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EXPERIMENTAL ANALYSIS OF BRAKE DISC COOLING CAPACITY

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Abstract: The car brake system performance has to be reliable at wide range of operating conditions. The friction based braking system reliability strongly depends on cooling capability of disc. According to this, different testing is needed to assure the performance of discs during their design and prototyping phase. The contribution presents the study of cooling capacity of different vented brake disc geometries.

Brake disc temperatures during thermal capacity test can exceed 600 °C. The temperatures are highly dependent on disc cooling capability. Vented disc have higher cooling capability. There is an open issue which factor has the most significant impact. Is it air flow, air flow distribution, turbulence or ...? Brake discs with the same external geometry but different internal geometry were tested on brake dynamometer and subsequently air flow parameters were analysed in cold condition to attempt to explain different maximum temperatures.

Keywords: brake disc, cooling, flow measurements

1. Introduction

Braking performance is crucial for the safety of the vehicle and its occupants. Braking performance can be influenced by wear, maintenance and braking history. Most vehicles use cast iron discs or drums. Brake drums are used in smaller cars and mostly for rear brakes since the majority of brake force is distributed on front axle (60-70%). The most important task of the brake system is to convert kinetic energy into heat. Braking performance is brake disc temperature dependent. Disc temperature rises with every braking and the braking performance decreases with the temperature. Brake disc is mostly cooled by air, although some heat is transmitted via radiation too. The cooling efficiency was studied by prof. Limpert (Limpert, 1975) and vented disc were proposed and a whole new area of study was opened dedicated to the question which remains actual: Which internal geometry of the disc is the best? Is a straight vanes design, curved vanes design or fins design? Beside the braking efficiency and temperature there are still other requirements to be fulfilled. Minimizing the disc mass, moment of inertia and increasing of resonant frequencies are also important but the production costs have very high priority when design is considered.

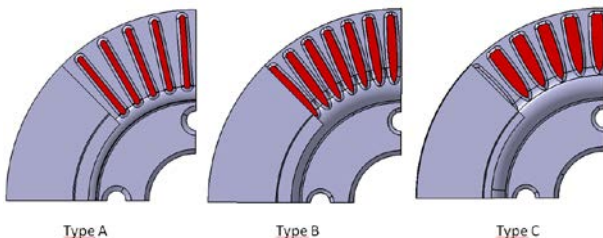


Fig. 1 Different shapes of disc vanes.

2. Problem

Two prototypes with aerofoil shaped vanes (B and C) were produced to find possible replacement for existing disc design with straight vanes (A). The discs were used on a B class car and are presented in Figure 1.

The results on dynamometer test were below expectations and the temperature after thermal capacity test (SAE J2522) was higher than in the case of the original design in case C and the same in case B. A more detailed analysis was performed and some of the results will be presented and discussed.

External disc geometry was the same for all three cases. The distance between the friction plates was 7 mm in type A, 8 mm in type B and 6 mm in type C. The number of vanes was 41 in case of type B and C and 53 in case of type A. The inner diameter of the friction surface was 145 mm for discs A and B and 154 mm for disc C. Vane length in case of type C disc was 4-5 mm shorter.

3. Air flow measurements

The first idea that comes to mind is to measure the air flow through the disc. The disc was placed on a rotating device driven by frequency controlled electro-motor. Most rotating device parts were the same as in appropriate car, although some modifications to the axle were made and the brake pads and the jaws were removed. It is quite complicated to measure the air flow at the disc exit. Air exit velocity in case of radial fan with straight vanes can be approximated by circumferential velocity of the vane tip which was approx. 10 m/s. Low velocities are difficult to measure with traditional methods like Pitot tube due to very low pressure differences. Additionally, exit velocity profile is not constant due to finite number of vanes and their thickness. Most of the studies were performed at 15.7 Hz rotational speed (corresponding to 100 km/h vehicle speed). When multiplying rotational frequency with the number of vanes frequency above 600 Hz can be expected. This frequency makes Pitot based measurements practically impossible. There are some reports of HWA measurements but our first idea was to simplify the mass flow measurements and the disc orientation was changed (friction surface faced outwards instead inwards). This enabled free access to the intake and enabled measurements of the intake velocity profile. Since the disc had no cross drilled holes the conservation of mass was assumed. Anemometer Testo 435-4 was placed on a traverse system and velocity profile in horizontal and vertical plane measured. Program controlling anemometer and traverse system was written in LabVIEW. The measurement results for disc type A are presented in Figure 2.

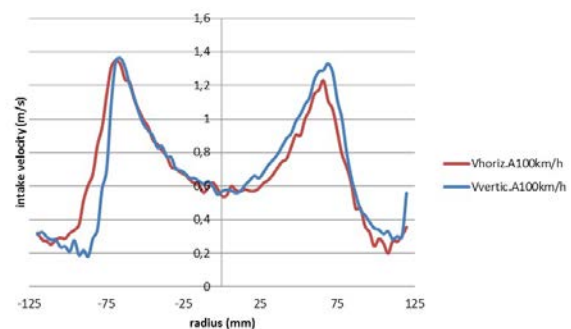


Fig. 2 Intake velocity profile type A disc at 100 km/h.

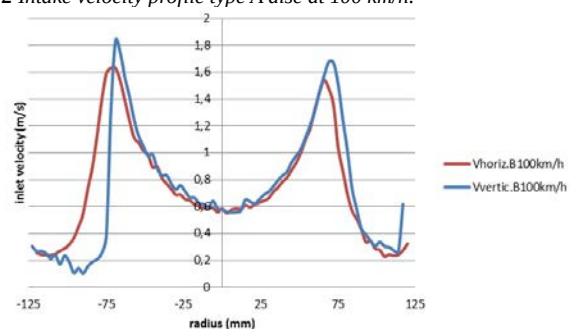


Fig. 3 : Intake velocity profile type B disc at 100 km/h.

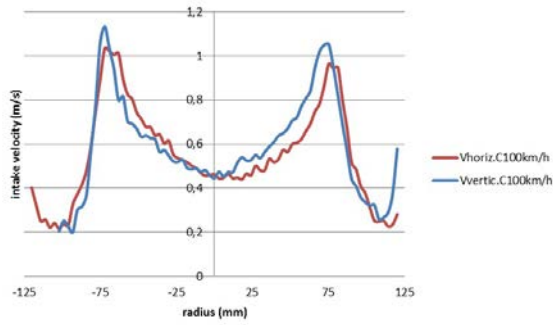


Fig. 4 Intake velocity profile type C disc at 100 km/h.

The procedure was repeated for several rotational speeds and the results for original disc (type A) are presented in Figure 5.

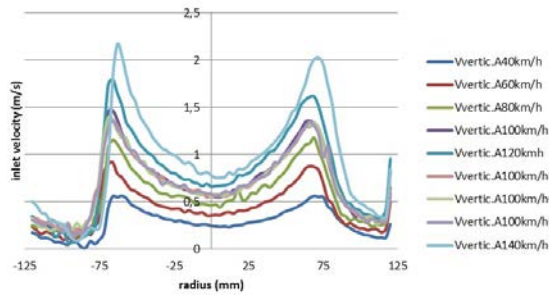


Fig. 5 Comparison of velocity profiles at different rotational speeds.

Velocity profile was used to calculate volumetric flow. Results for volumetric flow are presented and compared in Figure 6.

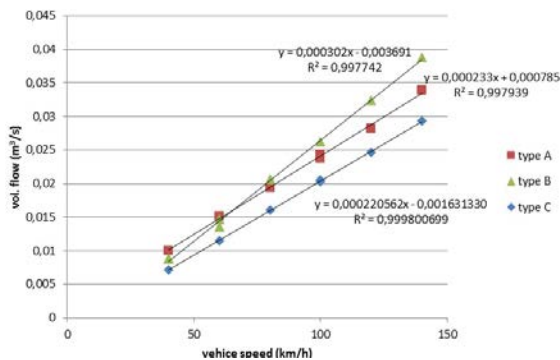


Fig. 6 Comparison of volumetric flow at different vehicle speeds.

Results presented in Figure 6 can be used to explain poor performance of type C disc since this type has the lowest volumetric flow and consequently lower heat dissipation. During testing according to SAE J2522 higher velocities prevail so Figure 6 cannot give a clue why there was practically identical maximum temperature in cases A and B.

Velocity distribution

Brake discs were tested again. This time they were oriented the same as in a car. Exit velocity was measured by Particle Image Velocimetry – PIV. Due to the time and other limitations only approx. 25 degrees of the disc were analyzed as shown in Figure 6. Velocity field derived from the PIV images (Figure 7) is presented in Cartesian coordinate as shown in Figure 8.

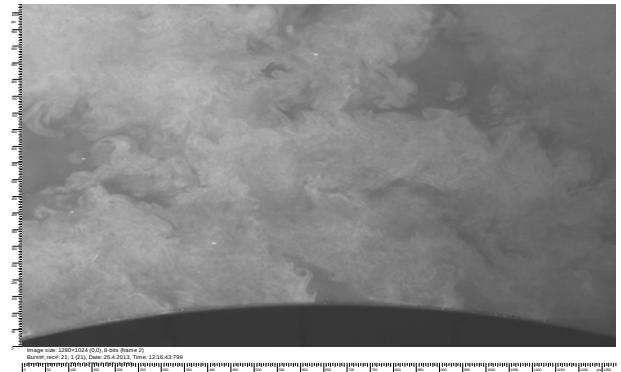


Fig. 7 PIV image of the disc-flow visualization.

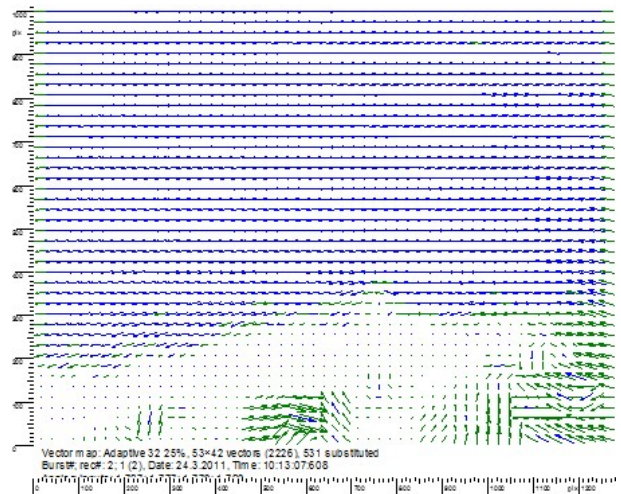


Fig. 8 PIV velocity field-cartesian coordinate system.

At least 240 images were averaged and radial velocity component at desired radius extracted. The procedure was repeated in several layers beginning at outward friction surface and ending at inward friction surface. The layers between friction plates were placed in 1mm interval and two layers were located in the middle of the friction plate. Radial velocity profiles are presented in Figure 9.

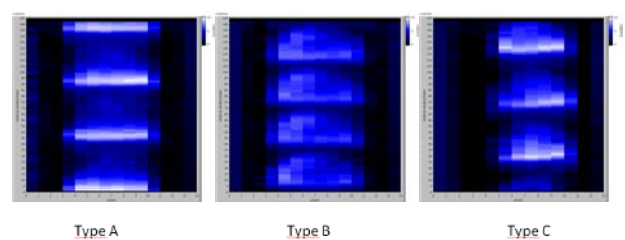


Fig. 9 Radial velocity profile.

By comparing results presented in Figure 9 it possible to observe different radial velocity distribution. The distribution in type A disc is along the vane, while in case of type B and type C it is concentrated in the middle of the channel. This fact can offer possible explanation for lower cooling capacity of type B and C discs. It is desirable to have cooling flow near hot surfaces. The hottest surfaces are friction planes and vanes.

4. Validation and comparison

Radial velocity field was used to calculate volumetric flow. It was assumed that there is no significant difference between the vanes and that 3 or 4 vanes covered by PIV analysis are representative. All internal surfaces are un-machined and sand-cast.

The results for volumetric flow at 100 km/h are presented in Table 1.

Table 1: Comparison of the results.

	vol.flow A (m ³ /s)	vol.flow B (m ³ /s)	vol.flow C (m ³ /s)
PIV	0.025268	0.026803	0.019168
anemometer	0.024063	0.026267	0.020346

As presented in Table 2 quite good agreement between the measurement methods was achieved for internal air flow which contributes the major part in convective cooling of the brake disc.

5. Influence of external disc diameter

We were fortunate to have at our disposal an enlarged version of the original disc A. The number and shape of the vanes is the same. The main difference is increase of external diameter of the disc by 22 mm. The comparison of mass flow is presented in Figure 10.

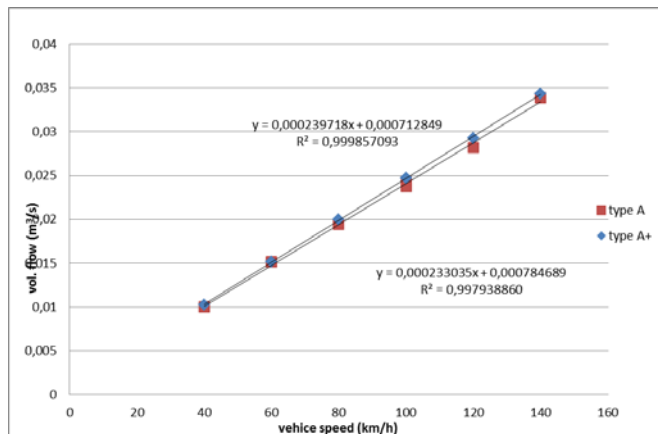


Fig. 10 Comparison of volumetric flow type A and A+

As presented in Figure 10 there is a less than 3% increase in air flow although the diameter increase is more than 8%. The vane length was increased by approx. 11 mm. The distance between the friction plates was 7 mm (the same as in case A) although casting tolerances must be considered. Simple expansion of the disc does not increase its cooling capacity much.

6. Influence of the internal vane diameter

A very similar disc (according to A+) was studied too. This disc had the same external diameter but only 40 vanes and the internal diameter of the friction plate 154 mm (like disc C). The air flow measurements are presented in Figure 11.

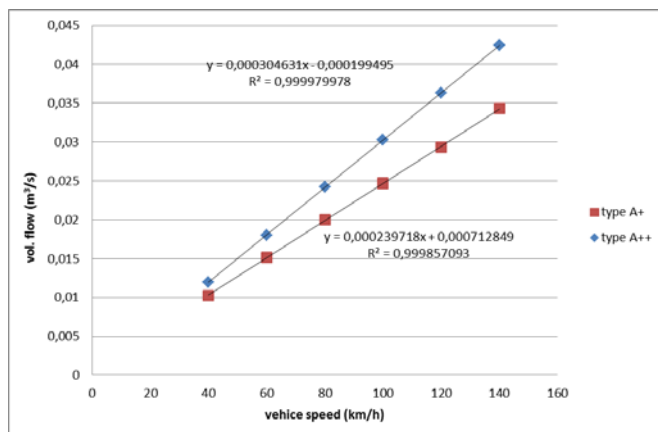


Fig. 11 Comparison of volumetric flow type A+ and A++

As presented in Figure 11 internal vane diameter has significant influence on air flow. The difference between the numbers of vanes

(41 and 40) was neglected. Vane length was reduced by approx. 5 mm (according to A+). External vane diameter was the same. The distance between the friction surfaces was again 7 mm.

7. Discussion

Air volumetric flow and radial exit velocity distribution were acquired during an attempt to explain unexpected results during thermal capacity test. Volumetric air flow is an important factor, but velocity distribution must not be neglected. It is convenient to have high velocity near hot surfaces even if it may cause lower cumulative flow. The radius between the vanes and the friction plates should be minimal since larger radius causes air flow concentration in the middle of the channel which is not desirable from the cooling point of view.

External vane diameter has lower influence on mass flow than internal diameter. The cooling air channel is defined by friction plates and two consecutive vanes. Since all vanes are oriented to the axis of rotation the channel has the bottleneck at vane internal diameter. Air flow is limited by the smallest distance between the vanes. Longer vanes (at limited external diameter) may increase pressure difference but they reduce intake area which at least in our case showed to be more influential.

Linear dependence between air flow and vehicle speed was observed in all presented cases. This fact is a bit surprising since quadratic dependence is expected in closed channels. Possible explanation could be existence of the recirculation area on the suction side of the vane. PIV visualization of recirculation area is presented in Figure 12

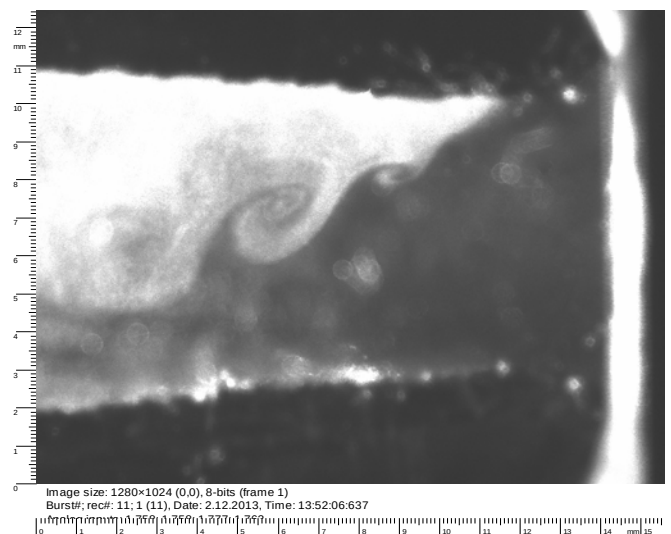


Fig. 12 PIV image of recirculation area in the inter vane channel

White (fog) area in figure 12 represents recirculation area. Disc was rotated clockwise. Recirculation area reduces the mass flow and heat transfer on the suction side of the vanes due to the lower air velocity and temperature difference.

It might be beneficial to modify the disc design to reduce recirculation area and maybe achieve better cooling capacity with lower air flow and consequently reduce acoustic emissions and deposition of moisture (corrosion) in recirculation areas.

5. References

Limpert, Rudolf. (1975). Cooling Analysis of Disc Brake Rotors. <http://dx.doi.org/10.4271/751014>

THE APPLICATION OF VIBRATION ANALYSIS FOR DIAGNOSIS OF BEARINGS AND GEARS OF THE REAR AXLE ASSEMBLY OF THE PASSENGER CARS

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Abstract: Predictive maintenance of machines, also known as Condition Based Maintenance, is based on monitoring operating parameters, and comparison with corresponding values of parameters obtained for the new equipment.

All machines with moving parts give rise to sound and vibration and each machine has a specific vibration signature related to the construction and the state of the machine. If the state of the machine changes the vibration signature will also change and a change in the vibration signature can be used to detect incipient defects before they become critical. The condition monitoring technique is based on detecting the presence of a fault, diagnosing the root cause of the fault, assessing its level of severity and making arrangements for its correction. A broad of condition monitoring and fault diagnosis techniques has been carried out for improving the accuracy and ability of condition monitoring and prognosis systems for bearing and gear components.

This paper introduces the method for diagnostic of the rear drive axle for the passenger cars without its demounting. The objective method of diagnosing the rear drive axle is done by vibrometer. Application of diagnostic method greatly would be contributed in quickly localization of the rear drive axle fault where diagnostic process of the servicer will done faster.

Keywords: Condition monitoring; vibration; fault diagnosis; bearing, gear;

1. Introduction

The rear axle assembly is used on rear-wheel drive vehicles. This assembly is the final leg of the drive train. It is often called the final drive or rear end. The rear axle assembly includes the differential assembly, the rear drive axles, and the rear axle housing. A typical rear axle assembly is shown in Figure 1.

In a rear axle assembly, engine power enters the drive pinion gear from the drive shaft assembly and differential pinion yoke/flange. The drive pinion gear, which is in mesh with the ring gear, causes the ring gear to turn. Power from the ring gear flows through the differential case, spider gears, and side gears to the drive axles. The drive axles transfer power from the differential assembly to the rear wheels.

The bearings and rear axle housing are components of the rear axle assembly. They are designed to support and align the differential assembly and the drive axles.

All moving parts of rear axle give rise to sound and vibration and each parts has a specific vibration signature related to the construction and the state of the rear axle assembly.

If the state of the machine changes the vibration signature will also change and a change in the vibration signature can be used to detect incipient defects before they become critical. This is the basics of vibration based condition monitoring methods. The condition monitoring technique is based on detecting the presence of a fault, diagnosing the root cause of the fault. A broad review of the state-of-art of condition monitoring and fault diagnosis techniques has been carried out for improving the accuracy and ability of condition monitoring and prognosis systems for bearing and gear components.

