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FEATURES UPON CONVERTING A CONVENTIONAL CAR INTO AN ELECTRIC CAR

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Abstract: Paper deals with specifics of converting a conventional car into an electric one. The main stages of the conversion process are dealt concise but thorough. The findings are the basis for launching a large scale project with the necessary duration and financing, as a result of carrying out the necessary development activities and experiments will proceed to the development of a prototype, which will ultimately be realized. The overall focus is on research and application in the students' learning process.

KEYWORDS: MOTOR DRIVES, ELECTRIC MACHINES, TRACTION MOTORS, INDUCTION MOTORS, ENERGY CONVERSION, BATTERIES, GEARS, STEERING SYSTEMS, ELECTROHYDRAULICS, AUTOMOTIVE COMPONENTS

1. Introduction

The trend towards creating and producing environmentally friendly and energy-saving cars in the world has become irreversible. This trend is constantly accelerating by the depletion of the raw materials of liquid fuel and natural gas as well as by global warming and environmental pollution caused by the rising consumption of these raw materials. An alternative to solving this problem is the *conversion* of various models of classic cars with internal combustion engine (ICE) in electric vehicles (EV).

Conversion of conventional cars with ICE to EV is not new - conversions have been made for a long time. In short, the reason for doing so is the desire for clean and alternative moving at a lower cost. Like most things, conversions have equipment/cost levels. Incidentally, it is precisely the subject of the conversion that is the main reason for the creation of the Electric Vehicles Industrial Cluster (EVIC) 8 years ago (registration on 25th November 2009) [21].

Conversion is a aggregation of all kinds of works and activities, the necessary new technical and software tools, mounting and complete parts, assemblies and constructions, which define and perform the conversion of an automobile with an ICE in a 100% EV (electric powered vehicle). In the world there has long been a system for converting available cars into EV. For conversion, training aids have been developed, courses are being conducted, complete kits are provided for the retrofitting itself in different ways of selecting the technical means. There are options for alternating current (AC) or direct current (DC) drive system. Typically AC systems are of higher voltage and give faster performance, but they can cost 2-3 times more than a simpler and proven DC system. Each system requires a motor, controller, batteries and charger. An additional advantage is that when converting, the equipment and functions most suited to the user's needs can be selected.

Regarding vehicle efficiency, it can be said that a thorough and accurate study of the advantages and disadvantages of all types of transport vehicles is a particularly important and interesting but difficult to solve problem [7]. Numerous studies to determine the optimal spheres for the use of particular types of transport, even under certain restrictive conditions, have shown that the task is difficult to solve, not least because of lack of accurately formulated and user-friendly assessment criteria. This allows in many cases to influence the final results.

Conventional vehicles with an ICE are, as an option, cheaper to buy. But the consumables - oils, filters, belts, clutch, brake linings, antifreeze, spark plugs, etc. have to be taken into account. In EV, the only consumables are batteries (and after a considerable amount of time), brake linings, and possibly some bearings. Many of the mechanical parts in conventional cars are missing in EV - for example, they do not have an exhaust system. On the other hand, On the other hand, batteries can be a problem. In EV, normal charging up to 100% of capacity (230V AC / 8-14A) lasts 6-11 hours, and fast charging up to 80% of the capacity (400V DC / 95A)

- about 30 minutes. Most manufacturers give them a warranty of 8 years or 100000 km, and it will not be a problem and a mileage of 150000 km. The latest models feature rechargeable batteries that last up to 250000 km and even 300000 km.

Over time and increasing mileage, it is certain that batteries become increasingly worn, which has an adverse effect on the maximum range of the EV. Autoproducers do not put restrictions on the number of quick charges, but advise adherence to the slow charge at the current level of technology. There is no point in focusing so much on fast charging and long endurance, because 95% of the trips are less than 50 km long, and the urban environment is better to focus on practical solutions around homes, offices and parking lots [18].

Energy efficiency is extremely important information on the consumption of electricity from power grid to travel kilometer of the road. It is obtained as the ratio of distance traveled per unit of electricity consumed [4].

In 2009, the company "Koortech" Ltd., Varna started its activity in the retrofitting (converting) of vehicles with ICE in fully electric [23]. Several separate built-in kits have been developed, depending on the type of vehicle, desired mileage and dynamics. For the first time in Bulgaria, new generation rechargeable batteries are used. Thanks to their high energy density and low weight, converted cars justify their investment. The drive chain consists of the following elements: a drive motor, computer for controlling the drive motor (modulator), a built-in charger - DC/DC converter, an internal high voltage charging cable, an internal high voltage quick charge cable, independent cable for normal charging of the car, computer for controlling the battery.

The company Caproni PLC, Kazanlak also has a successful car conversion - Opel Corsa in this case [19].

