which will operate at 6000 rpm as at lower rotational speeds. The limit during an air cooler exchange will surely be not to exceed usual values of cylinder maximal pressures (usual values are from 150 bars to 170 bars).

Peak values of in-cylinder pressure at 6000 rpm are: for naturally aspirated engine - 69.1 bars, for engine upgraded with turbocharger - 118.2 bars, and for engine upgraded with turbocharger and air cooler - 109.8 bars.

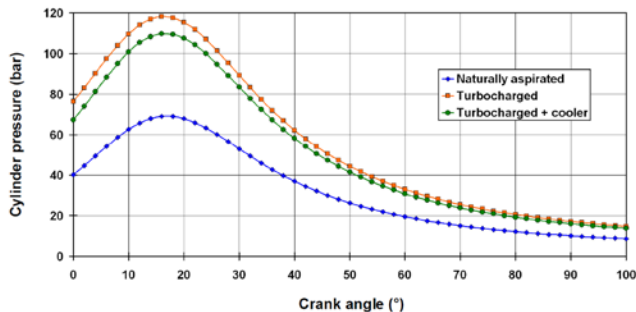


Fig. 7. Cylinder pressure change for the analyzed engine at rotational speed of 6000 rpm

5. Conclusions

This paper presents numerical analysis of in-cylinder pressure and temperature change for naturally aspirated gasoline engine and its upgrades - upgrade with turbocharger only and upgrade with turbocharger along with air cooler. It was analyzed by numerical 0D (zero-dimensional) model how engine upgrades influenced in-cylinder pressure and temperature change for the variety of engine rotational speeds.

In-cylinder temperatures, for each engine rotational speed, are the highest for engine upgraded only with the turbocharger. Engine upgraded with turbocharger and air cooler has lower in-cylinder temperatures than engine upgraded only with a turbocharger, what is expected because of air cooling before its entrance into engine cylinders. At the highest engine rotational speed (6000 rpm) air cooler significantly reduces in-cylinder temperature, so at the highest rotational speed, in-cylinder temperatures for an engine with turbocharger and air cooler are lower in comparison with naturally aspirated engine. As expected, the lowest in-cylinder temperatures are obtained for a naturally aspirated engine, for all engine rotational speeds except the highest one.

In-cylinder pressures are the highest for engine with two upgrades for all rotational speeds except the highest one. At 6000 rpm, air cooler after charger significantly reduces temperature of air which enters into engine cylinders and consequentially reduces the values of in-cylinder pressure.

Engine upgraded only with a turbocharger has values of in-cylinder pressure slightly lower in comparison with an engine which has both upgrades, for each engine rotational speed except the highest one. When compared turbocharged engine with naturally aspirated - turbocharged engine has significantly higher values of in-cylinder pressure at each engine rotational speed.

Presented analysis showed that selected air cooler (engine with both upgrades) can be improved at the highest engine rotational speed (6000 rpm) what will be the guideline for future research.

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