Early fault diagnosis of gears and bearings may prevent unnecessary failures of most of the parts and thereby increase operational reliability and availability of rear axle assembly. Fault diagnosis techniques are important for monitor the conditions in bearing and gear. Currently available fault diagnosis techniques have a variety of limitations. An effective and method has to be

researched and automated system has to be developed for industrial machinery component health diagnostic activities. (Taylor, 1995) discussed the dynamic performance of the rotating components is highly influential in the performance of any rotating machinery. (Endo and Randall, 2007) gave the importance of gear and bearings in the industrial rotating and transport machinery applications. Fault detection is the process of observing the measured system data and system status information and comparing them with a normal range of observed attributes to determine whether some measurements fall outside the range representing the healthy condition of the system. Unfortunately, no one technique is able to detect all machine faults. However, it has been suggested that vibration measurement, which is the most widely used condition monitoring technique in industry, can accurately identify 90% of all machinery failures by the change in vibration signals which they produce and the level of signal can give an accurate prediction of future failure (Randall, 2011). The task is to diagnose the fault at an early stage so corrective action can be taken as early as possible to extend the life of the machine (Latino, 1999).

Tandon and Nakara, (1992) compared the most commonly used vibration analysis methods for mechanical fault diagnosis such as time domain analysis, frequency domain analysis; time frequency analysis for defect detection in bearings.

In this work is presented condition monitoring of: ring and pinion gear, two side bearing and pinion bearing of the rear axle based on vibration analysis, through two parameters: frequency and amplitude of the vibrations.

In vibration analysis, measuring the vibration amplitude is made in broadband measurement. Broadband or overall measurement of the vibration amplitude is a measure of the total energy of all components of the machine vibrations. Generally accepted frequency range for broadband measurements is 10...10000Hz. An overall vibration measurement is a single value that is relatively easy and cheap to collect, process, analyzes and trend. Scales factors used to characterize the amplitude of vibration are: Peak value (Pk), Peak to Peak value (PtP) or Root Mean Square value (RMS).

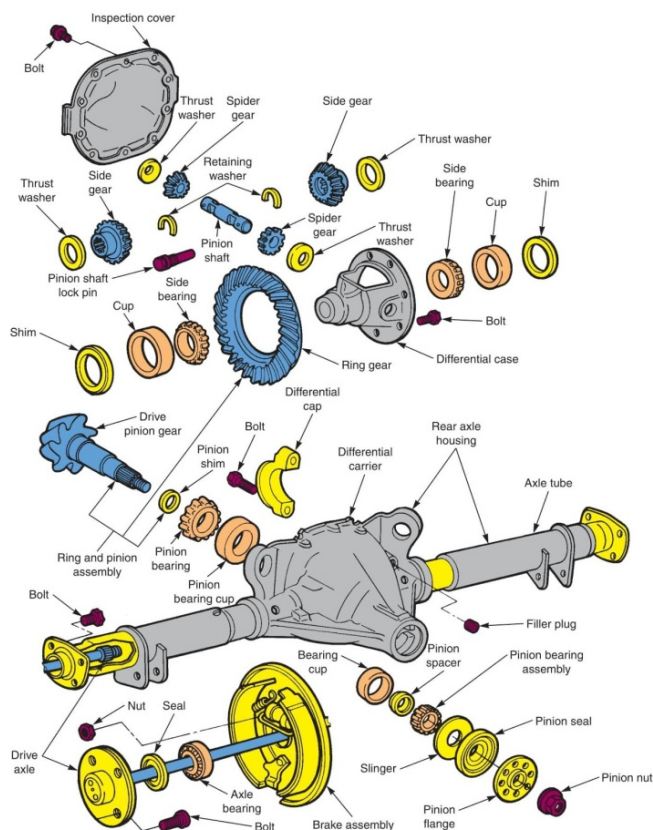


Figure 1. Exploded view of a rear axle assembly

2. Methodology for diagnostic of bearings and gears of the rear axle assembly for the passenger car Mercedes 190D

The preparation of the passenger car Mercedes 190 D to measure vibrations velocity, vibrations displacement and vibrations acceleration of the rear drive axle is presented in Figure 2. The vehicle is raised from the ground with crane and placed into two supports on both sides in order that during rotations of the wheels do not come into contact with the surface of the earth.



Figure 2. Preparing the passenger car Mercedes 190 D for vibrations measurement at the rear axle assembly

In the absence of the tachometer for measuring engine speeds, the measurements were made in the fourth gear of gearbox transmission (direct transmission ratio). In this case the vehicle speed is 100 [km/h], which corresponds to engine speed, respectively the speed of input drive pinion gear of rear axle assembly at 3000 rpm (Figure 3).



Figure 3. The vehicle speed which corresponding speed of drive pinion gear for rear axle assembly at 3000 rpm

During the test part of the handbrake is activated to simulate the rear axle load. The braking force is the same for both the left and right rear axle assemblies in order to simulate the straight movement of the vehicle.

Used tools to measure vibration have improved significantly in the past 25 years. The sensor of choice for most vibration data collection on industrial machinery is an accelerometer. As the name implies, the output is proportional to acceleration; however, it is normally integrated to display in units of velocity and displacement. Measurements of vibrations in the rear axle assembly of the passenger car Mercedes 190 D are made with vibrometer MANUAL PCE-VT 3000. Technical specification of vibrometer MANUAL PCE-VT 3000 is presented in Table 1.

Table 1. Technical specification of vibrometer MANUAL PCE-VT 3000

Technical Specifications	Measuring Range
Rang og aceleration	0.1.....392 m/s ² (Peak); (39.95 g force)
Range of Velocity	0.01..... 80 cm/s (RMS)
Range of Displacement	0.001....10 mm (Peak – Peak)

3. Results of vibration measurements for rear drive axle of the passenger car Mercedes 190

Measurements of the vibration are done in five specific points, which are presented in Figure 4. The measuring sensor with needle shape is used for measurements in points 3 and 4, while the measuring sensor with electromagnet is used in other measurement points.

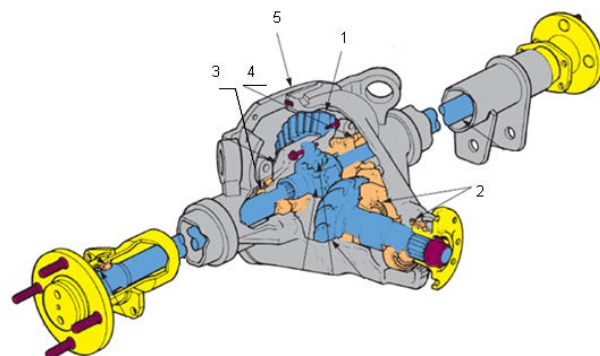


Figure 4. Measurement points in the rear axle assembly: 1 - Differential carrier, 2 – Bearing of the pinion gear, 3 –Right side bearing differential case, 4 - Left side bearing differential case, 5 - Back part of the rear drive axle

In Figures 5, 6 and 7, are shown the measured values for the vibration velocity, vibration displacement, and vibration acceleration at the five specific points for rear axle assembly of passenger car Mercedes 190 D, when the input speed of the drive pinion gear is 3000 rpm (50 Hz).

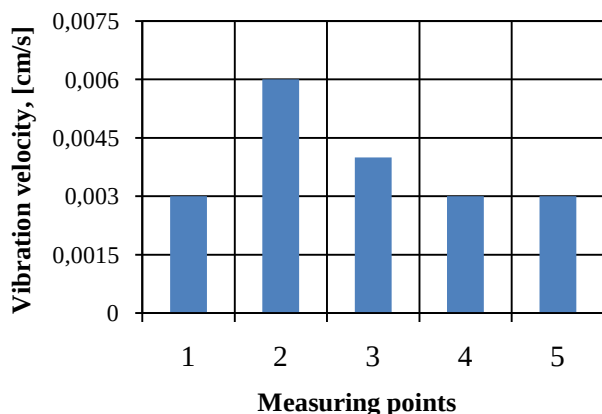


Figure 5. Graphic presentation of the vibration velocities at the five specific measuring points

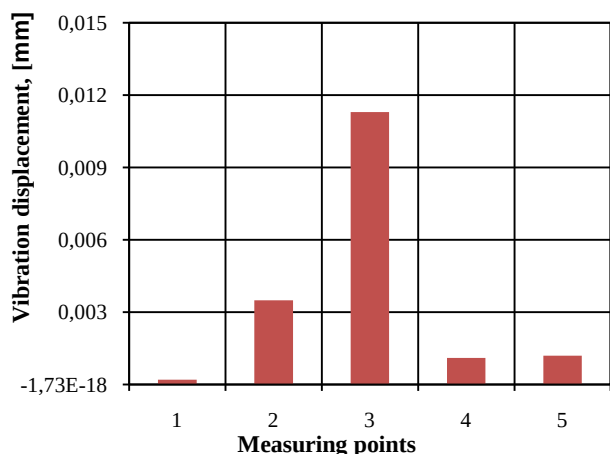


Figure 6. Graphic presentation of the vibration displacements at the five specific measuring points

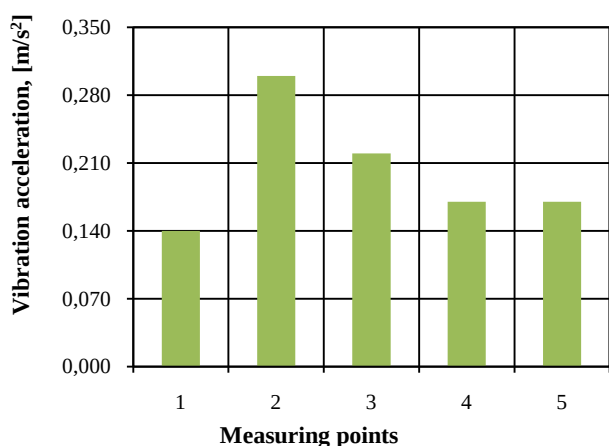


Figure 7. Graphic presentation of the vibration acceleration at the five specific measuring points

Figure 8 shows the measured values for displacement, speed and vibration acceleration on the display of the measuring device MANUAL PCE-VT 3000.

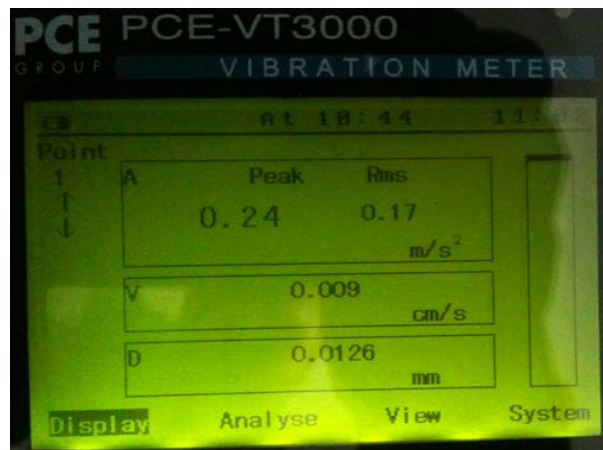


Figure 8. The values of vibration measuring for: the vibration acceleration, vibration velocity and vibration displacement are shown in display of vibrometer, MANUAL PCE-VT 3000

4. Vibration analysis

After measuring the vibration is necessary to evaluate the vibration severity. At the first method is compared the measured values with the vibration severity charts. Depending on the recorded values of the vibrations speed (RMS values) and the size of equipment, the ISO 10816-1995 standard evaluates the vibrations severity as in the Table 2. The ISO 10816-1995 standard is the most common example of absolute criteria and is a good guide for engineers who do not have any historical data on a machine.

Table 2: Vibrations Severity Chart – ISO 10816-1995

Vibration velocity v_{max} [mm/s]	Type of machine			
	Class I $P_e < 15$ [kW]	Class II $15 [kW] < P_e < 75$ [kW]	Class III $P_e > 75$ [kW]	Class IV
0.00 ÷ 0.28	A	A	A	A
0.28 ÷ 0.45				
0.45 ÷ 0.71				
0.71 ÷ 1.12	B	B	B	A
1.12 ÷ 1.80				
1.80 ÷ 2.80	C	C	B	B
2.80 ÷ 4.50				
4.50 ÷ 7.10	D	D	C	B
7.10 ÷ 11.20				
11.20 ÷ 18.00			D	C
18.00 ÷ 28.00				
28.00 ÷ 45.00			D	D
45.00				

Note:

Area A - Good condition of machine,

Area B - Operation of machine is satisfactory,

Area C - Operation of machine is unsatisfactory, and

Area D - Operation of machine is unacceptable (to repair).

At the second method is compared the measured values with the Blake chart. Depending on the recorded values of the vibrations displacement, speed and acceleration, and the frequency, the Blake chart evaluates the vibrations severity as in the Figure 9 (Eshleman, 1999).

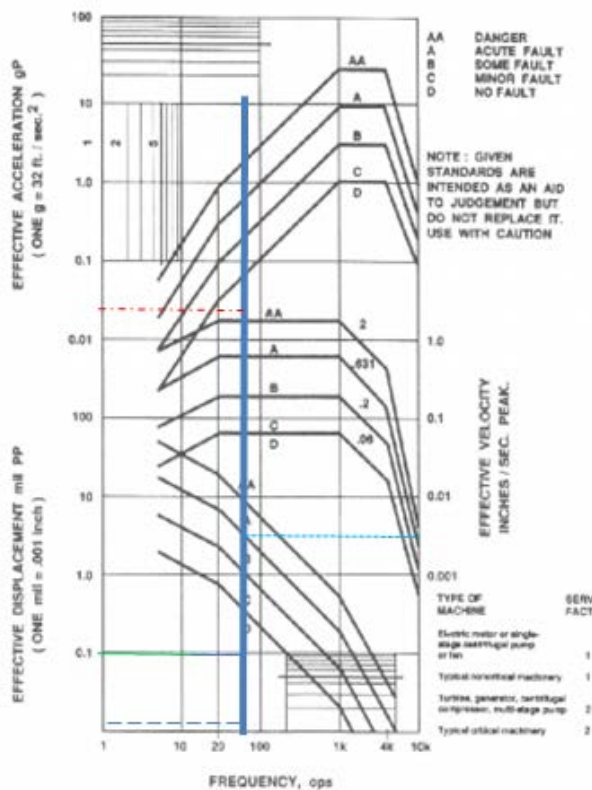


Figure 9. Blake chart: displacement, velocity and acceleration as function of frequency

In Figure 9 is drawn the vertical line at a frequency of 50 Hz that corresponds to the input speed of the drive pinion gear at 3000 rpm (blue line), then draw horizontal lines corresponding to the maximum displacement value (green line), speed (blue line) and acceleration (red line).

After comparing the results with the norms, it is noted that the values obtained correspond to the good condition of the bearings and the pinion and ring gear.

In Figure 10 is shown condition of component of the rear drive axle after measuring of vibration (after disassembling).



Figure 10. Condition of components of rear axle after disassembling

After measuring, the rear drive axle is disassembled and its components are observed carefully, where components are in good condition (haven't shown any damage).

4. Conclusion

The presented paper introduces diagnosing method for the gear mesh pinion gear and ring gear, two side bearing and pinion bearing of rear axle condition monitoring based on vibration analysis.

During the condition monitoring technique are made vibration measurements of the vibration velocity, vibration displacement and vibration acceleration by vibrometer device MANUAL PCE-VT 3000, when the vehicle speed is simulated to be 100 [km/h], which corresponds with speed drive pinion gear 3000 [rpm].

Obtained results for the vibration velocity, vibration displacement, and vibration acceleration measuring for five points in the rear drive axle are:

- In Area A - good condition (according to ISO),
- Greater values of vibration velocity are appeared in the side bearing differential case (points 3 and 4 of measurement),
- Vibration velocity and acceleration have similar behavior compared with vibration displacement.

The obtained results are suitable because after disassembling, the condition of the component of the rear drive axle are good (don't shown any damage) after measuring.

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MODELING OF PROCESSES IN TRANSPORT SYSTEMS BY FRACTAL METHODS

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Abstract: In the paper is proposed a model for studying of processes in a transport system by fractal methods. In view of the NDS general properties and examined categories: order, chaos and self-organization, the study is based on the synergistic approach to developing systems. On the basis of this has been performed research in the environment Matchcad with different values of system's parameters.

Keywords: TRANSPORT SYSTEMS, FRACTALS, DETERMENISTIC CHAOS, SELF-SIMILARITY, SCALE INVARIANCE

1. Introduction

Transport systems are complex technical systems consisting of a large number of interrelated elements: traffic participants, set of vehicles, a significant number of transportation process operations. They are characterized by interaction of heterogeneous traffic of passenger flows and a certain number of vehicles involved in the movement at the current time. This reflects a combination of deterministic and stochastic factors in the operation of transport systems.

Transport systems are nonlinear and deterministic, but exhibit complex chaotic behavior. They have a large number of possible states (stable and unstable), the transition between which is possible at any time. All of these features provide a basis to identify a transport system with a nonlinear dynamical system (NDS) [1].

For study of processes in transport systems general methods are used: physical experiments [2], visual diagnostics of the process [2], numerical methods [3], computer simulation [3]. In the scientific literature there are examples of application of the theory of nonlinear dynamics for prediction of motorised traffic flows [4,5,6]. In [7] is analyzed traffic flow data and characterized it as chaotic [8] showed that chaotic behavior in traffic can due to the delays in human reaction. Here a synergistic approach is manifested, designed to describe phenomena in the world of nonlinear systems, actively interacting with external environment. Their behavior has considerable dynamics and is described by similar mathematical models.

In the paper is proposed a model of examination of processes in a transport system by fractal methods. The existence of a fractal nature was investigated using the identification properties of chaotic processes [9,10].

2. The most important properties of chaotic processes

The first signs of the presence of chaotic properties of the processes are identified by observing time dependence. If during visual inspection signs of order or periodicity are not detected, it can be assumed that the process is chaotic.

Another method for visual diagnosis is associated with receipt and investigation of phase portraits. To characterize the attractor it is advisable to define its dimension, since non-integer fractal dimension indicates the presence of a fractal structure.

The chaotic processes are strongly dependent on initial conditions and susceptible to external influences. From the theory of nonlinear dynamics [1] it is known, that a small change in chaotic system's parameters may lead to changes in the type of solutions.

Methods that give a numerical estimate of chaotic state of the system, definition of autocorrelation function and calculation of capacity power spectrum of chaotic oscillations. For a chaotic process, the autocorrelation function decays exponentially. The spectrum obeys the law form:

$$S_x(f) = Bf^\beta \quad (1)$$

where f is the frequency and β is a constant.

Undoubtedly, however, the most important characteristics of the chaotic process are Lyapunov exponents and their spectrum [1]. A necessary and sufficient condition for chaotic state of the system remains positivity property of senior Lyapunov exponent [1].

Similar to the Lyapunov Exponents, a well-established parameter that is commonly used for testing for the chaos in systems is the Hurst exponent - H [1]. The Hurst Exponent, H , is a measure of the degree to which a given time series can be statistically expressed as a random walk (i.e., Brownian motion).

Another property of chaotic processes is the self-similarity [1]. It is the property we associate with fractals — the object appears the same regardless of the scale at which it is viewed. As the Hurst parameter H increases the degree of self-similarity is increasing ($0.5 < H < 1$).

3. Modeling of a transport system

Condition of transport system can be defined as a set of certain values

$$x_i, i = 1, \dots, n.$$

The meaning and the number of variables x_i may be different.

They are directly related to observed quantitative characteristics of the transport system.

As an example, in the simplest case when the dimension of the phase space is $n=3$:

- x_1 is a number of vehicles involved in the transport process at a given time;

- x_2 is a number of passengers;

- x_3 is a number of seats in vehicles.

The state of the transport system is described by system of nonlinear ordinary differential equations such as:

$$\dot{\mathbf{x}} = \mathbf{f}(\mathbf{x}, t, \mu) \quad , \quad (2)$$

where $\mathbf{x} = (x_1, x_2, x_3)^T$;

t is time;

μ is a set of parameters;

$\mathbf{f} = (f_1, f_2, f_3)^T$ are nonlinear functions.

The mathematical model (2) reflects the dynamic and active relations in the transport system.

The right elements of the equations (2) may be different depending on the kind of the functional dependence $\mathbf{f}$ and parameter values. The parameters of this kind include, for example, the intensity of the change in variables, maximum capacity of vehicles, etc. With such a basis the mathematical model (2) will reflect basis cause effect relationships of the transport system functioning and take into account its multi-element character.

On the basis of causes of changes in variables and their interrelationships, it is assumed that:

- change in the number of participating vehicles depends on presence of seats and a certain number of passengers in them;

-change in the number of passengers served depends on the number of available transport vehicles and the number of seats in them;

-change in the number of free seats is in proportion to the total number of vehicles, the number of seats in each of them and the number of passengers.

Then the model of transport system can be represented as:

$$\begin{cases} \dot{x}_1 = cx_3 - ex_2 \\ \dot{x}_2 = ax_1 + bx_2 \\ \dot{x}_3 = x_1 - dx_3 - x_2 \end{cases} \quad (3)$$

Parameters a, b, c, d, e in (3) have in relative terms the following values:

- a is coefficient taking into account the need to increase the vehicles in operation;

- b expresses the possibility of overload;

- c takes into account the percentage of occupied seats in vehicles;

- d reflects the marginal occupancy of seats;

- e expresses the intensity of passenger flow.

The system (3) is solved numerically in the software environment Mathcad for different values of parameters and initial conditions. Timing diagram, phase portrait and trajectories are obtained in Fig. 1, Fig.2 and Fig.3.