According to some estimates, it is precisely in the conversion that a market niche can be sought for rapid realization of technological solutions.

Some reasons for conversion as a step towards electromobility are:

- No large financial resources are required.
- There will be an opportunity to collect a serious database of tests and applied innovations when installing one or more electric motors.
- Quick return on investment.
- The implementation can be based on Bulgarian products - electric motors, cable network, regulators, rechargeable batteries.

Furthermore, EV can be modularly updated. If a better engine, controller or some more efficient batteries are found, new technologies can be adapted gradually when they become available. In addition, there will be an opportunity to control the project (the converted vehicle and the selected components); as well as the ability to quickly diagnose and fix problems.

In order to make the best decisions, the requirements must first be identified.

The weight of an EV is paramount for any design, but high acceleration will dictate a type of approach to design and gear ratios, while high mileage design pushes things in a different direction.

The conversion bonus is the structure that comes with a whole body, chassis, suspension, steering and braking system, designed, developed, tested and safe, proven to work together. There is also another bonus for the body - bumpers, lights, glazed windows, etc., which are already pre-approved and tested to meet all safety requirements.

Conventional models of cars in recent years are ideal for conversion - not only because of the lower cost according to new vehicles with full depreciation, but cars with 40000 to 100000 kilometers traveled are suitable because in the vehicle the kinematic circuits, brakes and wheels / tires generate less friction (bends and edges wear, gaskets are inserted, etc.) and they roll/ turn around more easily.

When converting a conventional car into an EV, a 8-step procedure can be followed [21]:

1. Choosing a donor car and components.
2. Preparing the donor car for conversion.
3. Technological solutions for rechargeable batteries.
4. Design of the electrical system.
5. Technological solutions for component assembly and technical documentation.
6. Delivery and production of components.
7. Mechanical and electrical mounting. Tests and adjustments of the EV.
8. Preparation of documentation and registration of the EV.

After the conversion, the car should have a certificate from the Technotest JSC (independent private company with accredited testing laboratory for road vehicles) and registration in Traffic Police as an EV.

Performing preparatory work on the 8 steps listed may be the basis for launching a large-scale project with the necessary duration and funding. As a result of carrying out the necessary development activities and experiments to proceed to the production of a prototype, the latter is ultimately realized. This is also related to specialized forms of education - master's degree, engineering, professional, and so on training.

In connection with the above, there is a compliance with one thematic area of the Republic of Bulgaria's Innovation Strategy for Smart Specialization 2014-2020, as follows: Thematic area 'Mechatronics and Clean Technologies', where the following priority axis has been identified: • Clean technologies focusing on transport and energetics (storage, saving and efficient energy distribution). There is also full compliance with the Economic Strategy of Bulgaria, where as a third defined priority are laid down 'Eco and energy saving technologies' and with the first priority direction of the Strategy for development of science in Bulgaria till 2020, which is: 'Energy, energy efficiency and transport. Development of green and eco-technologies'.

2. Choosing a donor car

Firstly, a lightweight construction is required.

An important indicator for modern vehicles is the mass per unit of power, which is determined by the dependence [1]:

$$g = M/P, \quad (1)$$

where

M the mass of the vehicle, kg;

P the rated power of the vehicle, kW.

Output data are also set acceleration and desired mileage.

The converted car will be able to move both in the original version with an ICE - the same (or better, due to the high torque of the electric motors at angular speeds close to zero) acceleration and speed, but with lower mileage provided by rechargeable batteries.

The key is in simplicity. Everything that requires power from the engine is not desirable. Hydraulics and ESP are not as necessary as electric windows and seat heating. Excessive weight should also be avoided because it will cause an unnecessary load on the already heavy vehicle after putting on batteries and an electric motor.

It is necessary to pay attention to the presence of a vacuum pump that allows the braking system to function properly and this is extremely important for road safety.

It is important to say that the original gearbox plays an important role in the performance of the system and its preservation is advisable - because of the gearbox number, the motor will not be loaded too much. It is also essential to limit the revolutions of the electric motor to about 6500 rpm (despite the possibility of higher speeds) because most ICE operate within this maximum range, the transmissions are tuned to it and are highly likely to be damaged, if they have to work with the range of revolutions of the electric motors. Standard automatic gearboxes are not particularly suited to electromobility conversions because they require a number of expensive modifications to withstand the load on the electric motors.

There is a concept with which an EV can be driven by means of electromotors mounted in its wheels and this solution is really elegant. Even if this is not the most appropriate word, such a system will certainly eliminate energy-dissipating devices such as transmissions, drive shafts and differentials, which would allow for a more modular approach to propulsion and would save extra space for devices storing or producing energy [22].