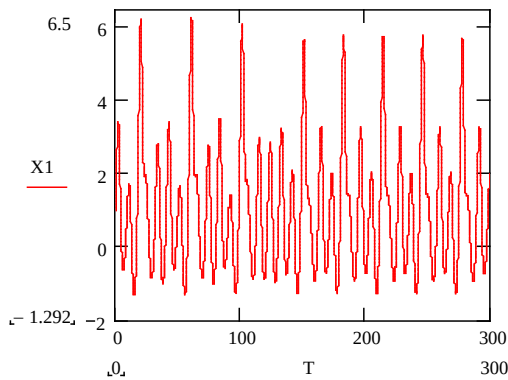


Fig. 1 Timing diagram

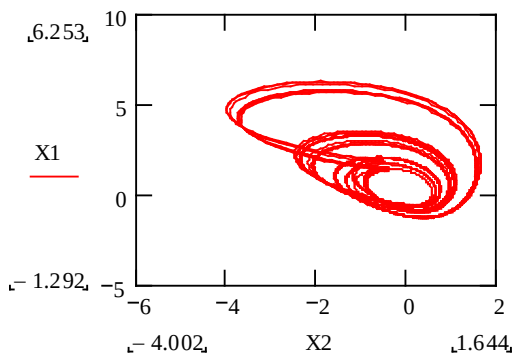
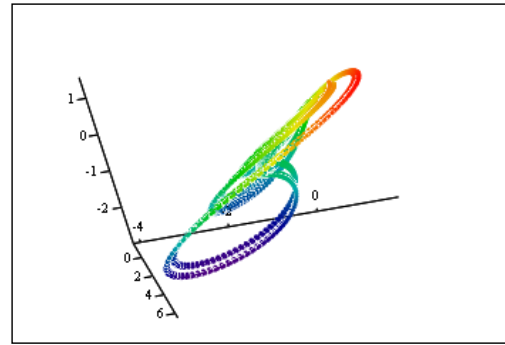


Fig. 2 Phase portrait

As can be seen from Fig.2 and Fig.3, the phase space of the system for certain values of the parameters is a strange attractor, which confirms the chaotic behaviour. In the time dependence from Fig.1 lacks periodicity of phase variables.

To verify the sensitivity of the solution to initial values time-base dependencies of system solutions with different initial values (Fig.4).



(X1, X2, X3)

Fig. 3 Phase trajectories

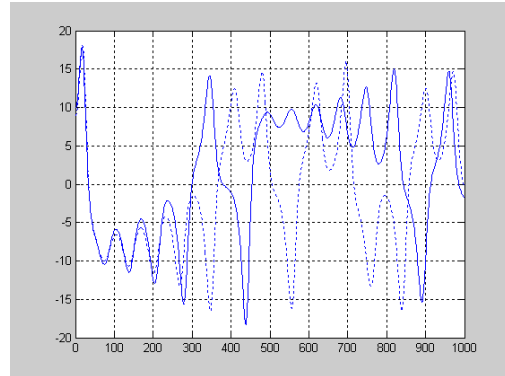


Fig.4 Time-base dependencies of system solution with different initial values

The resulting graph facilitates a preliminary conclusion about the exponential instability of trajectories, that is, about existence of a positive indicator in the spectrum of Lyapunov exponent.

The autocorrelation function of process (Fig.5) decays exponentially.

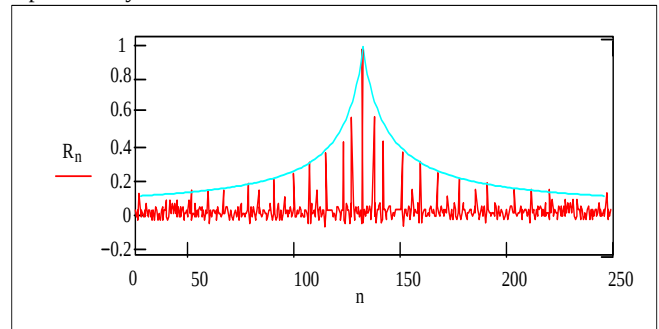


Fig.5 Autocorrelation function

4. Conclusion

A model by means of nonlinear dynamics is proposed, which from the standpoint of synergistic understanding in phenomena in the world of nonlinear systems is applicable to the study of transport processes. Using it, it is possible to find an answer to the question regarding identification of system parameters' values that cause chaotic behaviour. This method allows to control the dynamics of transport systems in order to achieve the desired mode of operation.

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IMPROVING THE EFFICIENCY OF ROAD FREIGHT TRANSPORT

ПОВЫШЕНИЕ ЭФФЕКТИВНОСТИ ГРУЗОВЫХ АВТОМОБИЛЬНЫХ ПЕРЕВОЗОК

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abstract: *The paper dwells on the technical and operational parameters affecting the efficiency of the road transport depending upon the performance of the motor transport enterprise. The paper also presents the justifications of criteria indicators to measure performance of road transport, and describes theoretical foundations of the process of studying and assessing the economic efficiency of motor transport systems. The influence of technical and operational parameters on the change in cost fluctuation of transport operation of motor power through a change in the total mileage and indicators that determine the value of variable and fixed costs: carrying capacity, loaded mileage proportion, utilization range, as well as the vehicle utilization, the average road speed and conveying distance. There have been considered three groups of indicators that define the ways and methods for increasing the efficiency of road freight transport in the existing operating conditions of the motor transport company.*

KEYWORDS: QUALITY OF CARRIAGE BY ROAD; PRODUCTIVITY OF ROAD TRANSPORT; TECHNICAL ECONOMICAL INDEXES; COST-EFFECTIVENESS; EFFECTIVENESS OF ROAD TRANSPORT.

1. Introduction

Economic efficiency theory tends to distinguish between the efficient functioning and development effectiveness of social production and its separate elements. The first case concerns the efficient use of available resources, and the second case involves the effectiveness of the activities aiming at improving resources management.

All changes taking place in organizing freight carriage affect the value of the technical and operational parameters, finally defining the efficient functioning of road transport in the region, as a result of organizational, technical, technological, economic, social and other actions.

So, the efficient functioning of road transport is assessed by the system of the technical and operational parameters characterizing the quantity and quality of the performed work.

2. Preconditions and means for resolving the problem

In order to draw a valid conclusion on the activity of road transport, it is not enough to establish the extent to which a transport plan is implemented for the analyzed period. It is necessary to compare the volumes of transportations for a number of the corresponding periods that will give an idea of the dynamics of the specified index. At the same time, it is necessary to establish the reasons which caused a particular dynamics of transport volumes or

goods turnover. The steady increase in transport work is a natural consequence.

The technical and operational parameters affecting the efficient functioning of road transport can be divided into two groups. The first group should include the parameters characterizing a degree of the efficient use of the motive power of road freight transport: truck availability rate; motive power capacity utilization rate; carrying capacity utilization rate and loaded mileage proportion; average distance of trip when loaded and average distance of carriage; standing time under loading un loading; duty time; technical and operational speeds.

The second group characterizes the effect of the results of the motive power performance: the number of trips; the total distance of carriage; ongoing runs; transports volume and transport activity.

We shall give calculation of some technical and operating parameters affecting the efficient functioning of road transport.

Productivity of the motive power in duty time is defined as the product the carrying capacity of vehicle q , its carrying capacity utilization rate γ and the number of trips n_e made by vehicle,

$$(1) \quad Q = q \gamma n_e$$

As can be seen from the formula, productivity of the motive power is formed under the influence of several technical and operating parameters characterizing the separate sides of road transport performance. Each parameter, in turn, is under the influence of various factors, including organizational-economic and material-technical, influencing on which, it is possible to change the

values of the parameters, and therefore the value of productivity of the vehicle fleet.

.Thus, the need and the direction of the influence can be determined on the basis of the analysis of the level of the vehicle fleet utilization rates. Any failures and shortcomings in transport reflect shortcomings in the applied methods for its management.

Change in the prime cost of carriage depends on two groups of factors: conditioned the reporting value of total expenditure, and determined the reporting volume of the total freight transportation (tonne-kilometers, passenger-kilometers, paid kilometers of running. Their influence on the prime cost is explained by various reasons. For example, the average number of vehicles with high carrying capacity was increased that resulted in change in the structure of the vehicle fleet. This has resulted in the increase in the amount of depreciation expense, fuel costs, maintenance operation, etc. However, the use of vehicles on the line on time was. Both contributed to change in the prime cost, but there is no connection between these reasons.

When analyzing the influence of technical and operational parameters on the prime cost of carriage, it is assumed that by a degree of the influence they are divided into two groups.

The first group should include carrying capacity of the motive power, carrying capacity utilization rate and loaded mileage proportion.

With the increase in in the parameters of this group, the efficient functioning of road transport without increase in in running, is increased. The influence of the parameters of this group on the prime cost is effective, since the variable and fixed costs for 1 t•km are reduced. At the same time, the amount of variable costs is changing insignificantly, that is the increase in the efficient functioning of road transport outstrips cost escalation.

The second group parameters – coefficient of the release of vehicles to the line, the duty time duration, technical speed, etc. – increase the efficient functioning of the motive power in case of the significant increase in running. With the growth in running, the variable costs depending on the movement (fuel and lubricants, spare parts, tires). Thus, this group of parameters influences on the prime cost only through the general running costs.

In the field of the motor transport, the development of a market economy is characterized by priority development of a service sector, buildup of the field of forwarding services for customers in the regions.

At present, significant importance should be attached to updating of transport products, the development of new types of transport and services, studying the need of the customers, and, first of all, it is necessary to pay attention to processing, intermediate storage, organization of loading and unloading operations, information and other services.

The general approach to determining the cost-effectiveness of the new types of the forwarding services (FS), at the current stage, can be reduced to the following options of the new types of services:

- to determine the costs, results and economic efficiency for each option;
- as the best will be recognized the option with a maximum value of the economic efficiency.

Economic efficiency is calculated by the formula:

$$(2) \quad E = R - V,$$

where, E – economic efficiency due to introduction of the new types of FS; R – the valuation (revenues) due to implementation of the new types; of FS(доходы) отреализацииновыхвидовТЭО; V – the valuation of costs.

The given expenses occurring at different times and the results of all years of the period of realization by target year, are carried out by multiplying their values for every year by a reduction factor, which is calculated according to the formula:

$$(3) \quad K=(1+E_n)^{y-t}$$

where, E_n – basic standard costs and results, numerically equal the investment performance standard ($E_n = 0,1$); t_y – target year; t – year, the costs and results of which are given by target year.

3. Conclusion

Results of the assessment of profitability should be directed at increasing the efficient functioning of road transport on time and productivity. The falling cost of carriage and improved productivity are the potentials for increasing profitability. In addition, there occur nonstandard inventory liquidation, sale of excess basic production assets, reduction and exclusion of unplanned expenses and losses.

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PECULIARITIES OF REDUCING THE NUMBER OF CUSTOMS-TRANSPORT FORMALITIES UNDER CONDITIONS OF TIME AND CONVEYING DISTANT CONSTRAINTS

ОСОБЕННОСТИ КОЛИЧЕСТВЕННОГО СОКРАЩЕНИЯ ТАМОЖЕННО-ТРАНСПОРТНЫХ ФОРМАЛЬНОСТЕЙ В УСЛОВИЯХ ОГРАНИЧЕННОГО ВРЕМЕНИ И РАССТОЯНИЯ ПЕРЕВОЗОК

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Abstract: Transport service in modern conditions includes not only cargo transfer itself from suppliers to customers, but also a large number of freight-forwarding, information, customs and transaction operations, cargo handling, insurance and protection services and so on.

The introduction of modern logistics management into the customs clearance practice allows for increasing organizational-economic stability of transshipping processes. The paper dwells on the tendencies in the application of customs logistics for the purpose of reducing the number of the customs clearance procedures for vehicles and goods under conditions of time and conveying distant constraints.

KEYWORDS: TRANSPORT SERVICE; CUSTOMS LOGISTICS; DISTANCE CONSTRAINT.

1. Introduction

Under conditions of an integrated world economy and the globalization of business, the new requirements to customs affairs are imposed. The customs service is required to contribute to the development of foreign economic activity. In modern world economic conditions, the purpose faced by the customs services throughout the world consists in facilitation of customs administration thereof, while ensuring compliance with the customs legislation.

Active globalization and liberalization of world trade create prerequisites for establishing the optimally organized system of interaction of all foreign trade actors in process of the customs clearance and customs controls used for goods and vehicles.

The use of logistics approach to the management of the export-import commodity flows has acquired special urgency at the current stage of Georgia's economic development. In the South Caucasus region, Georgia is situated in an advantageous position at the intersection of the Eurasian transport and logistics corridors that is a prerequisite for possible becoming as a full-fledged participant in the process of international movement of goods and services

Due to short-distance movement, transit goods moving through the territory of Georgia, cross, in a short time, at least four customs-transport frontiers and clear customs in accordance with legislations in these countries. Realization of these prospects substantially depends largely upon the activity of customs authorities of the country. Introduction of high-quality customs service, and the use of the effective innovative technologies in customs treatment and control, are the most important characteristics of customs activity. That is why the emphasis should be placed on studies of experience with the use of methods of logistics in organizing the system of customs treatment and controls.

In the context of the establishment and development of transport and logistics system in Georgia, it is possible to mention the non-

utilization of logistics approach in carrying out foreign commercial operations, since there are realized only separate logistical functions to reduce costs in movement of goods through the customs frontier. Customs authorities of Georgia, until recently, have been mainly focused on the solution of the fiscal and security tasks. At the same time, the natural evolution of customs development, predetermined by the influence of customs regulations on the processes of integration of national economy into the international economic environment, requires improvements in the technologies of customs treatment and customs controls. As one of the most important indicators of the efficiency of customs system, a minimization of the time spent for the customs formalities, is coming to the fore. Because the increase in prices for the goods within the country is the main consequence of delays of them at the border, when it comes to the imported goods, and loss of transit flows, in the case of delay of the goods moving to the third countries (transit goods).

When using logistics approach relating to the integration of all logistics operations in the management of export-import flows, the considerable reserve of the general decrease in expenses is created. This will become possible due to hi-tech interaction of business and the government institutions controlling foreign economic activity, first of all of the customs bodies, and will serve the interests not only of the end users, but also the state, and it will be a real step forward in taking benefit from the country's advantageous geopolitical position.

2. Preconditions and means for resolving the Problem

Logistics approach to improving the functioning of the customs bodies requires the system provided implementation of the following activities:

- Creation of the modern customs and logistic centers;
- Improvement of the customs legislation;
- Introduction of the latest information technology tools dedicated to the activities of the customs bodies;
- Creation of the uniform interdepartmental automated system for information collection, recording and processing in the implementation of all types of the state control of movement of goods through the customs frontiers;
- Reforming the institutional and management structure of the customs bodies based on the functional principle.

At present, the attention of the influential international organizations, such as the United Nations (UN) and the World Trade Organization (WTO) is drawn to the customs logistics now. Trade and transport services facilitation assume even-greater importance for the competitiveness of countries and their potential in economic development.

Large-scale research, analytical and consulting work, as well as the technical assistance to the developing countries on trade

facilitation is carried out by the United Nations Economic Commission for Europe (UNECE) and the United Nations Conference on Trade and Development (UNCTAD).

It was specified in the research works performed by the Organization for Economic Co-operation and Development (OECD) devoted to the benefits from trade facilitation, that the benefit from trade facilitation varies from 0,04% to 2,3% of GDP, and trade costs are reduced by 0,2 - 10%. Reduction of operational trade costs by 1% leads, on average, to the growth in welfare, equivalent to 0,13% of GDP.

Trade and transport services facilitation is in the inseparable relationship with the general economic level of the country's development. Most trade facilitation measures have a direct impact on the efficiency of both external, and domestic trade of the country, and affect the general condition of the human capital in the country, its legal framework, infrastructure and the use of information technology.

The interrelationships between the country's development level and its participation in trade facilitation is shown in Table 1.

Table 1: The interrelationships between the indicators of trade facilitation and income levels

Income levels of the countries	The average number of the required documents	The average number of the required signatures
High-income countries	7	4
Upper-middle-income countries	10	9
Lower-middle-income countries	12	16
Lower-income countries	13	28

Table 2 gives data on the number of different-type transit vehicles moving through the territory of Georgia by years

Table 2: The number of transit vehicles

Transport mode	2013	2014	2015	2016	2017 (2 months)
Maritime transport	39,0	75,0	8 588,0	41,0	33,0
Railroad transport	19 740,0	20 434,0	12 923,0	13 877,0	2 875,0
Overland transport	142 547,0	156 006,0	151 584,0	164 230,0	29 054,0
In all	162 326,0	178 529,0	173 095,0	164 365,0	31 962,0

As shown in the table, the largest part of transit attributed to the overland transport, and decreasing the time required for the customs treatment in organization of the sea-coast checkpoints

through the introduction of logistics principles, will give a considerable economic effect to transportation companies in terms of reducing the total time required for cargo shipping.

A logistics approach to the management of export-import commodity flows is fundamentally different from a traditional one in that it builds the optimally organized system of interaction of all participants of transport process in the implementation of customs procedures for achieving the maximum cumulative economic effect. It is obvious that specifics of the international logistics chains consist in fact that not everything depends on the participants of process. The certain significant operations are carried out by the customs bodies, whose purposes can both match, and contradict the purposes of the participants of transport process. Therefore, the essence of a logistics approach to the management of foreign trade flow processes consists also in establishing a system, whose principle of functioning is the optimization of time and financial costs of the implementation of procedures relating to movement of goods through the customs frontier, and to their subsequent involvement in the economic circulation, for the benefit of all participants of the foreign trade transaction.

The essence of merchandise distribution consists in a combination of physical and economic processes. Physical movement consists in its territorial displacement from one geographical point to another one. Here, of high importance is the choice of transport mode, as well as the transport and customs infrastructures existing in the country, which ensure the implementations of the capacities of individual modes of transport and the effective use of multimodal transportations. Movement in economic environment consists in transferring the rights to use, possess and dispose the goods, from one owner, user, or possessor to another one. Both aspects are in the field of interest not only of a private international law, but of the customs law as well – that may provide the basis for making a conclusion on significant influence on customs logistics, in addition to an economic, legal factor.

Table 3 gives data on the quantity of goods delivered to Turkey, Armenia, Azerbaijan and Russia by transit through the territory of Georgia by years .

Table 3: The quantity of goods delivered to Turkey, Armenia, Azerbaijan and Russia by transit through the territory of Georgia, by years

Country	2013	2014	2015	2016	2017 (2 months)
	Quantity, t				
Azerbaijan	2 982 836	3 252 115	2 281 382	1 972 187	303 222
Turkey	710 700	396 953	573 884	584 322	70 954
Russia	172 858	171 916	242 826	319 995	41 789
Armenia	1 371 651	1 430 295	1 664 439	1 624 967	235 488
In all	5 238 047	5 251 281	4 762 532	4 501 472	651 454

3. Conclusion

Since most countries in the South Caucasus region are developing States, the overall objective of their frontier-customs points is such organization, which unites processes of the implementation of the customs procedures relating to physical and economic movement of foreign trade cargo through the customs frontier. Introduction of customs logistics principles in their activities has to ensure coherence of material, information and financial flows in the customs activity, the optimum technology of movement of goods through the customs frontier, for the purpose of accelerating this process, as well as the development of standard logistics requirements regarding both the customs procedures, and activity of the participants of transport process. To that end, of high importance is

the existence of intergovernmental and interdepartmental associations, will prepare a set of proposals for the coordinated implementation at the legislative level, by balancing the interests of all the interested parties.

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VEHICLES FOR THE 21ST CENTURY – PERSPECTIVES FOR THE FUTURE

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*Putuju zagrljene daljine i vreme
/ Hugged distances and time travel/.*

Abstract: Since January this year, all trains of the Dutch Railways use electricity from wind energy. The electricity from this renewable source is increasingly being used in the world. Insight into the future of transportation will provide versions of "Hyperloop" transportation system, a super fast train that can develop a speed of 1.200 kilometers per hour.

At 23rd of January 2017 in Paris started to run the bus without driver also with aim to reduce pollution in the city. In February 2017 the public learnt of a new taxi service in Dubai that will be implemented from June 2017. These are drones on batteries, which are made in China, EHANG 174.

Authorities in Norway have reported that electric or hybrid cars make half of newly registered vehicles in the country during 2017. It is believed that this is a turning point on the way to the Norwegian fleet of electric vehicles and serves as the proof that policy of green transport produces results.

Lot of work is being done to make hydrogen-powered cars a reality. So many automakers are developing hydrogen-powered cars. These hydrogen-powered cars we can expect to see in the near future. Not many people have heard of the technology and from an infrastructure standpoint, purely electric vehicles make more sense. In the new 2017 „Faraday Future“, American manufacturer of electric cars in Las Vegas presented the "new kind of car," electric sedan that will have acceleration of the "Formula 1" and the ability to learn and adapt to the driver. Did "Tesla" won the competition, and it is FF-91, which should be produced in 2018?

KEY WORDS: VEHICLES, FUTURE, ECOLOGY, WORLD.

INTRODUCTION

*Experience taught me that only creativity is the road out of stony
forts of habits.*

Today, at the beginning of 2017 drivers agree that the most reliable are Japanese cars¹. Also "Audi" buys technology for cars using hydrogen. Since January this year, all trains of the Dutch² Railways use electricity from wind energy. The electricity from this renewable source is increasingly being used in the world. And in the Norwegian capital, Oslo, driving diesel cars is prohibited from 6 am to 22 hours in the evening and this will last until the air pollution is reduced.³ After the "Folkswagen" 's scandal with fixing data related to harmful gases emissions, we learn that sports car producer "Porsche"⁴, which is owned by "Folkswagen" - Group withdraws 16,429 vehicles because of problems with screws – the reason was problematic connection with the distribution pipes for fuel.

In the Republic of Serbia Agency for traffic safety and company NIS organized a joint campaign on the theme of road traffic safety in winter conditions. The campaign was implemented by the company NIS in the year 2016 declared as the Year of HSE-a (Health, Safety, Environment).

ENVIRONMENTAL PROTECTION AND NEW TRENDS IN CAR INDUSTRY

The European Parliament adopted more strict regulations with aim to prevent repetition of "Volkswagen's" scandal with manipulations by harmful gases emissions. For the draft law that will strengthen control and allow passing sentences⁵ to car manufacturers, from the Brussels Parliament voted 585 deputies, while 77 of them were against. So the new measures will ultimately remove diesel cars from the roads, and the EU member states will, according to the new law, have to finance centers for testing the exhaust gases. The official Brussels will get authorization to carry

out checks of vehicles and to determine the punishment in case of violation.

In response to information that the French authorities have begun an investigation "Renault" has issued a statement in which they insisted that their diesel vehicles do not have the software for cheating on tests of harmful gases emissions. They also emphasized that they observe all French and European laws. The question is whether the "Renault" will bear the brunt of the prosecution? Although during year 2016 "Renault" has withdrawn 15,000 vehicles because they emitted elevated levels of harmful gases.

An interesting example of Mexico City is showing that limiting of the use of cars is not the safe way to reduce the level of harmful substances in the air. 25 years ago this lovely city that I had the opportunity to visit in 1999, was proclaimed by the United Nations, the most polluted city on the planet. Although from year 2008⁶ the measure that prohibits driving on Saturday to the inhabitants of Mexico City is in effect, the latest study suggests that the air pollution in this metropolis was not reduced.

While some scientists consider our Planet to be the chronical ecological patient, from Scandinavia come the information that authorities in Norway have reported that electric or hybrid cars make half of newly registered vehicles in the country during 2017. It is believed that this is a turning point on the way to the Norwegian fleet of electric vehicles and serves as the proof that policy of green transport produces results. This Scandinavian country has adopted a strategy to encourage the purchase of environmentally friendly cars, under which owners of electric cars are exempted from almost all taxes.⁷

At 23rd of January 2017 in Paris started to run the bus without driver also with aim to reduce pollution in the city. Bus E310 possesses sensors and cameras that show when they go and when to stop, in which direction to go and how fast. This bus runs on the test route between the railway stations "Lion" and "Austerlitz", and this year there will be, according to the announcement of the city authorities, other established routes. Also superfast trains become a reality. Insight into the future of transportation will provide versions of "Hyperloop" transportation system, a super fast train⁸ that can develop a speed of 1.200 kilometers per hour.

¹ "Toyota C-HR" /means coupe-high rider/ is the type Eu 6, with a maximum speed of 190 km per hour, and in the winter of 2017, on temperatures in the minus, proved to be a true samurai on ice and snow in Belgrade.

² Dutch energy company "Eneko" communicated to operate without prejudice to the environment, and that one windmill for an hour produces enough electricity for train to run 200 kilometers.

³ This temporary ban is valid for all urban roads, but not for the national highway passing through Oslo.

⁴ It is being discussed on the "Porsche" models "911", "Boxster" and "Cayman" produced in the period from September 2015 to October 2016.

⁵ The amount of the penalty would be 30 000 euros per vehicle.

⁶ Already in 1989 driving during one day, from Monday to Friday, depending on the last digit on the license plates, was prohibited to the drivers in Mexico.

⁷ The owners of these cars enjoy other benefits, like for example the free use of the roads where tolls are charged, as well as public parking lots, but also the possibility of driving in bus lanes.

⁸ It is the structure on the pressure, with the brake system and electronics, i.e. works on the principle of passive magnets, but still

In February 2017 the public learnt of a new taxi service in Dubai that will be implemented from June 2017. These are drones⁹ on batteries, which are made in China, EHANG 174, range up to 100 km/h, and with single charge cover 50 kilometers.

NEW MODELS AND ENVIRONMENTAL FRIENDLY CARS

From 24th of March till 2nd April 2017, under the cupolas of the Belgrade's Fair more than 410 exhibitors from thirty countries, 34 automobile brands, 10 manufacturers of light commercial vehicles, 39 models of motorcycles presented themselves. This international Motor Show is the oldest regional review of the car industry and this year with slogan "Years pass, passion does not stop" and emphasis is placed on alternative hybrid and electric drives.¹⁰

However, the most stylish Japanese cars ever are "Toyota 2000 GT", it was the "Japanese E-type". The "Corolia" might be Japan's most successful export, but the "2000 GT" is its most beautiful. Then "Mazda RX-7 FD", "Toyota Celica" A 20 (the "Toyota MR 2" will go down in history as Japan's first mass production mid-engined car, but it also happened to be a very fine sport car).

"Hyundai Santa Fe" was named in 2014 as the best family car in the choice of the US site Cars.com. Many are also interested to become owners of the sport edition of the LEXUS CT 200h, the luxe version hybride.

It is interesting to note that even in 1939 the Government of Japan expelled from the country "General Motors" and "Ford" and in 1949 saved "Toyota" of bankruptcy with the money that was taken from the Central Bank of Japan. "Toyota" started as a factory for the production of textile machines - Toyota automatic looms. A first car with the name "Tojopet"¹¹ suffered a debacle, while half a century later the luxurious brand "Lexus" has become something like an icon of globalization.

The first generation "Celica" was the "Japanese Mustang", then "Datsun 240 Z", "Nissan skyline GT-R PGC 10" and "Nissan 300 ZX Z 32", "Lexus LFA", "Acura NSX", "Mazda Cosmo 110 S", "Subaru XT", "Datsun Cherry E 10", "Honda CR-X".

Today, the "Hyundai ioniq", Korean brand that with a modified "ioniq" achieved a speed of 253.94 km/hour for the world record in the class of hybrid cars (FIA Category A, Group XI).

All of us know that the most popular European cars in USA are "Volkswagen"¹² Jetta" produced in 1979, "BMW 3" -series produced in six different generations, "Mercedes-Benz" C-class introduced in 1993, "Volvo S 80", that came out in 1998, etc. But

works as the science fiction. The author of this project is the team from Delft University.

⁹ It weighs 227 kilograms and it can transport one passenger of weight to 100 kg and a small luggage /bag, which is placed in a special compartment.

¹⁰ Importers and distributors presented 67 novelties.

¹¹ It was the first passenger car exported by "Toyota" to the US market.

¹² Today, the "Volkswagen" is seriously turning toward electric models. At the Motor Show in Los Angeles "Volkswagen" presented redesigned and improved electric "e-golf" which now in ideal conditions can travel up to 300 kilometers on a single charge. Otherwise battery technology is evolving very quickly. Model S of company "Tesla Motors" can travel 500 kilometers with a single charge of the battery. Models "Nissan" and "Kia-e" can cross about 160 km after charging during the night, what is enough for an average driver. Power of battery enters in the public transport: the bus produced by "Mercedes" with a battery that is charged by solar energy.

In Sweden the ferry "AiriEl" that runs on batteries and uses a new type of power, that makes no vibration, was tested. This ferry does not pollute the environment and moves faster than traditional ferries on diesel fuel. The ferry "AiriEl" is moving on lithium-titanium battery rechargeable in about 15 minutes, so the vessel can run more than 25 kilometers.

little is known that a lot of work is being done to make hydrogen-powered cars a reality. So many automakers are developing hydrogen-powered cars. These hydrogen-powered cars we can expect to see in the near future. Not many people have heard of this technology and from an infrastructure standpoint, purely electric vehicles make more sense. For example, there are 14,618 electric stations in United States, and hydrogen stations are really only available in California.

From the City of light, from Paris Motor Show 2016 the favorite cars were: 1. Renault -Tresor, 2. GLM -G4 - Electric social supercar, 3. 2018 Honda Civic, Type R, 4. Citroen-CXperience Concept, 5. Volkswagen -ID Concept, 6. Mercedes Benz- Generation EQ Concept, 7. Hyundai -RN 30, 8. BMW - X2 Concept, 9. Ferrari-Laferrari Aperta, 10. Land Rover - Discovery, 11. Mercedes AMG-GT-R, 12. 2018 Audi SS-Sportback.

Of significance is the city car for all purposes whose customers are mostly women, and it is "Opel Adam Roc 1,0-115 KS"¹³. Carbon dioxide emissions with this car are 119 grams/kilometer, and a multitude of electronics makes it easier to drive, and Electronic Stability Control, Brake Assist, as well as warnings on vehicles in the "blind spot". Finally we should mention the "Renault talisman"¹⁴ French giant's car, with 4.85 meters in length.

The wider European project Central European Green Corridors (CEGC) included Slovakia, Germany, Austria, Croatia and Slovenia where a dense network of 115 modern high speed charging for electric cars is placed.

CONCLUSION

Way back in 1935, the trams have forever changed the destiny of our capital Belgrade and Zemun.

In the new 2017 „Faraday Future“¹⁵, American manufacturer of electric cars in Las Vegas presented the "new kind of car," electric sedan that will have acceleration of the "Formula 1" and the ability to learn and adapt to the driver. Did "Tesla" won the competition, and it is FF-91, which should be produced in 2018? American company "Apple" in California tested the car without driver too. Is was incredible few years ago? Significant research is also carried out today in Technological Institute in Massachusetts in America.

It is well known that transport produces a quarter of the load of all Greenhouse Gas in European Union. Let's make our planet not to be environmentally patient, although unfortunately some plant and animal species disappear. Nowadays the fight for health of the planetary ecosystem continues as well as for alternative fuels such as electricity and auto-gas.

However primary concern should be the safety and the exchange of experience of experts in the field of traffic both on land and on water and air is necessary. And while experts are monitoring the melting of ice on our planet by satellite photographs, the American satellite "Landsat 8" is collecting photos of the whole surface of the Earth every 16 days, and the picture of the rising sea level on the Planet is more precise.

In the final version of the Climate Action Plan German government has lowered its goals on reducing carbon dioxide emissions in the industrial sector for only 20% by year 2030 in relation to the year 2014.

In this paper new trends in the car industry are presented together with new models in the world and especially environmental friendly cars. It is necessary to provide a cleaner

¹³ The basic version of this car is shown back in 2012 at the Paris Motor Show. With great width (1,720 mm) and length (3,747 mm) it is very stable real small tank and fulfills the EU 6 standard.

¹⁴ This car is larger and more luxurious model than "Renault Laguna", possesses comfort, safe brakes and French charm.

¹⁵ The founder is a Chinese billionaire, who is dedicated to this project and looks for investors and highlights that this is a "global ecological system of mobility".

mobility in cities and provide infrastructure for environmentally friendly fuel.

Fabula docet, i.e. story teaches us, that hence we can conclude that with the advancement of technology and our know-how in the field of transport is significant, but continued vigilance is always required...

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STATUS AND PERSPECTIVES OF PORT COMMUNITY SYSTEMS DEVELOPMENT IN THE EUROPEAN UNION: THE CASE OF BULGARIAN BLACK SEA PORTS

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Abstract: The present paper analyses the status and current issues of port information exchange systems in the European Union and the Bulgarian Black Sea ports. Port Community Systems (PCS), being a complement to the Maritime Single Windows (MSW), are based on specific EU legislation thus achieving realization of documentary data exchange in maritime transportation through a single interface with various levels of access. The main objective of this paper is to outline the feasibility, the benefits of PCS development and integration within the European Union as well as the role of the developed MSW system of Bulgarian Black Sea ports for the PCS integration environment. The PCS integration process aims at decreasing of administrative burden, reduction of documentary errors, introduction of standardized electronic data interchange and reduction of service time for port users.

Keywords: PORT COMMUNITY SYSTEMS, MARITIME SINGLE WINDOW, MARITIME TRANSPORTATION, INFORMATION EXCHANGE SYSTEMS

1. Introduction

The globalization of maritime transport requires establishment of legal regulations at international (International Maritime Organization) and at regional (European Union) levels. European Union (EU) policy issues and regulations are seldom related to one member state only. The common framework approach to regulations related to electronic data exchange systems of EU ports and of the economic operators in maritime transport is a prerequisite for efficient coordination and implementation of strategic policies and measures. Main policy objectives for promoting transparent and efficient solutions based on innovative information technologies in maritime transportation within the EU include:

- improving the safety and security of maritime transport services and environmental protection (integrated surveillance, monitoring and control systems incorporating adequate intelligence means for proactive, remedial and cross-border operations);

- increasing the competitiveness of the EU maritime transport and logistics industry (improved utilization of advanced information and communication technologies leading to higher quality of shipping services and facilitating reduction of operational costs and increased competitiveness of the sector);

- reinforcing the human factor (there is a serious shortage of qualified people in seafaring and maritime professions within EU due to the lack of flexible continuing professional education at sea and ashore whereas ICT solutions can support competence development through long-distance learning).

The development of the MSW and of the port communication systems has led to the introduction of the concept of Port Community Systems (PCS) serving as integration points for all stakeholders of the community being interconnected via Maritime Single Windows (MSW). The ideal operation of a Port Community System involves no need for bi-directional communication lines between the various port-related actors as they all have access to the information they need through the central communication system [11].

2. Theoretical background and legal framework

The European Union White Paper for the future of transport sets the guidelines for a Single European Transport Area in which all barriers between modes and between borders are to be eliminated. In particular, it calls for a Blue Belt in the seas around Europe which would simplify the formalities for ships travelling between EU ports [5].

EU Maritime Single Windows have been associated primarily with two interrelated policies [3]:

- Directive 2002/59/EC for vessel traffic monitoring (the "VTMIS Directive") aimed to improve safety and environmental protection in European seas;

- Directive 2010/65/EU for ships arriving in and/or departing from ports of the Member States (Reporting Formalities Directive), describing the actions that Member States should implement to make efficient use of electronic data transmission and information exchange systems.

Further to above, the legal basis for the adoption of EU Directive 2002/6/EC is the International Maritime Organization (IMO) Convention on Facilitation of International Maritime Traffic (FAL Convention) that entered into force in 1967. The purpose of the convention is to enhance the efficiency of maritime transport by digitalization, formalities simplification, setting forth documentary requirements and procedures associated with vessels' movements in international voyages. However, every port communication system reflects the port specific requirements therefore vessels' reports and cargo documentation are often specific to the port [11]. Reporting requirements and hence the use of the single window will depend on where a ship or the cargo is on its voyage [6]. The timeline in the transportation process by sea is presented in Figure 1.

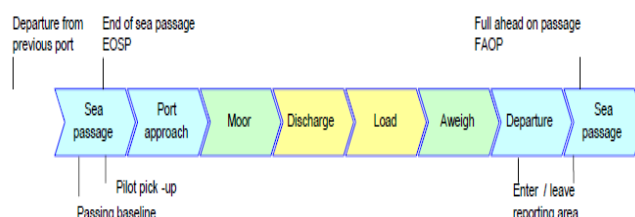


Figure 1. Timeline in a transport process [6]

EU Directive 2002/59/EC (SafeSeaNet) sets forth the guidelines that the ship operator, agent or master have to notify the competent authority, at certain time prior to entry into a port of a member state and provide strictly specific data related to the cargo or the vessel. Member states are obliged to monitor the status of all ships operating in their mandatory reporting systems and vessel traffic services as pursuant to the requirements of the IMO FAL Convention [11]. SafeSeaNet (SSN) is a specialized network facilitating the data exchange in an electronic format between the maritime administrations of the member states [11]. The system has been designed basis the EU legislation, regulations related to port reception facilities (waste disposal) and Port State Control (Paris Memorandum of Understanding) having significant level of reliability and security. All EU member states have developed systems to accept electronic reports via a Maritime Single Window as of June 1, 2015 for reporting formalities applicable to maritime

transport for arriving and departing ships within EU ports. Thus integration of information flows is achieved providing the business stakeholders, local customs and government administrations with relevant import and export data. Furthermore, the EU Directive 2002/59/EC requires that each country organizes coordinated methods for request of reporting procedures.

SafeSeaNet was established as a centralized European platform for maritime data exchange, linking together maritime authorities from across Europe. Evolution of SafeSeaNet during the last decade includes a number of developments that had an impact on Maritime Single Window solutions. Some of them are: integrated distribution of LRIT/AIS information via SSN, integration of SSN and CleanSeaNet functionality to facilitate pollution incidents analysis and identification of potential polluters, visualization of ship inspection information on the SSN GIS interface, SSN access mechanism improvement, etc. [3].

[12] defines the Single Window concept as “a facility that allows parties involved in trade and transport to lodge standardized information and documents via a single entry point to fulfill all import, export and transit-related regulatory requirements. If information is electronic, then individual data elements should only be submitted once.”

The European Port Community System Association (EPCSA) represents the interests of the Port Community Systems Operators in Europe and promotes the role of PCSs in the MSW. EPCSA’s policy is aimed at encouraging the development of Port Community Systems as an efficient way of simplifying port procedures and means by which the requirements of Directive 2010/65/EC can be implemented. Some of the vital issues in the role of PCSs in MSW systems include: transition paths to unifying messages submitted by carriers and cargo agents to PCSs; potential of harmonization between PCS messages with the requirements of the ship formalities directive as agreed by all Member States.

PCS in general is a local initiative that is realized in an IT environment being specific to a port while the MSW is a country-level national system [9]. The MSWs are controlled by the government as pursuant to Directive 2010/65/EU. As the latter is not directly providing guidelines for the PCS therefore they are to be developed in addition to the MSWs initiatives in the ports. The PCSs can be either privately or publicly controlled and developed. Port community systems can integrate functionalities that are required by the parties benefiting from the PCS. In practice, PCS serve as electronic gateways for the MSW. The main differences between PCS and NSW are [9]:

- MSWs are country-specific, while PCSs are port-specific;
- Data submitted to MSW cannot be reused whereas PCS data can be used further or for other purposes;
- MSWs are government-controlled while PCS can be either government or public driven

The specific ports Single Window systems has a Business-to-Government (B2G) character as it provides local level information about the vessel to the authorities on a port level, while a Port Community System has a Business-to-Business (B2B) character acting as a tool to exchange commercial and logistics information among the members of a port’s community [10].

3. Functionalities, benefits and integration of PCSs in the European Union

According to EPCSA’s White Paper [4] the PCS supports electronic transmission of: vessel notification towards Harbor Master/Port Authority and Customs; cargo declaration, manifest filling/summary declaration towards Customs; ship’s stores declaration; crew’s effects declaration; dangerous goods declaration towards the Harbor Master/Port Authority, waste disposal and port

dues declarations. The economic operators can further use the information already stored in the PCSs for business-to-business processes (outturn reports, vessel information, etc.). The definition of a Port Community System is: a neutral and open electronic platform enabling intelligent and secure exchange of information between public and private stakeholders in order to improve the competitive position of the sea and air ports’ communities [4]. The PCS optimizes, manages and automates port and logistics processes through a single submission of data and connecting transport and logistics chains. According to [7] a PCS Operator is an organization that is either public, private or public/private that operates and maintains a Port Community System and where the Port Community System represents the core of that organization’s business.

As per [8], research on the functions of PCSs have been carried out outlining the following functional areas: shipping lines, freight forwarders, terminal operators, port operators, customs, land carriers, container freight stations. The main functionalities for port operators are: ship arrival/departure confirmation, harbor dues, vessel inspection request, immigration clearance, reception of dangerous goods declaration, vessel arrival notification, notification waste disposal, statistics of supply chain performance, berth allocation management. Based on research of various authors [2] have summarized the benefits of the PCS (Table 1).

Table 1: Benefits of PCS and evaluation methods (adapted from[2])

Digital economies benefits		Quantification Method
Economic benefits	Reduce cost of information access	Value of time and labor saved
	Reduce cost of communication	Cost of previous forms of communication
	Extra revenue (government authority or administrator)	Value of revenue
	Correct taxation (port authority services)	Difference between the before and after tax revenue
	Prevention of illegal transactions	Per cent of illegal transactions reduction
Increased quality of information	Decrease of errors rate	Time and labor consumed to correct errors
	Elimination of data inconsistency	Time and labor consumed to sort and verify data
Increased performance	Fast access to information	Measurement of the increased labor productivity
	Efficient use of resources	Better use of equipment capacities
Community attendance benefits		Quantification Method
Increased competitiveness at stakeholder level	Increased access to information	Savings in costs of information
	Added value services	Revenue in added value services through PCS
Increased efficiency	Compliance with community standards and regulations	Less investment needed for business growth

Current integration pilots in EU ports are concentrated on close integration efforts between several PCSs for achievement of a specific purpose via common user interface and single access for all participating PCSs. Another potentially feasible functionality of integrated PCSs within the EU is the multiple use of data provided by ships from previous port(s) which ensures for saving of time. Yet another developed area is the realization of the global data exchange where PCSs exchange data with extra-community PCSs. The latter is a prerequisite for integration with customs data exchange systems. Based on the present status of the PCSs integration level within the EU the following challenges can be outlined: heterogeneity of PCSs due to national/local regulations, technological diversity of existing PCSs, refraining from sharing confidential business information, need for benefits sharing between main beneficiaries of information and parties investing in PCSs integration.