An important component is the steering system. Electromechanical servo drive is appropriate. Electromechanical power steering is electrically adjustable, depending on the speed supporting steering effort, which works only when the driver needs it. This control does not include any hydraulic elements. It acts on the principle - by turning the wheel of the car, it does not spin the front axle directly, but rotates the mechanism of a machine that rotates the front axle.

Electromechanical is called because at the bottom of the steering rack there is an electric motor mounted with a control unit that boosts/drives the rake. The advantage over an electro-hydraulic power steering is that the vehicles equipped with it consume less energy in the end (the standard pump in the car always rotates with electro-hydraulic power steering).

The servo motors are equipped with speed and rotor position sensors relative to the stator. Typical of servomotors is the minimum start-up time to set revs and the minimum braking time. This means instantaneous achievement of the electronically controlled revolutions, as well as termination of the action. The torque is transmitted through a torsion shaft that is incorporated into the steering system. Electromechanical servo drive acts on the principle of current variation. For example, when turning the steering wheel, the force is transmitted through the torsion shaft. The torque sensor detects this variation and transmits it to the control electronics and the electric motor is doing this instantly.

3. Preparing the donor car for conversion

Removing the entire drive system. The engine, the radiator, the fuel tank, the starter, the exhaust system and the fuel pipes are removed from the car. Without compromising safety, the other components can also be removed to reduce weight. In addition, from a car costing only €500, you can get decent money from unnecessary components.

Somehow, the electricity has to reach the wheels, so the original transmission of the car is preserved. About the way the gearbox

engages the engine and the way it is fully attached to the chassis - because the original gearbox is mounted to the engine, and with a couple of tampons in different places holding onto the passenger compartment, removing the ICE gearbox hangs.

An adapter plate made of solid aluminum to connect the motor to the transmission has to be made. First you have to make a template and make sure that the input shaft of the transmission and the output of the electric motor will fit perfectly. You need a little welding to connect the two shafts. A toothed adapter must be mounted on each shaft, which means that the motor and the transmission will be able to connect mechanically to each other to transmit power to the wheels. A number of mechanical problems can also arise, especially in the connection between an electric motor and a transmission. If they are not well aligned, the vibrations and shaft oscillations can lead to a serious mechanical problem.

The wide variety of the practical types of EV determines the exceptional variety of traction motors [7]. They can be classified by several features, the more important of which are:

- depending on cooling: with independent, inherent or mixed ventilation or convection;
- according to the way of suspension: for immediate, bearing-axle, bearing frame or special suspension;
- according to the way of transmission of the torque from the drive motor shaft to the motor axles: for individual, group or special drive of the axles or wheels.

The traction motors can be classified according to the type and size of the supply voltage, the type of EV for which they are intended, the rated power, the degree of protection, the insulation class, etc.

Comparison of different motor design is done in [3].

At present, for the purpose of better efficiency, and due to their known advantages, mainly AC electric motors are used in EV.

Although scientist Nikola Tesla wrote and discussed the use of EV with the alternate (induction) motor until 1904. in [16], when the EV is already contained in the traffic in the United States a decade ago founded the company bearing his name, Tesla Motors, which is producing very interesting and modern sports EV.

In contemporary EV the choice of propulsion (traction) motor is not only related to the price/quality criterion. Frequently defined are the specific weight-overall dimensions indicators, as these motors have to fit in a certain volume and have satisfactory electromagnetic and mechanical performance [15].

Depending on the purpose of the EV, the maximum efficiency value of the electric motor is selected at a certain load. This is achieved at the expense of an appropriate choice of the ratio between the variable (electrical) and the constant (mechanical and magnetic) losses of the electric machine [1].

Creating an optimal custom motor for electric vehicles requires that multiple electro and mechanical components are designed and tested together as a system. All of the parameters to be optimized have to be considered simultaneously. It is necessary to account for the dynamic interactions between the components, as well as all the necessary parameters to determine optimal solutions [12].

4. Designing (preliminary) calculations

Determination of the total weight of the electric vehicle [6]

The total weight of an EV G is determined by the number of passengers using the formula:

$$G = G_0 + G_T = (1 + k_T) G_T \quad (2)$$

where

$G_0 = k_T G_T$ the own weight of an EV;

G_T the load capacity of the EV (the weight of the payload, together with the passengers and the driver);

$$k_T = \frac{G_0}{G_T} \quad \text{the coefficient of load of the EV.}$$

The load capacity of an EV is determined by the number of passenger seats through the formula:

$$G_T = G_P z + G_L \quad (3)$$

where

G_P the weight per 1 passenger, which is assumed on average at 0.75 kN;

z the number of passenger and driver seats;

G_L the luggage weight, which is taken up to 0.5 kN.

The following values can be used for EV:

$$k_T = 2.5 \div 3.5.$$

Selection of the electric motor and gear ratio of the transmission box [6]

The key to a better EV is more efficient propulsion.