Table 2 illustrates the features and building blocks that were incorporated into the MSW pilot projects of the EU countries of the Mediterranean and the Black Sea regions.

Table 2: Main features incorporated into MSW in the Mediterranean and Black Sea regions (adapted from [1])

Functionalities	Pilot Projects in EU Countries (December, 2015)					
	CY	GR	IT	RO	BG	SE
Digital Reporting	*	*	*	*	*	*
Internal public communication - multiple use of data	*	*	*	*	*	*
PCS	*		*			*
SafeSeaNet			*	*	*	*
Health	*	*		*	*	
Passengers	*	*	*	*	*	
Crew	*	*	*	*	*	
Customs (reporting to MSW)	*		*		*	
IT security	*	*	*	*	*	*

Figure 2 [9] presents the four main PCS integration designs. The “Bilateral message exchange” design represents the most feasible integration option which realization requires only a limited amount of data from another PCS. The data exchange is performed via transfer of messages or specific data. In cases where there are more than two PCSs to be integrated, the “Multilateral message exchange” is applied and it provides for a central connectivity platform functioning at national or European levels. Front office cooperation in Bremerhaven and Hamburg is an example of the latter design. Barcelona and Marseille integration case is based on bilateral or consortium data sharing of specific messages between the PCSs and the development of shared services. The “Full bilateral system integration” design presents the case whereas two ports completely integrate their original PCSs into one IT system providing the same interface for both ports. There might be a practical limit on functionalities of one system that takes into account all diverse regional, local and municipal specifics and regulations. With the “Central PCS or multilateral system integration” design complete PCS integration between a larger number of systems is achieved by provision of a common interface for all participants but maintaining the port-specific PCS for locally-specific functionalities.

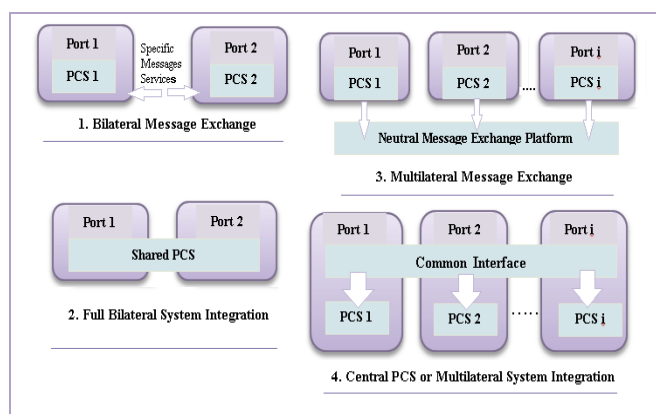


Figure 2: The four main PCS integrating designs [9]

4. PCS in Bulgarian Black Sea ports

Based on the EU “Operational Program on Transport 2007-2013” and as pursuant to EU Directive 2010/65/EC, a new organizational and technological structure has been established in Bulgaria: National Centre for Electronic Exchange of Documents in Maritime Transport (NCEEDMT) that is functioning as a MSW. The operational functionalities of NCEEDMT allow for single electronic input of data whereas competent authorities receive the required information automatically which considerably reduces the time for documentary exchange. NCEEDMT has two structural entities: Bourgas Information Center and Varna Information Centre that coordinate the activities in the port terminals in Bourgas and Varna respectively.

As of December 2015, based on [1] the Bulgarian Port Infrastructure Company introduced a pilot project “Mover” as an extension of the already developed MSW. The objectives of the pilot project include: improvement of the technology of movement of vessels in the ports, improvement of the safety and quality, facilitation of the business. The pilot project (Figure 3) involves the following stakeholders: VTMS authorities, pilot stations, port terminals, tug companies, state authorities (customs, immigration, economic operators).

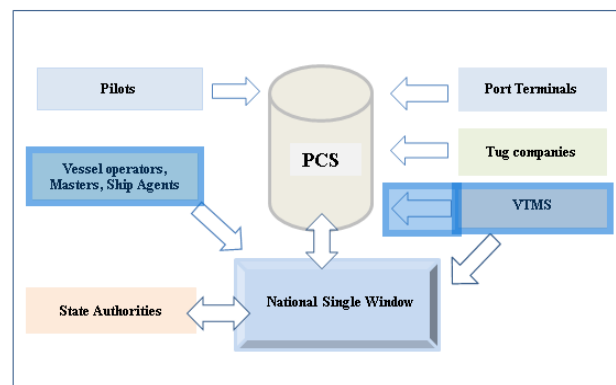


Figure 3: Pilot PCS project for Bulgarian Black Sea ports (adapted from [1])

Common interface is used for access to data and traffic planning is made by the VTMS control bodies whereas automatic messages are sent to the users for each re-planning. The model consists of a database, a business layer, validation module, service layer. Data elements cover several classes: initial data, secondary data and reference data. The expected results are related to achieving more efficient traffic planning, facilitation of the planning process, reduction of ships’ stay in ports, financial benefits for the business. The pilot project is an useful technological tool for validating the flow of data between parties and improvement of the functional capabilities of the MSW in general being a technical add-on to the existing MSW.

5. Conclusion

Despite recent trends for digitalization in maritime transport most of the services are still realized via paper-based solutions. The EU legal framework and the achievements of national authorities for development of the MSWs have traced the path for the introduction of PCS. Although the benefits of PCS are clear to all stakeholders the provision of standardized exchange of information is a technological challenge. The design, realization and usage of a PCS is a multi-stage process incorporating diverse layers and modules enabling transactions of business entities, port operators, customs, government agencies, etc. The development of the PCSs in Bulgarian Black Sea ports is inevitably on the right track on the basis of the already fully functioning MSW and the applicable national legal framework.

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ROLE OF PROJECT PREPARATION IN FORMATION PROFESSIONAL COMPETENCE OF FUTURE SPECIALISTS IN AGROENGINEERING

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Summary. New educational standards include significant changes in the structure, content, aims and objectives of education of Agroengineering specialists. According to this the research of the role of project preparation in the professional competence formation of future specialists in agroengineering was conducted. The results of the investigation the preparatory stages that are based on the systematic approach, which inclines four main components for making an agroengineer as a specialist be ready for project activity, are represented. Beginning at the first preparatory course the improvement of educational pedagogical technologies should be directed to the target integration of subjects with providing growth of the results at each stage - physics and mathematics, general and special. The role of physical and mathematical education and formation of general professional competence of the future agroengineers, activity and the level of teachers' influence on the project training of students was investigated.

Keywords: project training, professional competence, activity, future specialists in agricultural engineering

Introduction.

European integration development of education in Ukraine is characterized by increasing of innovational and social and humanistic components based on new scientific and informational pedagogical technologies of education. The Law of Ukraine on Higher Education [1] creates conditions for improvement of the combination of education with science and industry to prepare highly-qualified specialists, who are able to compete, for high-tech and innovative development of the country, self-identity, and meeting the needs of the labor market at the highest international standards.

Professional competence of Bachelor (major #208 "Agroengineering") includes:

- to develop rational scheme of the technological process for the specific producing conditions basing on the economic efficiency;
- to choose technical means for main and additional operations;
- to adjust parameters and modes of machines work in the technological process and technological lines;
- to develop operation maps for operations and processes accomplishment;
- to design transportation processes;
- to create technological maps of machinery repairing and restoring its pieces;
- to design equipage of the industrial zones and sites;
- to design compounds and mechanisms of machines and equipment;
- to calculate details and compounds of machines and non-standard equipment;
- to perform composite drawings of machines and equipment basing on the standard pieces, joins and machinery;
- to develop and improve the schedule of complexes, machines and equipment;
- to organize service and diagnostics of machines;
- to select materials and modes for the repairing and restoration of pieces;
- to calculate and evaluate index of exploiter of machine train in the areas of business;
- to control the quality of the mechanized operations and products;
- to determine compliance відповідність of operating modes of machines with their design features;
- to select machines and combine machine units in existing technological lines of manufacturing crop and livestock products;
- to determine the technical condition of tractors, cars and sophisticated machine units.

Prerequisites and means for solving the problem.

Brukhanova N.O. [2] investigated the designing of pedagogical training of future engineers system. Basing on the problematic research analysis she found out that training teachers of vocational schools and higher educational institutions of I and II accreditation level should be conducted during the whole

educational period. It is claimed that training of teachers should have external and internal connections due to which high level of preparation future specialists is provided. This includes spatial, temporal and informative coherence, educational and logically formed sequences and the continuity of professional and educational development. The author noted that the implementation of partial solutions is insufficient, that's why she recommended the mechanism of future teachers' complex designing of engineering basing on the system approach. Unity of systematic, activity, person-centered and competence approaches and their complex integration is in the base of the pedagogical designing offered by this scientist.

She proved that the teaching system for future specialists should be designed according to the means of integration system of activity and student-centered approach.

Project preparation as a term could be regarded in two ways:

1. as a process of making a future agroengineer be ready for project activity in Higher Educational Institution gradually;
2. as a result of professional training and the ability to implement professional competence in an actual industrial project activity.

Solution of the examined problem.

The process of gradual formation consists of four stages, which correspond to four Bachelor Degree courses and additionally one or two Master Degree courses. During the first one phasing is based on the system approach which involves four main components of formation agroengineers' readiness for project activity. They are:

- the first stage (about the first and the second year of study) is advanced Physics and Mathematics training and capacity for competent analytical thinking;
- the second stage is formation of general engineering competency and constructive abstract thinking;
- the third stage is study of special subjects based on machine designing, design of working bodies;
- the fourth stage is formation of special disciplines on exploiter, repair of technical facilities and economic components of agribusiness;
- the fifth stage is formation of the ability to research, to find the optimal technological and constructive solutions.

Beginning from the first year (the first stage) of teaching a future agroengineer in Higher Educational Institutions development of educational methodology should be directed on target integration (connection, interpenetration, converging, and formation of interrelations) of subjects with further growth due to integration processes and efficiency of each particularly and everyone generally that are influential on competence of a future specialist. To solve this problem effectively end-to-end-design technology should be imbedded into the educational process, because one of its implementation is discipline integration. Especially it concerns the theory and methodology of interdisciplinary integration in designing of continuing teaching process of agroengineer. End-to-end-design method is based on fundamental principle and vocational orientation

through target integration of physics and mathematics, basic and special disciplines. This method makes it possible to create a sequential actions system to create progressive teaching methods. Studying the Physics and Mathematics module is the base that will help students catch on basic and special disciplines, master project activity successfully.

Analysis of academic literature shows that range of authors distinguish the following stages of designing:

- a graphical object modeling;
- making schematical and calculation diagrams;
- development of constructive solutions of the product and its parts [3].

Having analyzed the process of solving practical tasks of physics and mathematics module we can claim that calculation is an important part of basic process to prepare a student for the project activity. Organization of educational methodology of training an agroengineer based on end-to-end-designing helps to sufficiently increase students' interest to study Physics and Mathematics module, and, consequently, general and special ones. Students begin to understand all the necessity and importance of knowledge from these areas for their future project activity [3].

Researches made by T.I. Shyshelova, M.P. Bazhneva, T.K. Konovalov, T.O. Pavlova show the actuality of using project method during the training specialists able to compete, for didactic scientific base of pedagogical methodology and teaching that includes consequences, forms of organization and means of education which are vital in the distinguishing efficiency and rationality of a subject, that influence on the progress and the results of educational process. Scientists mentioned above made and implemented organizational and pedagogical model of important for education projects for junior grades of Bachelor's Degree. They showed that the key to successful usage of this method is educational process to be directed on formation skill of project activity and active cooperation with teachers of special disciplines, in other words, establishment of interdisciplinary connection of physical and mathematical module, basic and special ones.

It should be noted that the method of projects was analyzed in the article "*Method of projects in the theory learning of a future agricultural engineer*" [4].

It is important to start studying elements of the method of projects from the first courses at the university, and actual manufacturing processes should become the basis for the topics of course projects. It means that the method implemented into educational process allows students to complete course and thesis projects successfully.

Themes of educational design research in the first phase are agreed with the discharging departments which enables to realize the holistic approach to vocational training of future specialists in agricultural production, provides professional orientation training after the method of breakthrough projecting. It should be noted that it is appropriate to start breakthrough projecting even among schoolchildren for the sake of vocational training of talented schools leavers (as well as that of vocational schools and colleges) to enter higher agricultural schools where they will be able to continue their projecting activities during the phased studying of program subjects.

It is important to work more actively on the formation of higher school students' project activities themes while studying the course "Introduction to Specialty" in the first semester. It is here where students can get acquainted with research themes of departments, university, regional peculiarities of the use of agricultural equipment. While in the first months of studying are students organized to develop their project activities, starting from physical and mathematical sciences unit, the tasks of breakthrough through projecting will be resolved more successfully. Shyshelov T.I., Konovalov M.P., Bazhenova T.K., Konovalov P.M., Pavlova T.O. developed, tested and organized the first phase of the professionally directed teaching physics after the method of breakthrough projecting objects of professional activity. A result, the conditions for self-creative activity of students are formed as wells as their professional competence, cooperation between teachers of related disciplines is improved, the role of motivational

factors for professional self-development of a future specialist as personality, motivational components needed to studying physics (higher mathematics, theoretical mechanics) are conceptualized for solving future professional tasks. Effective motivation is a powerful driving force and an efficient mechanism aimed at a more successful mastering of project activity stages [3].

An important role belongs to physical and mathematical education in formation of overall professional competence of future specialists in agroengineering. Educational institutions that train professionals of agroengineering in accordance with the Ministry of Education and Science of Ukraine and standards of education, that should create conditions for training highly qualified specialists, which acquire professional competences, including those associated with the project. In general, the concept of "design expertise of agroengineering" refers to the willingness and ability of graduates based on knowledge and skills, purposefully organized methodically correctly, independently [5] and also in groups [6] and teams to solve relevant issues and problems of professional project activities and evaluate the results of the generated projects.

To form the general and professional competencies of project activity, student must master a number of subjects, that are important mathematical engineering professional-professional values. Each training course is capable of making a contribution to the professional development of future specialist. An important role in this belongs to mathematics and related disciplines as universal interdisciplinary analytical system, which provides a logical, precise and objective description and study of objects and processes.

Always mathematics was important in forming the thinking style of the students, and it has not lost its meaning is important and will always be. With the transition to new educational standards, that are adapted to European and other countries with high developed economies, from the standpoint of system competence approach in education, developed pedagogical technologies of education, in which growing role belongs to improving the quality and depth of study of mathematics, as the fundamental basis of intellectual abilities and the formation of professional, including professionally-oriented competencies.

The basic physical and mathematical foundations of future specialist, taking into account of professional competences of agroengineer, which should have a graduate of university as a specialist in higher education are formed mainly on the first and second courses of studying.

During the formation of mathematical analytical system it is important to be based on the development of motivation to study of mathematics, achieved in the implementation of the educational process by teachers of physical and mathematical sciences, innovative technologies, active and interactive methods, the use of electronic educational resources are aimed at training future professional in agricultural engineering. Teachers often use play and practically oriented learning in the classroom. We use educational technologies such as working in groups of four - five students, problematic education, search and differentiated methods for studying disciplines of mathematical cycle. The University conducts annual Olympiad in mathematics and physics and other activities for students. As a result of the students activities the we form the importance of the role of mathematics in professional engineering project activity.

The key to the deep fundamental knowledge of mathematics is the first comprehensive thorough study of all sections of physical and mathematical disciplines in the educational programs, providing sufficient knowledge solving engineering and special tasks of project activities to meet the needs of training and production, and secondly, mastering skills of mathematical modeling in the field of future professional activity of graduates will be demanded in the labor market.

The fundamental mathematical training of graduates is an important component for his/her project activities, as it will promote understanding and rapid development of new techniques and technologies, their further modernization and development, introduction of new production in agriculture economically viable principles and methods of agribusiness.

Mathematical modeling skills enable maximum application of mathematical knowledge to adapt to the development of science and practice, which proves the importance of the formation of professional competence of graduate. Mathematical modeling applications in the specialty allows students to combine theoretical knowledge with their needs, makes it possible to seek ways to enhance the application of theoretical knowledge in the future specialty directly in the learning process.

Physical and mathematical knowledge develop, expand and get deeper in the study of theoretical mechanics (first - second courses Bachelor).

We formed basic mathematical tools used in almost all disciplines, aimed at developing of project activity. For example, during the performance of course project of agricultural machines the students are recommended to perform a special section "Mechanical and technological preconditions for the development and theoretical analysis of the functioning of the device". It is based on analytical relations, formulas, systems of equations conducted theoretical studies, in which set numeric value or the change of speeds, power, capacity, etc., may be necessary to determine the structural and technological parameters designing, calculating, spare parts for the strength of hardware in a complex environment, etc.

Teachers and students, who are subjects of the educational process, play an important role in pedagogical technologies of project preparation for agroengineers. Their interaction is multifactorial in nature and affects the criteria for assessing the quality of education, forming the integral, general and special competencies of the specialist in different ways. The teacher can act as a lecturer on theoretical training of specialists, the supervisor (head) of course and diploma projects, a consultant (assistant) from the features of the project activity, the moderator of project preparation and in other functional roles.

According to the scientists [7], the lecturer is the first to influence the process of project preparation of future specialists; he develops the part of calculation algorithm of the project, summarizes the literature while taking into account the regional features of agribusiness, brings to the students the overall meaning of the project work, presents a general plan for achieving the goal of the project work and the stages of its implementation. He teaches students consistently, logically and with regard to the pragmatic component, carry out the assigned tasks. Also the lecturer develops methodical support and organizes independent project work both in the form of individual and complex projects. The main control over the quality of the project preparation of future specialists remains with the lecturer, although it should be noted that the lecturer coordinates the general didactic training of specialists with the head of the department, where the process of forming future agroengineers is being conducted.

The teacher who is the project manager issues the task taking into account the initial data, teaches students to use scientific, methodical and reference literature, information training tools, develops an action plan, provides detailed information on the issues to be solved, suggests ways to solve them, etc. Thus directive behavior is specific for the project manager (Figure 1.1.).

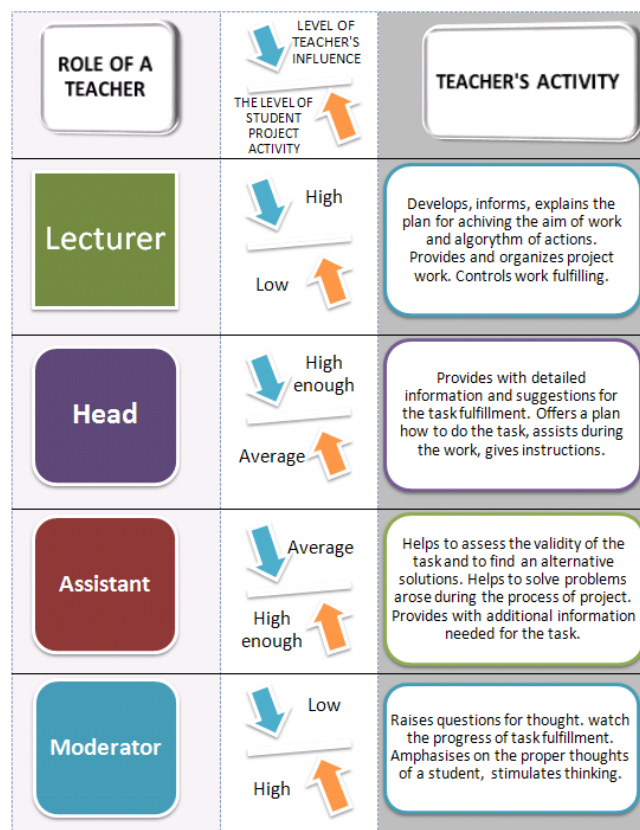


Figure 1. Role of a teacher according to the level of his influence on independent project activity of a student

In the process of project preparation of specialists, the role of the teacher-consultant is limited to helping in solving problems, finding alternatives, searching for literature sources, providing additional information on certain issues of project activities. If necessary, he helps to assess the reliability of the task and find an alternative solution to problems that are arising in the process of independent design work, and also provides additional information for the task implementation.

The teacher also can act as a moderator. He sets the overall strategic goal for students' project activities, controls the discussion and debates, develops, communicates, explains the plan for achieving the goal of the work and the course of action, raises the issue for reflection, oversees the process of accomplishing the assignment, focuses on the relevant thoughts of the student, stimulates thinking.

The role of the teacher is very important in the technological process of forming readiness for independent, individual or collective project activities of the student in the implementation of educational projects. The effectiveness of the organization, the motivation of the work of students and the success in the performance of the assignment depends on the quality work of the teacher, whether he takes into account all factors that are affecting on the result of independent work, timely and qualitatively examination of the tasks.

In higher education institutions teachers act as a consultant or, under certain conditions, a moderator in preparing students for conferences, olympiads, diploma projects, etc. During the individual preparation of students on issues of independent project work, the teacher should direct the student's activity, adjust and evaluate their work, and motivate their activities. At the same time, the teacher should require the consolidation of certain knowledge, as well as enable the student to form and express their thoughts. In other words, the role of the teacher depends on the purpose of the student's learning and the type of activity with which to achieve this goal.

Results and discussion. At the first stage of forming readiness for the project activity of the future agroengineer, it is important to ensure the development of common physical and

mathematical competencies with their integration with special competencies. The skills of the bachelor's project activity are formed gradually during 4 stages. Mathematical modeling of applied problems by specialty makes it possible to apply theoretical knowledge in practice during the production activity of a graduate of a higher agricultural educational institution. To achieve the goal, effective creative cooperation between the teacher and student is important.

Conclusion. An effective process of forming readiness for the project activity of future specialists in agroengineering is possible on the basis of innovative training technologies in accordance with the preparation program. The physico-mathematical apparatus that is formed at the first stage of training is the basis for studying practically all educational disciplines that ensure the formation of professional project competences. An experienced, educated, pedagogically trained teacher as a lecturer, supervisor (head), consultant, moderator, mentor is able to help students solve their tasks, as well as effectively manage the process of educational project activities both in the implementation of individual and complex projects. The role of the teacher depends on the set goal of learning at a certain stage. The results of the research showed that creative motivated-oriented cooperation with the use of didactic training facilities ensures the quality training of agroengineering specialists in higher educational institutions.

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AUTOMOBILE COMPRESSION IGNITION ENGINES POLLUTION

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Abstract: *The dynamic intensity in growth of the number of motor vehicles, and with that the high quantity of exhaust emissions, significantly contributes the air contamination and other serious problems with his quality, especially in urban places. Today, the total number of vehicles globally exceeds 800 million; from witch 300 million are loading freight vehicles. These numbers are disturbing, and the concern is that the constant growth of these vehicles and the consumption of the fossil fuels will continue to raise the negative effects on the environment through the air contamination and to cause serious health problems. In this document is given the analyses for the quality of exhaust emission of diesel engines, identification of the factors which have dominant affect, actual situation about pollution from diesel engines and conclusions about future use of diesel engines vehicles, especially in the countries which are not member of EU.*

Keywords: EXHAUST EMISSION, COMPRESSION IGNITION ENGINES, TOXICALLY COMPONENTS

1. Introduction

According the fact that needs for transportation are increasing, International Community (Agencies) have had effort for ecology protection, for decreasing bad impact of environment from transportation. For obtaining results which are lower than valid Euro standards, investigations for exploring all relevant factors which have had influence on the quality of exhaust emissions, like: Quality of the fuel; Quality of the lubricants; Constructive parameters of diesel engine which have had direct or indirect influence of exhaust emission quality; Regime of the vehicle exploitation; Influence of the systems which regulate fuel-air mixture and ignition process; The influence of elements and devices reliability on the engine exploitation.

With detail analysis of all factors, we can conclude that some factors have had an influence in the time of engine construction, but others are appearing and influent on the exhaust emission in the time of engine exploitation.

Old generation of Diesel engines are characteristic with smoking of exhaust gases. Besides that exhaust emissions are having more PM, which are high percent cancer-causing particles consisted.

1.1 Products of combustion of compression ignition engines

- Not combustion carbon hydrogen (CH)

In the process of combustion, carbon hydrogen are forming in the region of not burning nucleus of a jet, the fuel on the walls and post splashing part of the fuel. Molecules of CH mechanism of forming and oxidation depending of work parameters of combustion engines.

- Coefficient of surplus air - λ

Increase the ratio fuel - air has depending from the oxidation reactions on different ways. It results in long periods of splashing besides that periods and quantities staying constant, more fuel is splashing later in the cycle.

Increasing the ratio fuel - air also causes lower concentration of oxygen. Higher temperature is attaching a bit because it's burnt more fuel.

On lower loading and an empty course, we've predicted that the fuel is not arrived to the walls and that it's concentration in the nucleus is low. On this conditions not burning CH are generally from the area of not burning.

The ratio of not burning CH according to splashing fuel is the highest on an empty course, and this ratio decrease with the increasing the ratio fuel-air.

- filling up

Increasing of pressure and temperature in the cycle is filling up causing. With the same concentration of O_2 this increase is increasing the quantity of oxidation reactions and we have lower CH in the combustion products. Higher temperatures of the products of the combustion also cause longer oxidation in the exhaust branch.

- Angle of before splashing

Increasing the angle of splashing follow longer period of hiding combustion which condition creating higher quantities of vapor and lower drop will be transported with air - storm and it's broadness the area of not burning.

- storming

With increasing the storm its better the process of mixing and oxidation of CH. Exaggeration storm can negative depending producing more quantity of CH in the products of combustion, because of broadness the area of not burning.

- Carbon monoxide CO

In time of early stadiums of combustion CO is forming on the limit between the area of un-burning and before on time burning. Because the local temperatures are not enough high so it becomes low reactions of oxidation. In time of process of combustion, temperatures increase and improve this reaction.

On low loading ratio fuel - air is high because of low temperatures of gas and low oxidation reactions. With increasing the loading or with ratio fuel - air, it is decreasing emission of carbon monoxide because of higher temperature.

- Smoking

Depending of work conditions it is different kinds of smoking:

Liquid components like a white cloud of vapor on cold starting, an empty course and low loading are generally consisting from fuel and small quantity of oil for lubrication which is not burning;

Black smoke is a product of uncompleted combustion by maximum loading, remaining products, including oil for lubrication and additives of the oil. Black smoke is consisting from bigger fine parts of carbon hydrogen's. They are forming in present or absent of oxygen.

Components in the smoke also are forming from a deposit on the walls with same mechanism like in the nucleus of the jet on high loading. These components of carbon can be oxidized later in the flame formed on time of the process of combustion. Intensity of the oxidizing reactions depends from the present of oxygen near the surface of particles of ashes and from a temperature.

Parameters which depending from the intensity of smoking is:

Fuel: Investigations are showing that higher “Ceten” - number which are used for speed course transport compression ignition engines have pretended to more smoking. This can be explained with low level stability of these fuels.

Angle of earlier splashing: Earlier splashing besides rest unchangeable parameters and later splashing have decreasing smoking.

Holes on jet-makers: Dimensions of holes and ratio of their lengths have influence on smoking. Bigger diameters are slightly atomizing the fuel and smoke is bigger. Increasing the ratio l/d over the limit also has some influence.

Temperature of the air in the cylinder: Higher temperature of the air is giving higher temperature in the time of combustion and emptying which go to increase the intensity of smoking.

- Nitrogen oxide

Nitrogen oxide is forming in time of combustion on all parts of a yet. Reactions are:



NO_x is forming in the flame in bigger quantities with richer mixtures from stoichiometry, but final concentration is the biggest on little poor mixture. On concentration of NO_x have depending ratio fuel - air (Fig. 1).

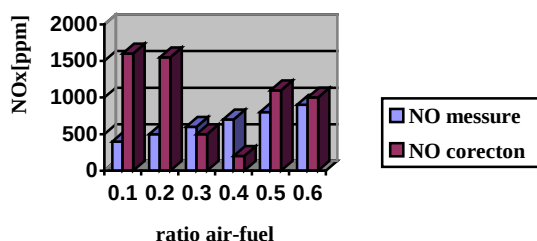


Fig. 1 NO_x concentration from the ratio of fuel-air dependence for mono-cylinder with direct splashing.

Quality of the fuel, lower "Ceten" - number, angle of before splashing (bigger angle of before splashing cause higher concentration of NO_x) and filling ups cause higher concentration of NO_x .

2. Emission standards¹

Emission standards are the legal requirements governing air pollutants released into the atmosphere. Emission standards set quantitative limits on the permissible amount of specific air pollutants that may be released from specific sources over specific timeframes. They are generally designed to achieve air quality standards and to protect human health.

European emission standards define the acceptable limits for exhaust emissions of new vehicles sold in EU and EEA member states. The emission standards are defined in a series of European Union directives staging the progressive introduction of increasingly stringent standards.

According to these standards, values are depending from these division: passenger cars (Category M*); light commercial vehicle ≤ 1305 kg reference mass (Category N₁-I); light commercial vehicles 1305–1760 kg reference mass (Category N₁-II); light commercial vehicles >1760 kg reference mass max 3500 kg (Category N₁-III & N₂); Emissions for trucks and buses (for HD Diesel Engines, g/kWh; Emissions for large goods vehicle (for category N3);

2.1 European emission standards for passenger cars (Category M*)¹

These standards are dividing depending type of vehicles; they are different for various types or categories. Polutant are from exhaust emission diesel cars which have to be measured given below.

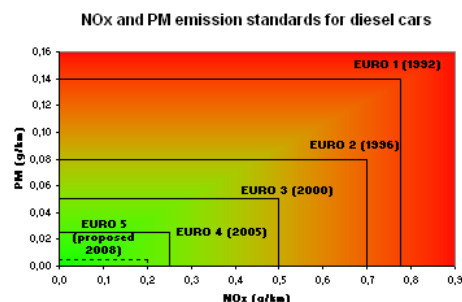


Fig. 2 Emission standards for NO_x and PM of diesel cars.

Table 1: European emission standards for passenger cars (Category M*), g/km.

Tier	Date	CO	THC	NMHC	NO _x	HC+NO _x	PM
Diesel							
Euro 1	July. 1992	2.72 (3.16)	-	-	-	0.97 (1.13)	0.14 (0.18)
Euro 2	Jan. 1996	1.0	-	-	-	0.7	0.08
Euro 3	Jan. 2000	0.64	-	-	0.50	0.56	0.05
Euro 4	Jan. 2005	0.50	-	-	0.25	0.30	0.025
Euro 5a	Sept. 2009	0.50	-	-	0.180	0.230	0.005
Euro 5b	Sept. 2011	0.50	-	-	0.180	0.230	0.005
Euro 6	Sept. 2014	0.50	-	-	0.080	0.170	0.005

3. Pollution from the diesel engines, actual situation in the Republic of Macedonia

Today, compression ignition engines are 95% of Commercial vehicles powered. Besides that, they are used for off-road equipment from construction, agricultural, warehouse and mining equipment, locomotive and marine engines and mobile and stationary generators.

Diesel has long been known for delivering power and performance along with fuel efficiency. At the United States of America is Diesel Forum web site formed for data contribution all over the world.

New developing technology of compression ignition engines must follow new European standards, which are very restricting with past compared. Significant developing is for new standards satisfying evidenced on 2014 year, but on 2015 year reduction of emissions from exhaust vehicles emission is from 88% to 96% decreasing on new “clean” technologies, and the reductions are about PM particulars and NO_x gases⁶ (Fig 3 and Fig 4).

Table 2: NO_x and PM review reduction in the period of 1988-2015 year.

Year	NO _x in grams per brake horsepower-hour [g/bHp-hr]	PM [g/bHp-hr]
1988	14,96	0,6
1991	5,64	0,25
1994	5,64	0,1
1997	5,64	0,1
2000	4,01	0,1
2003	4,01	0,1
2006	2,00	0,1
2009	2,00	0,09
2012	0,19	0,09
2015	0,15	0,09

A lot of studies all over the world are done about directions and opportunities to change diesel engines with new technology – diesel engines. So, when asked during the Congressional hearings on the VW situation about its random vehicle audit of all light-duty diesels, Chris Gundler, U.S. EPA Director of the Office of Transportation & Air Quality, replied: “I don’t have concerns with diesel technology in general. I don’t expect to find widespread problems but we are going to be taking a very close look.”

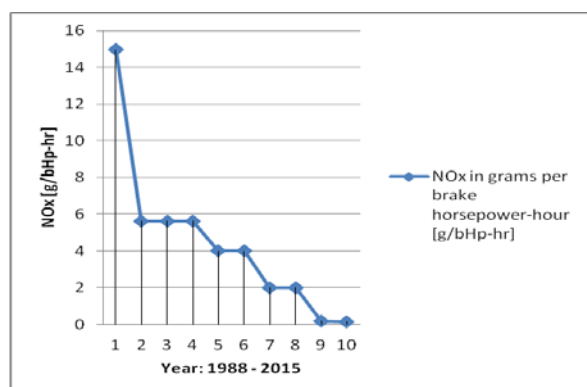


Fig.3 NO_x reduction of emissions in the period 1988-2015 year.

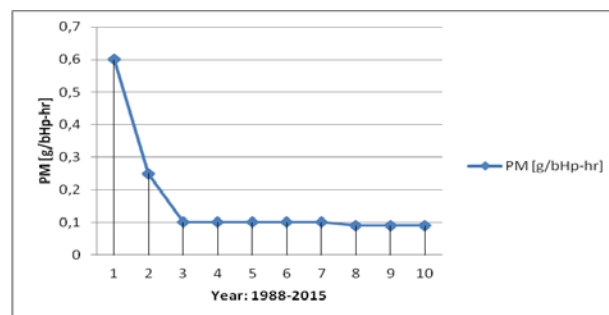


Fig.4 A PM emission reduction in the period 1988-2015 year.

In the European Union countries European emission standards are implementing, but in the European not member countries, like in Macedonia, today is very hard for emission standards implementation.

Besides with changing the Law for environment protection including additive taxes, upon year of vehicle produced, active engine volume and kind of vehicles using fuel, used M1 categories vehicles with Euro 2 standard (not produced before 1996 year) started to be imported from 5th of July 2010 year until 31 of December 2014 year. Today, the number of imported used vehicles, where in the Technical Inspection Organizations were homologation made is around 52,000 (fifty-two thousand).

From the 1st of January 2015 year, in Republic of Macedonia were started to import used vehicles with minimum Euro 3 standard and produced not later than 2000 year.

According to the low regulative connecting motor vehicles, which are correspondence of Ministry of Economy, there are not any obligations for vehicles to be installed catalyst or other ecological systems for reduction the toxicant elements of exhaust emissions. Statistical analysis of Ministry of economy at 2010 year has shown that around 55,000 used vehicles are imported (for all categories), more than 35,000 at 2011 year, around 18,000 at 2012 and 2013 year, and more than 20,000 at 2014 year. These numbers are shown big ecological problem which have to be solved next years.

4. Factors which have had most influence of the exhaust emission quality

Producers of combustion engines have had different possibilities to assent exhaust emission with low regulations. Like the most new possibilities which are applying on the last constructions of engines with internal combustion for decrease the toxicant of the exhaust emission are:

Recirculation of the exhaust gases

On compression ignition engines recirculation is more effect on direct splashing and better working on low number of rotation. With cooling the products of combustion in the system of filling are received better results.

Level of compression - ϵ

With increasing the value of ϵ we have got: decreasing a period of hide combustion and emission of carbon hydrogen's; increasing: a temperature to the end of compression, a quantity of smoke, emission of NO_x and economic of fuel consumption. Because of high temperatures of gas oxidation of carbon hydrogen's - CH we have lower them in the exhaust emission. Situation with NO_x is worse; NO_x is forming by maximum loading but CH by low loading.

With changing a dynamic angle of splashing can be received very well results. Because of bigger smoking, limit of a smoke we can move to the bigger value of ϵ decreasing the power of engine. With increasing the value of ϵ it comes to increase a tension in engine.

Level of storming in engines with internal combustion

Level of storming in engines with internal combustion is caused air moving. Destination of storming is to be prepared need energy for mixing the fuel and air to be received more homogeny mixture what will result complete combustion. Storming can be ensured with adequate construction of combustion chamber or with adequate construction of filling up line branch or by using deflectors on the filling valve.

Angle of before splashing

Decreasing the value of the angle of before splashing can be acceptable depending on decreasing NO_x on engines with internal combustion with direct or undirected splashing. It is result of decreasing the period of hide combustion and maximum temperatures in the place of combustion.

On engines with internal combustion with direct splashing smoking is increasing with decreasing the period of before on time burning (because of the smaller mixing of the fuel and air). With increasing the level of air storming we have smaller sensitive of changing the angle of before splashing, what results optimization by rest of searching.

On engines with internal combustion with undirected splashing, storming is bigger when the piston is moving to the outside limit position where the mixing of the fuel and air is the biggest, than smoking is decreasing with decreasing the angle of before splashing. But if with this work is over limit, it will not be filling, what increase CH. It is obviously that searching for decreasing NO_x and CH are opposite so we have to find optimum.

Engines with internal combustion with direct splashing have more quantities of NO_x than engines with internal combustion with undirected splashing because of a small lose of heat which is beginning with the storming.

With increasing the number of rotating of engines with internal combustion, the time for burning is smaller. To have bigger angle of before splashing, in this situation is need, for not to become increasing the emission of CH. With decreasing the load decrease fuel quality and temperature in the combustion place and because of a dangerous for skipping the burning we must move splashing forward. This two searching must be satisfied by splashing fuel equipment to have less toxicant components in the exhaust emission.

Because of a Low, regulations for air pollution, besides intensively working for declining imperfections of engines with internal combustion in look of pollution the life surrounding. It is working on investigation and perfection to the other systems for power the vehicles, like: electric (with accumulator battery), gas turbine, steam engine, etc.

5. Conclusion

New generations of Diesel engines are cleaner than ever before, and in the next few years the diesel industry will virtually eliminate key emissions associated with on and off-road diesel equipment. This environmental progress is the result of the new clean diesel system - combining clean diesel fuel, advanced engines and effective exhaust-control technology.

Refiners are working to reduce the sulfur content in diesel fuel by 97 percent. Just as taking the lead out of gasoline in the 1970s enabled a new generation of emissions control technologies that have made gasoline vehicles over 95 percent cleaner, so will removing the sulfur from diesel help usher in a new generation of clean diesel technology. By October 2006, clean diesel refiners are committed to making ultra-low sulfur fuel (ULSD) available nationwide.

Diesel is the world's most efficient internal combustion engine. It provides more power and more fuel efficiency than alternatives such as gasoline, compressed natural gas or liquefied natural gas.

Advanced new technologies such as electronic controls, common rail fuel injection, variable injection timing, improved combustion chamber configuration and turbo charging have made diesel engines cleaner, quieter and more powerful than past vehicles.

With the introduction of lower sulfur diesel fuel, a number of exhaust treatment systems can further reduce emissions from diesel engines. Particulate Traps - collect particulate matter as the exhaust gases pass through and can reduce particulate emissions by 80-90 percent using a catalytic reaction or an auxiliary heating element. Catalytic Converters - use a chemical reaction to convert emissions into harmless substances. Some catalysts - such as selective catalytic reduction (SCR) devices and NO_x absorbers - focus on nitrogen oxides and can reduce these emissions by 25-50 percent.

In nearly future, Macedonia and other countries from the Balkan must have one common Strategy for environmental protection from used motor vehicles. We have to be organized, not just formally, through our Ministries (for Ministry of Environment and Physical planning and Ministry of Economy) and to be Action plans for environmental protection made from used vehicles pollution.

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APPLICATION OF 1D SIMULATION TO OPTIMIZE PERFORMANCE AND EMISSIONS OF LARGE GAS ENGINES WITH EXHAUST GAS RECIRCULATION

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Abstract: Future emission legislation will be increasingly stringent. The current German TA Luft limit for nitric oxide (NO_x) emissions from large gas engines is 500 mg/mn³ @ 5% O₂ and there is a clear trend toward further reductions. One possible strategy to meet these limits for gas engines is exhaust gas recirculation (EGR). This paper focuses on the application of 1D simulation to a variety of different tasks in gas engine development. First, the basic effects of EGR in gas engines are explained by discussing several 1D simulation results from two 1D simulation models for a large stationary gas engine. A detailed single cylinder engine model is used to study the interaction between the pre-chamber and the main combustion chamber. The boundary conditions are provided by a multicylinder engine model that includes a turbocharger. Based on simulation calculations with both models as well as measurements from a single cylinder research engine, the thermodynamic conditions in the combustion chamber and the gas dynamics are analyzed.

Keywords: INTERNAL COMBUSTION ENGINES, 1D SIMULATION, EXHAUST GAS RECIRCULATION

1. Introduction

The trend towards high power output, higher efficiencies as well as stringent emission legislation are greatly pushing the development of large gas engines.

When a new gas engine is developed, many design parameters have to be defined and optimized in advance. The number of degrees of freedom is even higher when exhaust gas recirculation (EGR) is applied. With pre-chamber gas engines, the thermodynamic states in the pre-chamber and in the main combustion chamber have to be investigated in detail in order to ensure stable ignition and combustion. 1D simulation is a good choice that allows the demands of this kind of investigation to be met. This paper explains how 1D simulation is applied to a variety of different tasks in gas engine development with EGR.