The electric motor of the designed electric vehicle is selected according to the set maximum speed. The power required to ensure movement is determined by the formula:

$$P_{V_{\max}} = \frac{F_k V_{\max}}{3.6 \eta_E \eta_M} = \left(f G + k_a S \frac{V_{\max}^2}{13} \right) \frac{V_{\max}}{3.6 \eta_E \eta_M} \quad (4)$$

where

F_k motive force, N;

$V_{\max}$ set maximum speed, m/s;

η_E efficiency of the electric motor;

η_M mechanical efficiency of the transmission;

f coefficient of the movement resistivity, takes values [0.012÷0.08] depending on road conditions (pavement)

k_a coefficient of the aerodynamic drag, kNs^2/m^4 , takes values [2÷3] 10^{-4} kNs^2/m^4 ;

S front area, m^2 , takes values [1.5÷2.8] m^2 .

After selecting the electric motor, the gear ratio of the transmission box is determined by the formula:

$$i_T = \frac{\omega_N r_k}{V_{\max}} \quad (5)$$

where

ω_N rated angular speed of the electric motor, rad/s.

After determining the gear ratio of the transmission box, a check has to be carried out to overcome the maximum angle of inclination $\alpha_{\max}$, which must be set at the beginning. The check can be made by bringing the total resistance force from the path F_k to the shaft of the electric motor.

$$M_{\alpha_{\max}} = \frac{F_k}{\eta_M i_T} (f \cos \alpha_{\max} + \sin \alpha_{\max}) G. \quad (6)$$

The following condition is required

$$M_{\alpha_{\max}} < M_{\max}.$$

The last variable is the maximum torque of the electric motor shaft.

If this condition is not met, a more powerful electric motor must be used or the gear ratio to be increased at the expense of the maximum movement speed.

The following technical data are important for the electric drive of EV:

Motor Technical Data

Rated power, kW
Peak torque, Nm
Battery voltage, V (one of the preferred values is 144 V)
Nominal speed, rpm
Speed range, 0-xxxx
Efficiency, %
Insulation class, (for example F-class)
Protection (IP 54 preferred)
Cooling (natural air)
Overall dimensions: Φ and length, mm
Weight, kg

Inverter technical data

Max. Capacity, kVA
Input voltage, DCV
Output voltage, V
Current rating, A
Ambient temperature (for example -25-60°C)
Peak current, A
Efficiency, %
Protection (IP 54 preferred)
Cooling (forced air)
Weight, kg

The electric motor undergoing research in [4] and a major component in the electric drive of an EV, obtained by the conversion of Opel Corsa, is induction type with a double-cage rotor manufactured by Caproni JSC, Kazanlak [19]. This motor has the following technical data:

Purpose - electric motor for mounting on electric vehicles;
Mode of operation – continuous duty S1; Rated power: 16.5 kW;
Rated voltage: 135 VAC; Rated rotational frequency: 2600 min⁻¹;
Number of poles pairs: 2p=4; Frequency of supply voltage: 86 Hz;
Rated torque: 61 Nm; Rated current: 94.5 A; Rated efficiency: 92.5%; cos ϕ_{nom} : 0,81; Degree of protection: IP21; Insulation class: F; Weight: 104 kg; Temperature sensor: KTY84/130; Sensor bearing SKF – number of impulses 80; Battery voltage: 144 VDC.

5. Batteries and controller

The number and size of the batteries depend on the selected motor. For example, if it is for the 72 V voltage the car will need six 12 V batteries. For lithium batteries, each cell has a rated voltage of 3.2 V. Given that batteries are heavy, weight distribution is essential. It is recommended to place two-thirds of the batteries in the boot, and the others under the hood to the motor. The batteries are connected, and an electric charge plug can be placed in place of the tank cap. The location of the batteries is chosen to be charged both on the electric vehicle and on the outside, while at the same time ensuring a uniform distribution of the mass of the whole EV and achieving a fairly good center of gravity [17].

The controller is required to adjust the power from the batteries to the motor, indicating the current value in amps. It uses a potentiometer to provide electric current and power regulation. It connects to the accelerator and provides the connection between batteries and an electric motor. The prospects for controllers are in the new ways to regulate the performance of traction motors.

Depending on the size of the motor and the amperage of the controller, a single mileage can be expected with one charge when driving at normal urban speeds. The acceleration can be quite impressive, taking into account the lower total weight of the EV. However, the maximum speed is usually limited (for example up to about 100 km/h) due to the motor's rotation speed.

Parameters to check the performance of an EV are battery capacity and mileage with one charge.

Electric vehicles must be equipped with charging ports to which special cables with standardized terminals are connected. Charging is done by plugging into a standard power outlet or in a dedicated charging station (power box). Standard charging takes 4-8 hours, and there are also fast charging stations that shorten the charging time to 15-30 minutes. Also tested are wireless charging technologies where a built-in EV receiver captures an electromagnetic field emitted by a transmitter.