2. Emission limits

The current trend is towards lowering emission limits for large combustion engines. As Figure 1 shows, pollutant emissions from large engines and nitric oxide emissions (NO_x) in particular are strictly regulated [1]. Whereas the current German TA Luft legislation [2] for gas engines defines the maximum nitric oxide emissions as 500 mg/m³ (norm) @ 5% O₂, the trend is towards a further reduction to 250 mg/m³ (norm) @ 5% O₂ (Gothenburg Protocol [3]) or 75 mg/m³ (norm) @ 15% O₂ (EU Directive 2010/75/EU [4]), whereas 75 mg/m³ (norm) @ 15% O₂ is equivalent to 200 mg/m³ (norm) @ 5% O₂. In certain European regions, emissions below 100 mg/m³ (norm) @ 5% O₂ are even required [5].

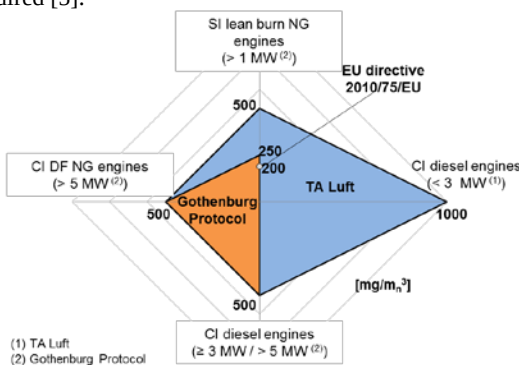


Fig. 1 NO_x emission limits for stationary gas engines in the EU.

3. Engine concepts for EGR operation

The formation rate of nitrogen oxides is controlled by the temperature in the reaction zone and the equilibrium concentrations of the relevant species. One possible strategy to reduce NO_x

emissions is exhaust gas recirculation (EGR). The mechanism of temperature reduction with EGR is caused by the increased specific heat capacity determined by the content of carbon dioxide and water in the burned gas (caloric effect) [6].

There are three main combustion concepts for gas engines used with EGR: a lean burn concept with moderate EGR (< 15%), stoichiometric combustion with EGR and a three-way catalyst, and HCCI combustion. Furthermore, the ignition system is very important to the EGR combustion concept. It must provide good inflammation and stable combustion in the cylinder. The ignition systems that are most commonly used are: open chamber with direct spark ignition, pre-chamber with spark ignition and diesel pilot ignition of the mixture. The pre-chamber variant can be a small unscavenged pre-chamber spark plug, an unscavenged pre-chamber or a scavenged pre-chamber.

The investigations in this paper focus on the stoichiometric combustion concept with pre-chamber ignition using EGR. The EGR dilutes the mixture in the cylinder so that the engine can be operated at higher loads with reduced knock tendency and low NO_x formation.

4. Application of 1D simulation to develop a new engine with EGR

The following section provides three examples of applications that use 1D simulation in the process of developing a new engine with an EGR system. First, the role of 1D simulation in the design of a single cylinder engine test bed and the determination of boundary conditions for testing is explained. Furthermore, basic investigations on the influence of pre-chamber scavenging and the influence of the scavenging pressure gradient on combustion in the pre-chamber are discussed in detail.

4.1. Design of a single cylinder test bed and determination of boundary conditions for testing

While the piping system of the single cylinder engine (SCE) test bed is being designed, it is important to adapt the gas dynamics in the intake and exhaust piping system. The objective is to achieve similar conditions in the cylinder of the SCE and the corresponding multicylinder engine (MCE). During the design phase, the measured pressure curves upstream and downstream of the cylinder head are compared using a 1D model of the SCE. The piping system of the SCE is adjusted according to these results; the engine setup and the adapted piping system on the test bed can be seen in Figure 2. To this end, satisfactory agreement between the pressure traces resulting from the gas dynamics of the 1D SCE model and the measured pressure curves from the MCE at different loads and engine speeds is found.

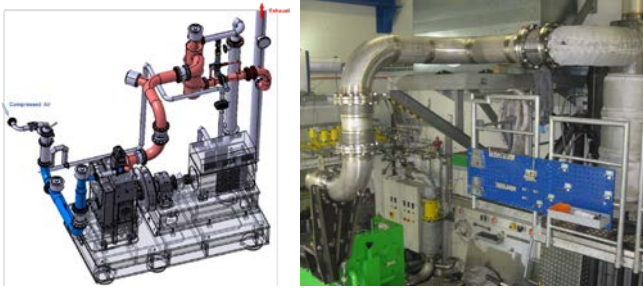


Fig. 2 Piping system of the single cylinder research engine on the LEC test bed.

For a detailed analysis of the combustion system, a 1D simulation model of the multicylinder gas engine has been used to generate the boundary conditions required for calculations with the 1D single cylinder model. The multicylinder engine is equipped with one-stage turbocharging. Its system layout is a low pressure EGR system with an EGR cooler and a back pressure flap on the exhaust side.

The 1D SCE model corresponds to the engine integrated on the test bed. Figure 3 shows the topology of the model in the commercial software package GT Power including the design of the EGR system on the test bed.

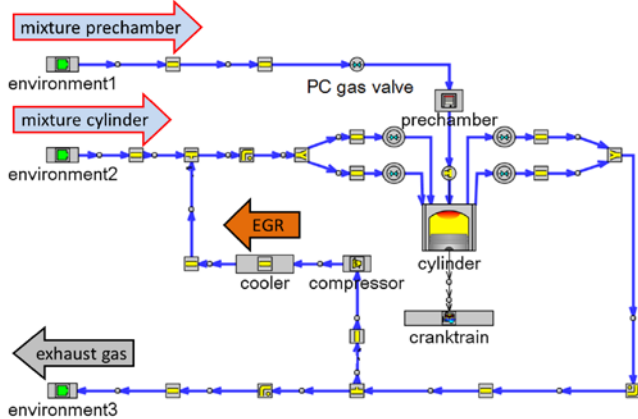


Fig. 3 Topology of the 1D model of the single cylinder research engine including the EGR system.

The challenge in developing the model is to determine the conditions in the pre-chamber as precisely as possible, therefore also the pre-chamber is depicted in the 1D model. Air and gaseous fuel is mixed in the intake system. Exhaust gas is taken from the exhaust pipe, pumped via a compressor to the desired pressure level and cooled in the heat exchanger. The recirculated exhaust gas is mixed with the fresh charge in the intake pipe upstream of the cylinder head. On the real test bed, water condensing in the EGR cooler on the test bench is removed. This part of the EGR system is not displayed in the 1D SCE model. The pre-chamber mixture flows through the gas rail and the pre-chamber gas valve.

4.2. Influence of pre-chamber scavenging

In an unscavenged pre-chamber, the mixture from the main combustion chamber is pushed into the pre-chamber during the compression stroke. Depending on the concept, a certain amount of residual gas from the previous cycle remains in the pre-chamber, thereby increasing the residual gas content in the pre-chamber at ignition timing.

With a stoichiometric combustion concept, a purely gas scavenged pre-chamber concept inevitably leads to an understoichiometric mixture in the pre-chamber in combination with EGR from the main combustion chamber [7]. Ideally, the pre-chamber is scavenged until shortly before ignition timing in order to keep the amount of residual gas in the pre-chamber low. An alternative procedure is scavenging either with pure air or $\lambda=1$ mixture without EGR at a lower pressure level. With comparatively

low system complexity, it is thus possible to lower the residual gas content in the pre-chamber at ignition timing. To demonstrate the influence of the scavenging gas and different moderate rail pressures, simulations were carried out with the 1D SCE model.

Figure 3 shows the single cylinder model used for the calculations with all the concepts. The baseline was a measuring point with a pre-chamber spark plug and about 30% EGR. A gas injector was used as a pre-chamber gas valve. The boundary conditions for pre-chamber scavenging were baseline rail pressure, baseline rail pressure +2.5bar and baseline rail pressure +7.5bar.

Figure 4 provides examples of pre-chamber gas feed flow curves with $\lambda=1$ scavenging mixture. The start of injection is derived from the calculation with baseline rail pressure and is kept constant for all variations. It is the earliest crank angle at which a positive mass flow is possible because of the pressure scavenging gradient between the rail and the pre-chamber. The end of injection can be shifted in the direction of ignition timing by increasing the rail pressure.

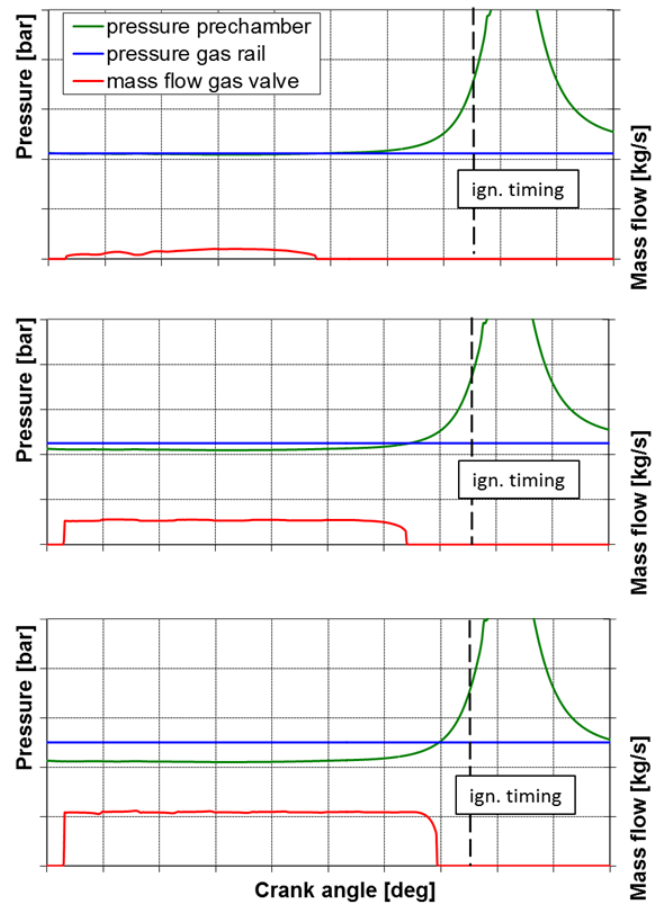


Fig. 4 Pre-chamber gas feed mass flow at different gas rail pressures.

In the unscavenged pre-chamber, the residual gas content decreases during the compression phase because a fresh mixture flows from the cylinder into the pre-chamber. In the pre-chamber scavenged with a $\lambda=1$ mixture, the residual gas fraction increases during the compression phase because the fresh mixture in the main combustion chamber contains recirculated exhaust gas. Figure 5 to Figure 7 show the simulation results with 30% EGR and pre-chamber scavenging with a stoichiometric mixture. Figure 5 contains a graph of the amount of residual gas in the pre-chamber versus crank angle. In contrast to the unscavenged baseline variant, the residual gas content can be reduced by approximately 20% points at the ignition timing with the highest rail pressure (gas rail variant 1). In comparison to the unscavenged pre-chamber, the reduction of the residual gas at the ignition timing for the scavenging variant with $\lambda=1$ and baseline rail pressure (variant 3) is only 8%.

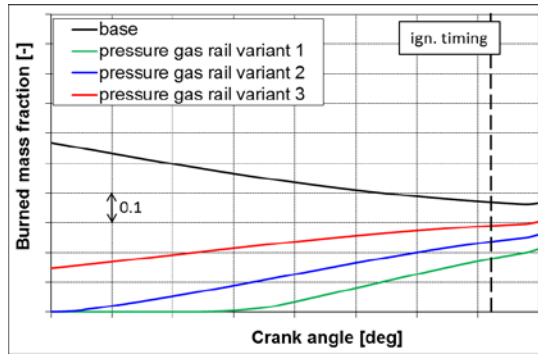


Fig. 5 Scavenging with a stoichiometric mixture: burned mass fraction in the pre-chamber at different gas rail pressures.

With the $\lambda=1$ scavenged pre-chamber, the fuel mass and thus the energy in the pre-chamber at the ignition timing can be increased, see Figure 6.

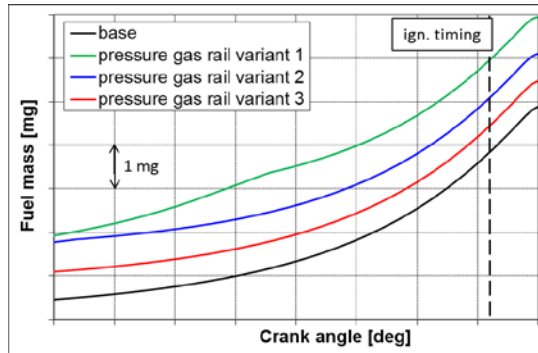


Fig. 6 Scavenging with a stoichiometric mixture: fuel mass in the pre-chamber at different gas rail pressures.

However, the temperature in the pre-chamber is lower with all the scavenging variants, see Figure 7. The temperature reduction is about 150K with the scavenging variant with $\lambda=1$ and the highest rail pressure (variant 1) in comparison to the unscavenged pre-chamber. Although there is a higher fuel mass and lower residual gas content at ignition timing, the effect of temperature reduction can impair the ignition conditions in the pre-chamber.

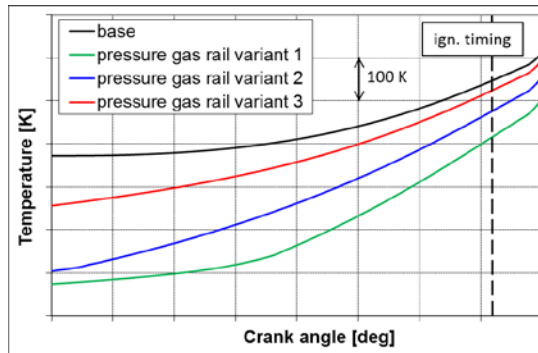


Fig. 7 Scavenging with a stoichiometric mixture: temperature in the pre-chamber at different gas rail pressures.

The effect of different scavenging gases on the conditions in the pre-chamber was also investigated. Figure 8 to Figure 11 compare the simulation results with 30% EGR and pre-chamber scavenging with methane, air and a stoichiometric mixture to those with the unscavenged baseline. The rail pressure is the same for all simulated variants and is equal to the boost pressure.

Due to the different densities of the scavenging gases, the mass flows through the pre-chamber gas rail vary, resulting in different residual gas fractions in the pre-chamber at the ignition timing. The burned mass fraction can be up to 8% points lower than that of the unscavenged pre-chamber variant, see Figure 8.

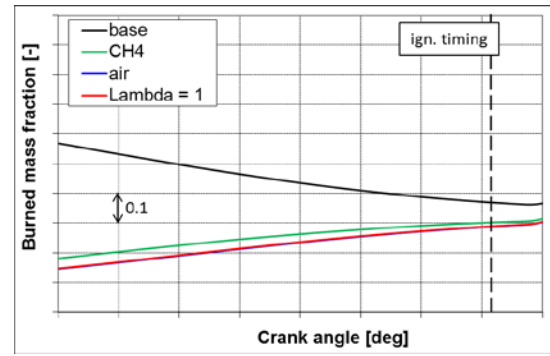


Fig. 8 Scavenging with different gases and baseline gas rail pressure: burned mass fraction in the pre-chamber.

The fuel mass and hence the energy in the pre-chamber at ignition timing increases when it is scavenged with methane, see Figure 9. A slight increase occurs even with a stoichiometric mixture. Scavenging with air leaves the fuel mass in the pre-chamber unchanged compared to the baseline variant.

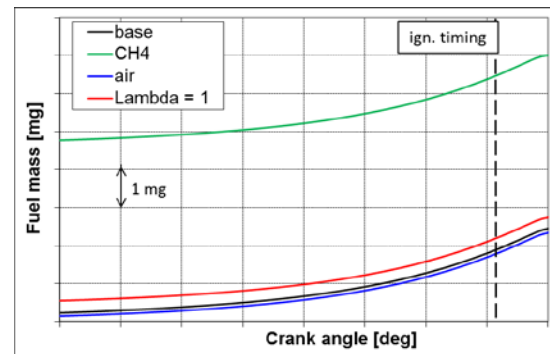


Fig. 9 Scavenging with different gases and baseline gas rail pressure: fuel mass in the pre-chamber.

Slight temperature differences in the pre-chamber at ignition timing are due to the different specific heat capacities of methane, air and $\lambda=1$ mixture. The higher specific heat capacity of methane causes the greatest reduction in temperature (50K) compared to the baseline variant, see Figure 10.

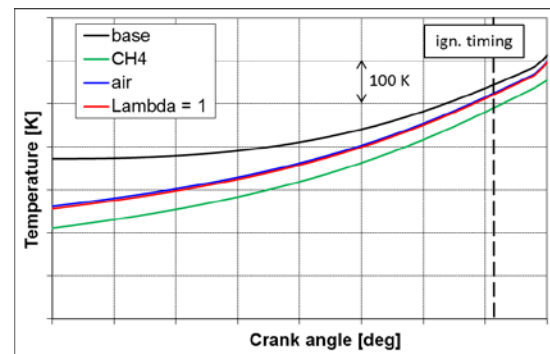


Fig. 10 Scavenging with different gases and baseline gas rail pressure: temperature in the pre-chamber.

As expected, pre-chamber scavenging with a stoichiometric mixture and the unscavenged baseline have a $\lambda=1$ mixture at ignition timing, (see Figure 11). Scavenging with air results in a higher λ value in the pre-chamber while scavenging with methane leads to a very rich mixture.

Scavenging with a stoichiometric mixture as well as scavenging with air yield similar temperatures and residual gas contents in the pre-chamber. The $\lambda=1$ mixture has a higher energy content at ignition timing.

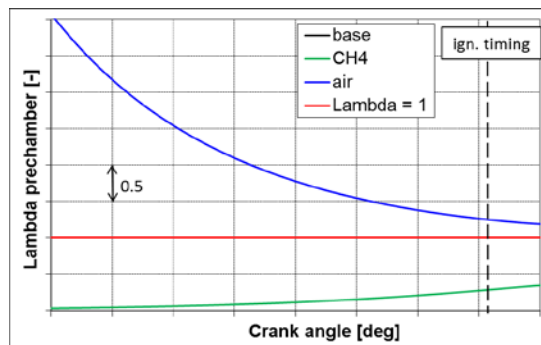


Fig. 11 Scavenging with different gases and baseline gas rail pressure: lambda in the pre-chamber.

4.3. Influence of the scavenging pressure gradient on combustion in the pre-chamber

The scavenging pressure gradient across the engine was investigated using a 1D SCE simulation model calibrated using measurements from the single cylinder research engine. These SCE measurements have shown that the scavenging pressure gradient has a clear influence on the exhaust temperature and combustion phasing. As shown in Figure 12, operating points with a variation in scavenging pressure gradient were simulated. The input parameters (burn rate, lambda, etc.) required for the simulation model were taken from the measurements. The measurements show that a high scavenging pressure gradient causes earlier combustion phasing as a result of the shorter ignition delay. The difference in ignition delay is mainly due to the states in the pre-chamber at ignition timing.

Figure 12 shows the residual gas content in the pre-chamber depending on scavenging pressure gradient.

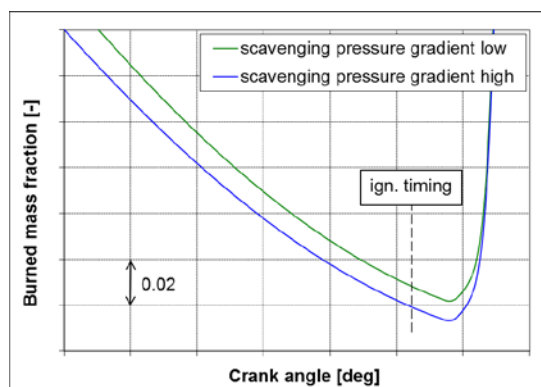


Fig. 12 Variation in the scavenging pressure gradient, burned mass fraction in the pre-chamber.

When the scavenging pressure gradient is high, the residual gas content in the pre-chamber is around 1% point lower than with a low scavenging pressure gradient. The difference between the low pressure gradient and the high pressure gradient is about 300 mbar. Since there is less residual gas mass in the pre-chamber, the fuel mass increases in the relevant crank angle range. The measurements from the SCE have shown that the scavenging pressure gradient influences the exhaust gas temperature. A higher scavenging pressure gradient results in a lower exhaust gas temperature. 1D simulation with a constant burn rate yields a reduction in exhaust gas temperature of about 12K with a high scavenging pressure gradient. The different pre-chamber scavenging concepts (including the unscavenged concept) were tested on the SCE test bench at LEC in order to evaluate them in terms of operating behavior and engine map limits. The results from the 1D simulation were confirmed. For example, the scavenged pre-chamber with a stoichiometric mixture and EGR operation leads to a greater pressure increase in the pre-chamber during combustion due to the higher fuel mass at ignition timing. As a consequence, the mixture in the main chamber burns faster.

5. Summary and Conclusions

In this paper several examples of the application of 1D simulation in the development of combustion systems for large gas engines with special focus on ignition concepts with EGR and $\lambda=1$ were shown.

The unscavenged pre-chamber ignition concept and the scavenged ignition concept were evaluated in terms of their suitability for operation with $\lambda=1$ and EGR. While experimental research was mainly conducted on a single cylinder research engine, 1D simulation was used to pre-design the concepts and to support the interpretation of the results.