Besides recharging, most EV also have another source of energy: they themselves, in view of the available possibility of recuperation of electricity to the source under different conditions and modes of operation. In fact, during the speed reduction phases, the motor could function as a generator and transform the vehicle's kinetic energy into electricity that recharges the batteries. Mechanical assemblies greatly reduce the efficiency that an electric vehicle is supposed to have - which is its main advantage. And if the batteries are not charged during braking, the main advantages of this type of drive are lost. In addition, rechargeable batteries can be charged electrically by the sun, wind and other renewable energy sources [8].

Problems arise from the cost of replacing batteries at certain years. Expenditures also include worn suspension due to the increased front axle weight.

If the weight is raised above the norm, because of more batteries (to extend the mileage), the EV will not be certified by the Technotest JSC.

6. Design of the electrical system

For small currents and high voltages, much smaller losses can be achieved both in wires and batteries and in the power elements of the regulator.

Everything in an EV is subject to maximum energy savings. All lights could have LEDs, making them 11 times more economical than standard lamps, and their efficiency is the same.

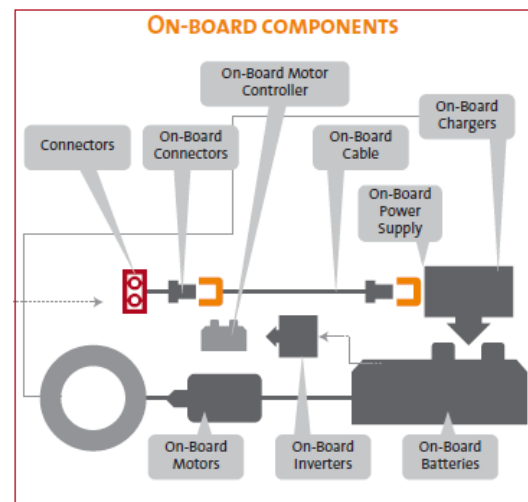


Fig. 1 EV on-board components. [14]

Battery Management System – controls through CAN interface charging, balances batteries, monitors motor speed and temperature. It shows everything on a touch screen display..

Converter - converts the relatively high voltage from the main batteries to 13.5 V for a 12 V battery charge (not always needed) to power the electrical devices in the car.

Contactors – 2 pieces contactors - to switch-off the high voltage from the main battery.

Fuses, Cables, Terminals

The power cables should pass in the shortest way (not the entire length of the car) so that the losses are not fairly large [20].

Mounting photovoltaic modules on the top of the EV.

From the perception of energy efficiency exhibitions, it can be concluded that no PV modules with a power above 50 W/m² are available. The efficiency is not high, but the price is more important. And protection from mechanical damage and theft. Apart from the cost of an investment, there is no other cost, no matter how much electricity it gets, it is still beneficial. The question here is that for every installed watt, we have to pay around €2 total costs. How long will the investment return?

7. Tests and adjustments of the EV

Full and accurate study of the advantages and disadvantages of all types of transport vehicles a particularly important and interesting but difficult to solve problem [7].

The theoretical drawings related to electric traction are of interest. Electric traction studies and investigates the forward movement of electric vehicles. In particular, it deals with the following issues: formation of motive and braking forces; forces of movement resistivity, cohesive forces and their influence on the motive and braking properties of EV, the reciprocal link between these forces and their relationship to acceleration, speed, distance gone and running time, electrical-traction characteristics of EV, methods to determine the electric energy consumption for the movement of the EV on a given area, determining the heating of the traction motors of the EV when moving on a given area, etc. [2].

The main task is to determine the variations of the starting current and voltage during the transient processes [5].

Running processes affect the change of current at a change in angular velocity ω . The presence of a controller reduces the flow of high value currents, yet their values are significant [9, 10, 11].

The starting current of the motor may result in an unacceptably high torque which may cause unacceptable accelerations of the EV and unacceptable mechanical stresses in the power kinematic transmission [13].

8. Conclusions

The results obtained could be of great practical importance when considering to start and possibly implement the EV by converting conventional car.

There is more and more talk about the benefits (and deficiencies) of electric vehicles.

By participating in the process of popularizing electric mobility in Bulgaria, we give a boost to every new step with one main goal - developing a new direction and changing the way of movement related to the realized efficiency. Because efficiency goes hand in hand with the benefits.

References

1. Balgaranov L. Electric transport, Sofia, 2009, ISBN 954-12-0103-2. (in Bulgarian)
2. Balgaranov L. Electric transport, Technical University - Sofia, 1991. (in Bulgarian)
3. David G. Dorrell; Andrew M. Knight; Mircea Popescu; Lyndon Evans; David A. Staton. Comparison of different motor design drives for hybrid electric vehicles, [Energy Conversion Congress and Exposition \(ECCE\), 2010 IEEE](#), Atlanta, GA, USA.
4. Dimitrov L., S. Rachev. Mathematical Model of Electric Vehicle with Induction Motor. National Conference with International Participation „Sliven 2014”. ‘Machinostroene i mashonoznanie’, vol. 3, 2014, pp. 41–45. (in Bulgarian)

5. Dimitrov L. Experimental study of electric starting processes of traction motor. National Conference with International Participation „Sliven 2015”. ‘Machinostroene i mashonoznanie’, vol. 3, 2015, pp. 39–42. ISSN 1312-8612. (in Bulgarian)
6. Evtimov I., R. Ivanov. Electric Vehicles. ‘Angel Kanchev University of Ruse, 2011. ISBN 978-954-712-521-6. (in Bulgarian)
7. Ganov M. Electrical Equipment of Electric Vehicles, Technical University -Sofia, 1990. (in Bulgarian)
8. James Larminie John Lowry Electric Vehicle Technology Explained Copyright © 2003 John Wiley & Sons Ltd, The Atrium, Southern Gate, Chichester, West Sussex PO19 8SQ, England ISBN 0-470-85163-5.
9. Kazakov Y.B., A. I. Tikhonov. Calculation of Traction Induction Motor Using Dynamic Model of the Field, Department of Electro Mechanics, Ivanovo State Power University named after V.I. Lenin, Ivanovo, Russian Federation, February 2010.
10. Larminie J. Electric Vehicle Technology Explained, Oxford Brookes University, Oxford, UK, 2003.
11. Liu Y., L. Xu. The Dual-Current-Loop Controlled Fed Induction Motor for EV/HEV Applications. IEEE Transactions on Energy Conversion, Vol. 27, №4, October, 1994.
12. Marc Brück ENGINEERING E-MOTORS. ANSYS ADVANTAGE, ISSUE 3/2017. Canonsburg, PA U.S.A.
13. Минков П. Електрическа тяга, София, 1992. (in Bulgarian)
14. Pauly Chris. Powering the New Generation of Electric Vehicle: Issues and Challenges, City Investment Research&Analysis, 2011. <http://www.ceres.org/resources/reports/>
15. Roderick V. N. Melnik, Ningning Song. Dynamics of Torque-Speed Profiles for Electric Vehicles and Nonlinear Models Based on Differential-Algebraic Equations, University of Southern Denmark, MCI, Faculty of Science and Engineering, Sonderborg, Denmark, 2002.
16. Tesla, N. Electric Autos, Special Correspondence. accessed 1 July 12. Manufacturers’ Record, December 29, 1904 <http://www.tfcbooks.com/tesla/>.
17. Xu Y. Optimal Distributed Charging Rate Control of Plug-In Electric Vehicles for Demand Management. IEEE Transactions on Energy Conversion, Vol. 30, №3, November 2012.
18. www.capital.bg
19. www.caproni.bg
20. www.eldrive.eu
21. www.emic-bg.org/
22. <https://evparts.alle.bg>
23. <http://koorteh.com/>

THE ANALYTICAL RESEARCH OF THE DYNAMIC LOADING EFFECT ON THE ROAD-HOLDING ABILITY CHARACTERISTIC SIGNS OF EARTH-MOVING MACHINE

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Abstract: In the process of performing of technological operations motor-graders are undergone severe loading conditions. The process of working medium development is accompanied by the action of time-varying parameters reluctances on the working equipment. At the situation of operative bodies blocking which are accompanied by intensive vehicle braking loads on working equipment are of shock character and can exceed considerably neutral layer of usual loads. Such loading can lead to the crabbing of the vehicle from projected path of motion. The developed dynamic model of earth-moving machine allows to take into consideration dynamic loads effect on the path configuration of its motion and formulate prompts to stabilize the characteristic signs of earth-moving machine road-holding ability.

Keywords: EARTH-MOVING MACHINES (EMM), MOTOR GRADER, ROAD-HOLDING ABILITY CHARACTERISTIC SIGNS, DYNAMIC LOADING, PATH OF MOTION.

1. Introduction

One of the characteristic sings of earth-moving machines (EMM) road holding ability are parameters characterising the quality of the work performed. In particular for machines realizing earth fill building one of the main parameters is a holding ability characteristic sing shoving the crabbing of operating trajectory of working unit path of motion from the projected trajectory. In the cases if EMM path of motion crabs considerably from the projected trajectory the need arises to perform additional passage ways that inevitably leads to productivity decrease and energy requirement increase. Taking into consideration the general trend in the EMM development in the direction of global automatisation of carrying out technological operations up to excluding "man-operator" from regulating system problems of pilot operation of motion path under conditions of severe external power action become burning.