Scavenged pre-chamber concepts were investigated using a 1D simulation model with a pre-chamber. The focus was on the composition of the charge in the pre-chamber at ignition timing. It turned out that the amount of residual gas in the pre-chamber is reduced when the pre-chamber is scavenged with pure air or a clean mixture ($\lambda=1$, without EGR).

The exhaust gas back pressure was reduced as a measure to reduce the exhaust gas temperature. Based on measurements on the SCE, the influence of back pressure was investigated with 1D simulation. The measurements and the 1D simulation reveal a reduction in exhaust gas temperature when the scavenging pressure gradient is increased. Measurements on the SCE test bench and results from 1D simulation show that combustion is highly sensitive to the conditions (residual gas content) in the pre-chamber. A reduction in the residual gas content in the pre-chamber of 1% point results in an earlier combustion phasing and a lower exhaust gas temperature (the scavenging pressure gradient is increased by 300mbar).

When operated with EGR, the pre-chamber scavenging concepts can be realized easily and offer benefits compared to the unscavenged variant.

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CHANGE OF EXERGY MOTION IN THE MARINE STEAM PLANT WITH MAIN SHAFT SPEED VARIATION

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Abstract: Exergy flow motion insight and analysis of plant requirements for a typical conventional LNG carrier with Rankine regenerative feed water heating steam cycle is given in this paper to clarify and distinguish auxiliary flow streams from the useful ones. Auxiliary flow supports the plant operation, but reduces exergy efficiency by certain amounts. Main boilers exergy flow streams are divided into two major groups: superheated and de-superheated flow stream consumers. A plant run test was carried out by varying main shaft revolutions to collect required thermodynamic data at various plant locations. In the presented marine steam plant is explained exergy flow streams for considering components and flow streams ratios of particular plant components. It is detected and explained the points of excessive auxiliary stream flows consumption and recommendations for possible reduction in saving auxiliary power or steam consumption are given.

Keywords: MARINE STEAM PLANT, AUXILIARY MACHINERY, EXERGY STREAM FLOWS, AUXILIARY LOAD REDUCTION

1. Introduction

Auxiliary power consumption is the power required for support plant operation and control. Stationary steam power plant auxiliary consumption was given by numerous authors, which varies with plant size. Although stationary steam power plants were wellbeing elaborated by many authors, marine steam plants have not been researched in that respect yet.

Thermal power plant auxiliary power consumption mainly varies about 5–8%, while in combined cycle power plant (CCPP) the auxiliary power consumption fall in the range of 2–5% of actual generating capacity [1]. According to ABB Ltd. Switzerland [2], auxiliary consumption of total electricity gained in thermal power plant is 6–15% of the total electricity generation, while it amounts 4–6% in nuclear power plants. EPRI [3], conducted an evidence-based analysis of internal plant usable power in the US for the fossil and nuclear generation fleet, with the conclusion that internal power need is roughly 5–10% of total power generation and that usage can vary by fuel type. Power need is also thought to vary somewhat across such parameters as age of unit, size of unit, heat rate, capacity factor and number of starts. Other variants can also include ambient temperature and cooling water temperature. Adate and Awale [4], specifies auxiliary power consumption of Indian thermal power plants, rated from less than 100 MW up to more than 500 MW as 10.31 to 6.13%.

Overview of the marine steam power plant [5] with regenerative feed water cycle analyzed in this paper is presented in Fig.1.

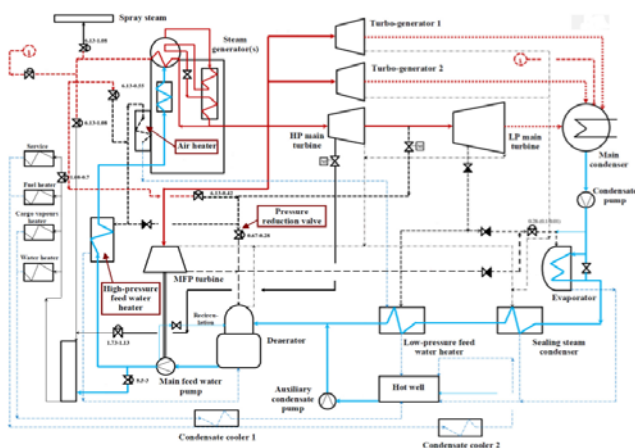


Fig.1. LNG carrier steam propulsion plant overview

2. Methodology

Although the ship's power plant is somewhat different in design from stationary power plants it may be compared with stationary cycles for the references in this study. Marine steam power plant uses regenerative feed water cycle in order to increase cycle

efficiency. For the sake of simplicity steam exergy flows may be divided into the six main groups, where the superheated exergy stream is divided into four sub streams: stream flow to the main turbine, stream flow to turbo generators No1 and No2 and stream flow to the feed pump steam turbine. Additional superheated exergy sub stream which is related to the losses is considered after main boilers outlet on the superheated steam line and is noted as an additional superheated sub stream. De superheated steam stream flow to the service is noted in opposite dashed direction from the main boilers as presented in Fig.2.

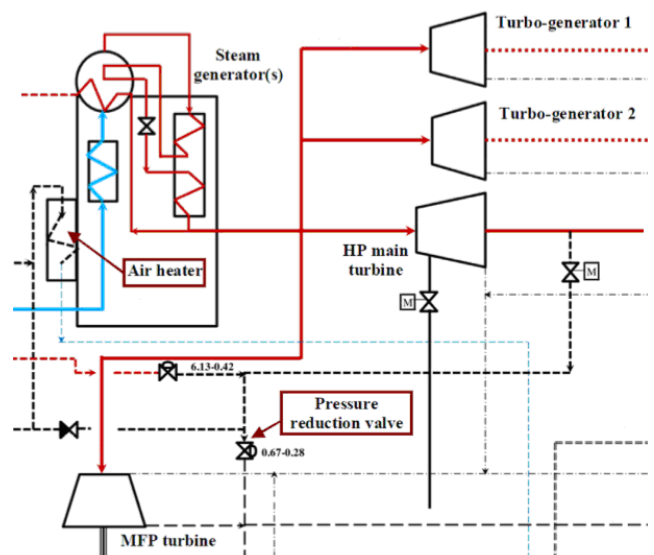


Fig.2. Exergy steam stream flows after main boilers

3. Thermodynamic analysis

Required pressures, temperatures and power for various places in the engine room were collected with standard engine measuring equipment, Table 1.

This measured data were the basis for calculating specific exergies of all steam streams. Based on specific exergies and mass stream flows were finally calculated and analyzed exergy steam flow rates. Dedicated exergy steam flows were calculated according to [6] and [7].

In the steady state process the mass balance of a control volume is:

$$\sum_{IN} \dot{m}_i = \sum_{OUT} \dot{m}_o \quad (1)$$

Table 1. Engine room measuring equipment

- Turbo generator and feed pump steam turbine inlet steam pressure	Pressure transmitter Yamatake 960A [8]
- Main propulsion turbine inlet steam pressure	
- Main boiler de superheating outlet steam pressure	
- Turbo generator and feed pump steam turbine inlet steam temperature	Temperature sensor MBT5113 [9]
- Main propulsion turbine inlet steam temperature	
- Main boiler de superheating steam outlet temperature	Thermocouple mV/I conversion module J-STP 90/95 [10]
- Main propulsion turbine shaft power	Kyma shaft power meter, Model KPM-PFS [11]
- Turbo generators power	Generator protection and power management unit HIMAP-BC [12]

The exergy balance of the control volume system is written as:

$$\sum_{IN} \dot{E}_{Xi} + \sum_k (1 - \frac{T_0}{T_k}) \cdot \dot{Q}_k = \sum_{OUT} \dot{E}_{Xo} + \dot{W} + \dot{E}_{Xd} \quad (2)$$

The exergy stream flow rate can be calculated as:

$$\dot{E}_X = \dot{m} \cdot e_X \quad (3)$$

The specific exergy is presented as:

$$e_X = (h - h_0) - T_0 \cdot (s - s_0) \quad (4)$$

Standard ambient state of marine steam plant is defined with ambient pressure and temperature:

$$p_0 = 0.1 \text{ MPa} \quad (5)$$

$$T_0 = 298 \text{ K} \quad (6)$$

Specific enthalpies and entropies of every steam flow were calculated by using measured pressures and temperatures.

Cumulative exergy flow from main boilers to all observed steam plant components can be defined with:

$$\sum ALL = \dot{m}_{MT} \cdot \varepsilon_{Xi,MT} + 2 \cdot \dot{m}_{TG} \cdot \varepsilon_{Xi,TG} + \dot{m}_{FP} \cdot \varepsilon_{Xi,FP} + \dot{m}_{SE} \cdot \varepsilon_{Xi,SE} + \dot{m}_{LO} \cdot \varepsilon_{Xi,LO} \quad (7)$$

It is important to emphasize that both turbo generators have identical mass flows and identical inlet pressures and temperatures (consequently identical inlet specific entropies).

Table 2. Exergy stream flow calculation routines

Mass flow	Exergy flow
$\dot{m}_{TG1} = \dot{m}_{TURBO \text{ GEN. NO1}}$	$\dot{E}_{X,TG1} = (\dot{m}_{TG1} \cdot e_{Xi,TG1})_{TURBO \text{ GEN. NO1}}$
$\dot{m}_{TG2} = \dot{m}_{TURBO \text{ GEN. NO2}}$	$\dot{E}_{X,TG2} = (\dot{m}_{TG2} \cdot e_{Xi,TG2})_{TURBO \text{ GEN. NO2}}$
$\dot{m}_{FP} = \dot{m}_{FEED \text{ PUMP}}$	$\dot{E}_{X,FP} = (\dot{m}_{FP} \cdot e_{Xi,FP})_{FEED \text{ PUMP}}$
$\dot{m}_{MT} = \dot{m}_{MAIN \text{ TURBINE}}$	$\dot{E}_{X,MT} = (\dot{m}_{MT} \cdot e_{Xi,MT})_{MAIN \text{ TURBINE}}$
$\dot{m}_{SE} = \dot{m}_{SERVICE \text{ STEAM}}$	$\dot{E}_{X,SE} = (\dot{m}_{SE} \cdot e_{Xi,SE})_{SERVICE \text{ STEAM}}$
$\dot{m}_{LO} = \dot{m}_{LOSSES}$	$\dot{E}_{X,LO} = (\dot{m}_{LO} \cdot e_{Xi,LO})_{LOSSES}$

Ratio of cumulative exergy flow stream distributed to the observed components is defined by the equations:

- Main turbine:

$$\dot{E}_{X,MT} = \frac{\dot{m}_{MT} \cdot e_{Xi,MT}}{\sum ALL} \cdot 100 \text{ [%]} \quad (8)$$

- Turbo generators No1 and No2:

$$\dot{E}_{X,TG1} = \frac{\dot{m}_{TG1} \cdot e_{Xi,TG1}}{\sum ALL} \cdot 100 \text{ [%]} \quad (9)$$

$$\dot{E}_{X,TG2} = \frac{\dot{m}_{TG2} \cdot e_{Xi,TG2}}{\sum ALL} \cdot 100 \text{ [%]} \quad (10)$$

- Feed pump steam turbine:

$$\dot{E}_{X,FP} = \frac{\dot{m}_{FP} \cdot e_{Xi,FP}}{\sum ALL} \cdot 100 \text{ [%]} \quad (11)$$

- Service steam:

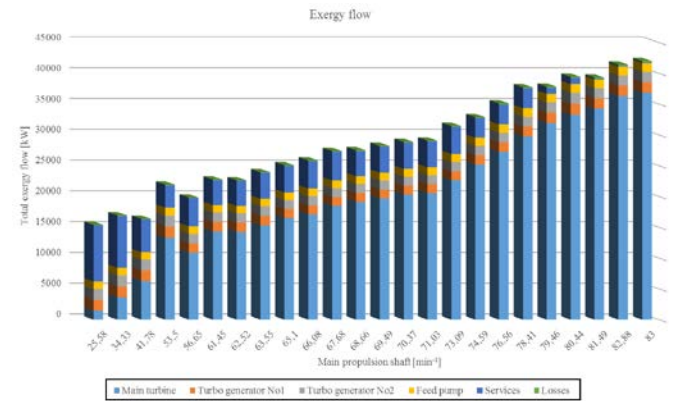
$$\dot{E}_{X,SE} = \frac{\dot{m}_{SE} \cdot e_{Xi,SE}}{\sum ALL} \cdot 100 \text{ [%]} \quad (12)$$

- Losses:

$$\dot{E}_{X,LO} = \frac{\dot{m}_{LO} \cdot e_{Xi,LO}}{\sum ALL} \cdot 100 \text{ [%]} \quad (13)$$

4. Analysis and discussion

Exergy stream flow power to dedicated directions with variation of revolutions at the ship main propulsion shaft is presented in Fig.3. On the lower propulsion shaft speeds, exergy power related to the main propulsion turbine (1445 kW at 25.58 min⁻¹) is almost negligible. With propulsion shaft speed increase, exergy power related to the main propulsion turbine (36824 kW at 83 min⁻¹) becomes an essential element in comparison with all the other exergy flow powers.

**Fig.3. Exergy flow rates under main propulsion shaft speed variation**

Exergy flow rates overview during variations of the main propulsion shaft speed to named groups and sub groups is given in Fig.4, where may be seen that on the lower propulsion shaft revolutions dominating auxiliary exergy stream flow request goes to the services, whereas the main turbine is taking the main part of the exergy flow stream at the higher propulsion shaft speeds.

Exergy flow request from the turbo generator decreases after maneuvering zone, as bow thruster is switched off. Additionally, after maneuvering zone tugs were let go along with mooring and windlass winches which are switched off as well. A further decrease

in the power request on the turbo generator units is explained by switching off the main condenser circulation pump power when the main condenser cooling system changes to scoop mode. In scoop mode the main condenser is cooled with ship's speed what has to be over 13 nautical miles in order to satisfy velocity request of sea water through main condenser.

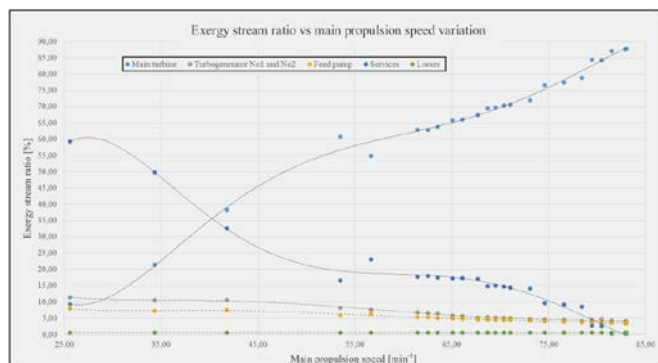


Fig.4. Exergy ratios of flow streams under speed variation at main propulsion shaft

Accordingly, at upper working ranges, close to the maximum continuous running zone of the last test point at 83 min^{-1} , the marine steam plant consumes 12.34% of the exergy flow ratio for auxiliary requirements. Feed pump steam turbine consumes 3.41% of exergy flow, while turbo generators consumes $2 \times 4.05\%$ of exergy flow, services and losses are taking less than one percent of exergy flow stream consumption in the plant, what is presented in Fig.5.

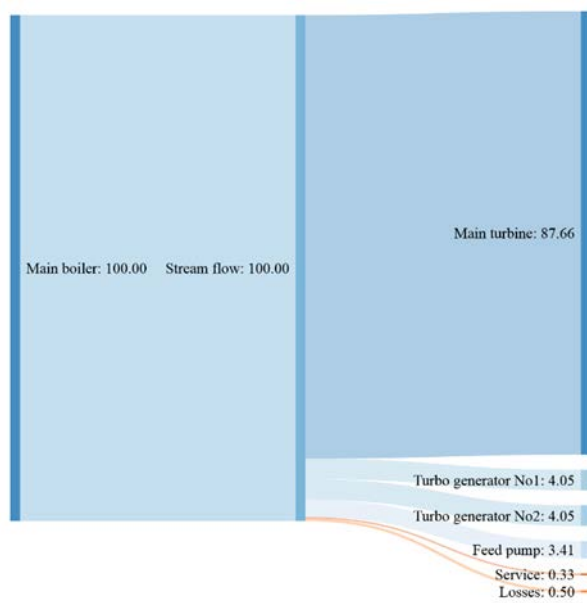


Fig.5. The exergy ratio in (%) at 83 min^{-1} of the main propulsion shaft

5. Conclusion

The analysis of auxiliary exergy power consumption of marine steam plant for conventional LNG carrier with Rankine regeneration feed water heating cycle is presented. It is found that due to safety and construction limitations, most auxiliary power are consumed at the lower operating zones of the main propulsion shaft, mainly due to manoeuvring with the vessel, where is additional electric power consumed for bow thruster propulsion and due to lower operation requirements of the main feed pump steam turbine, Fig.3. Deck auxiliary, mooring and windlass equipment is running by that time, until the captain estimates that vessel is safe for sea navigation.

Problematic consumption of the huge exergy flow portion to the service requirements at the lower propulsion shaft operating zones is due to steam dumping process, which is seen in the Fig.6. A reason behind of such a process is to avoid venting of LNG vapors to the atmosphere as methane is a far more potent greenhouse gas than is CO_2 [13], [14]. The global warming potential of methane compared to CO_2 is 105 and 33 on a mass-to-mass basis for 20 and 100 years, respectively, with an uncertainty of plus or minus 23%. Accordingly, steam dumping is useful concept from the viewpoint of greenhouse emission.

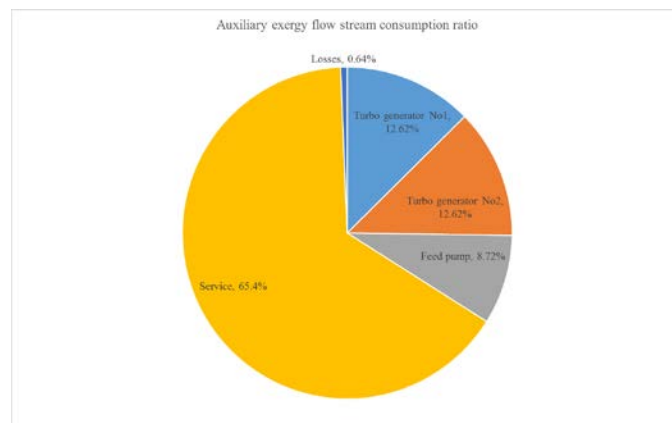


Fig.6. Exergy ratio of auxiliary requirements for marine plant at propulsion shaft speed of 25.52 min^{-1}

At higher continuous propulsion shaft revolutions, Fig.7, portion of service steam consumption is minor, due to extractions from the main turbine, which are used for regenerative feed water heating and for various system heating's. Turbo generator power in this operating zone is lower compared to manoeuvring zone, but its ratio in auxiliary consumption now dominates, what was to be expected. Unfortunately, around 28% of all exergy stream auxiliary flow in this operating zone goes to the feed pump steam turbine.

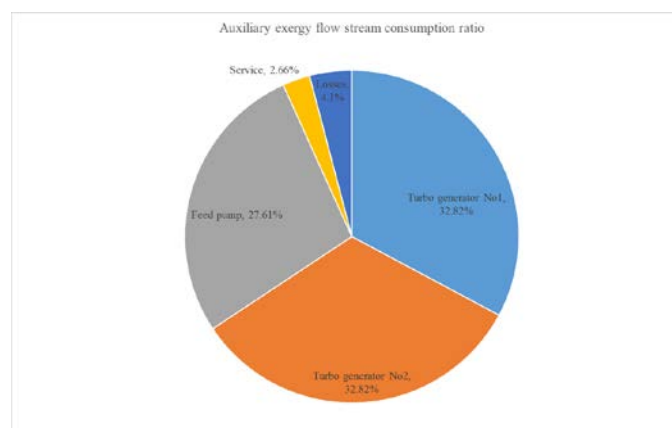


Fig.7. Exergy ratio of auxiliary requirements for marine plant at propulsion shaft speed of 83 min^{-1}

The auxiliary power consumption analysis clearly shows that the deeper and more accurate insight into auxiliary power consumption is given by the exergy flow analysis, where the quality of the flow streams is estimated and the exergy losses may be properly defined.

Comparing to stationary thermal plant, marine steam plant auxiliary consumption for conventional LNG carrier is in the range of 12% what is similar to the shore thermal plants according to ABB Ltd. Switzerland studies.

The analysis provided in this paper determines exact exergy stream flow consumption for the feed pump steam turbine, which is in the range from 7.91 to 3.41% as the power at main propulsion turbine increases.

Nomenclature

Symbols	Subscripts
$\dot{m}$ mass flow rate (kg/s)	d destruction
$\dot{E}_x$ exergy flow rate (kW)	MT main turbine
h specific enthalpy (kJ/kg)	TG turbo generator
e_x specific exergy (kJ/kg)	FP feed pump
$\dot{Q}$ heat power (kW)	SE service
$\dot{W}$ mechanical power (kW)	LO losses
s specific entropy (kJ/kg·K)	i inlet
T temperature (K)	o outlet
	k boundary temperature
	0 ambient condition

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