Peculiar features of EMM behavioral analysis in the process of carrying out technological operations are important for investigation of algorithm designs allowing machine regulating problems turn over on-board computer.

2. Analysis of publications

The review of scientific researches devoted to the problem of road holding ability loss in the process of technological operations showed that the greatest attention to this problem is devoted by the experts in the field of transport engineering, farm machine industry and earthmoving engineering. Among them: Podrygalo M. A., Pevsner Ya. M., Farobin Ya. Ye., Litvinov A. S., Knoroz V. I., Sevrov K. T., Alekseeva T. A., Artemiev K. F., Bromberg A. A., Malinovsky Ye. Yu., Koval A. B., Dontsov I. Ye., Bulgakov V. M., Usenko M. V., Prishlyak V. M., Tsygankov T. V., Artemov N. P., Huskov V. V., Ksenevich I. P., Petrov A. B. and others.

The loss of road-holding ability of vehicles (passenger cars and trucks) is linked first of all with the phenomenon of wheels drift which is caused by its elastic deflection in lateral direction while moving on turn. The reason of road-holding ability loss become centrifugal forces emerging at vehicle curvilinear motion [1, 2]. As a characteristic signs demonstrating the given process it is recommended to consider wheels coefficient.

$$k_y = \frac{d\gamma}{d\delta}. \quad (1)$$

Or vehicle drift coefficient

$$k_y = \frac{\dot{a}}{b} \cdot \frac{R_{\delta 1}}{R_{\delta 2}}, \quad (2)$$

where γ – transversal force acting along the wheel axle;
 δ – slip angle; a, b – projection coordinates of vehicle mass center into a horizontal plane; $R_{\delta 1}, R_{\delta 2}$ – road cornering force affecting wheels of front and rear axles.

As researches show the main reasons of road-holding ability loss are transversal efforts acting on working units, knee joint deformation between operating equipment and tool carrier as well as transverse grade of seating.

As a criterion of road-holding ability the authors use usually allowable transversal deflection in relation to initial trajectory [3]. Maximum allowable values of transversal deflections are assigned depending upon the kind of the technological operation performed. To estimate the mentioned parameters dynamic models of plane motion of articulated systems are considered. Comparison of the projected trajectory with the assigned one permits to estimate vehicle transversal deflection and offer actions excluding drift from the assigned trajectory.

The peculiar feature of the total drag formation acting on the operating equipment is the main reason of the EMM drift from path of motion. One can single out here two specific situations. When operating equipment has possibility of positioning in space as for example at motor-graders the resultant vector of external resistance may be positioned asymmetrically in relation to vehicle longitude axis [4, 5]. This phenomenon causes the emerging of the additional disturbing moments capable to drift the vehicle relatively the assigned path of motion. In this case the situation of static loading is considered most often. Herewith the characteristic sign of road-holding ability is estimated by means of coefficient:

$$k = \frac{M_s}{M_d} > 1, 2, \quad (3)$$

where M_s – stabilizing moment; M_d – disturbing moment.

The situation when operating mobile equipment is installed on the machine besides static loadings it is offered to take into consideration fatigue stressing [6]. Estimation of the road-holding parameters is carried out according to dependency (3), and as a

main parameter determining the value of the stabilizing moment the coefficient of adhesion with supporting surface is applied.

All approaches considered as a rule don't take into consideration peculiar features of EMM lading, in particular motor graders, and correspondently don't determine exactly parameters value which characterise formation process of machine path of motion during technological operation realization.

The purpose and objectives

The development of motor grader motion mathematical model allowing to estimate objectively reasons of machine misalignment from initially assigned path of motion.

Factors affecting the formation of motor grader path of motion

Experimental studies carried out at the testing ground of the department of building and road machines of the Kharkiv National Automobile and Highway University allowed to single out a number of factors affecting the formation of motor grader path of motion at carrying out technological operations [7, 8, 9]. Firstly, one must stress that the motor grader path of motion is affected mostly by the peculiar features forming power pattern of machine landing namely:

- coefficient of application of resultant vector external impedances resultant vector on working equipment;
- direction of external impedances resultant vector;
- time variation character of external impedances.

All mentioned above parameters are variable and depend on type of technological operation performed and geometric parameters characterising operating unit position relatively medium developed.

For example at carrying out seating planning and profiling the expected application coordinate of external impedances vector $\sum W$ falls at blade midpoint (fig. 1, a). Soil gouging operations the point of application $\sum W$ misaligns to the blade edge (fig. 1, b).

As the resultant vector of external impedances is directed on the mitre to the machine longitudinal axis it causes the emergence of the additional lateral loading W_s and misalignment of the resultant impedances vector $\sum W$ in relation to longitudinal axis emergence of additional torques in horizontal plane. Both these factors may lead to the variation of machine path of motion.

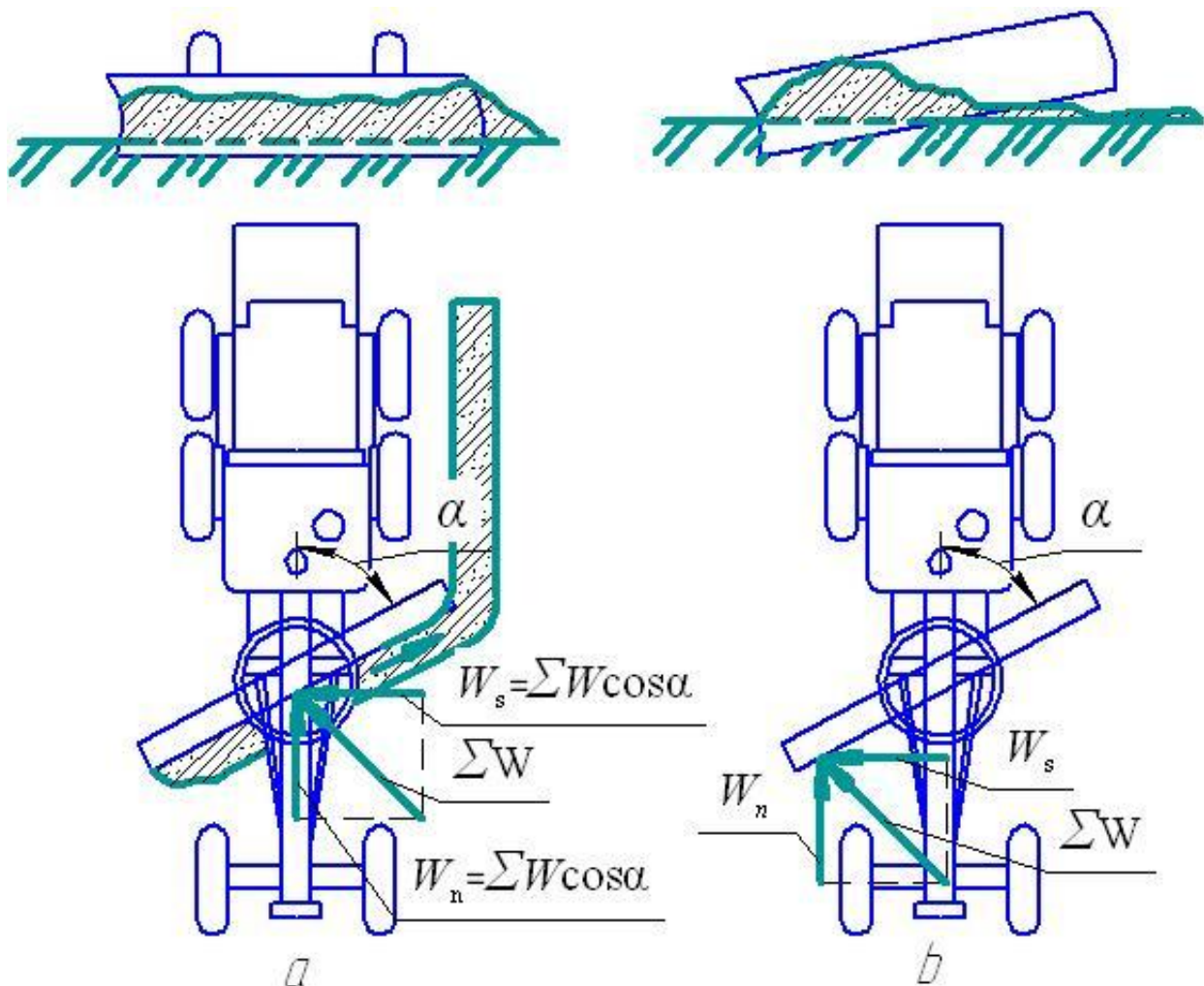


Fig.1 Application coordinate variation impedances resultant vector determining upon the type of the operation performed: a – seating planning and profiling; b – soil gouging

The performed experimental studies [7, 8] showed that in case of road cut in accordance with the scheme presented on the fig. 1, b, the possibility of misalignment of the real trajectory from the planned one will increase considerably. One must mark especially path configuration of motion which consists of linear selections.

From the physical viewpoint motor graders motion is implemented in the following way (fig. 2). At the section of AB trajectory soil gouging and formation from it the prism in front of blade. This leads to the growth of $\sum W$ values. At the point A it machine stops and simultaneously turn about the point of the blade barring

which coincides with the application coordinate of the resultant vector external impedances $\sum W$. While motor grader turning the volume of soil prisms decreases and consequently decreases the $\sum W$ value.

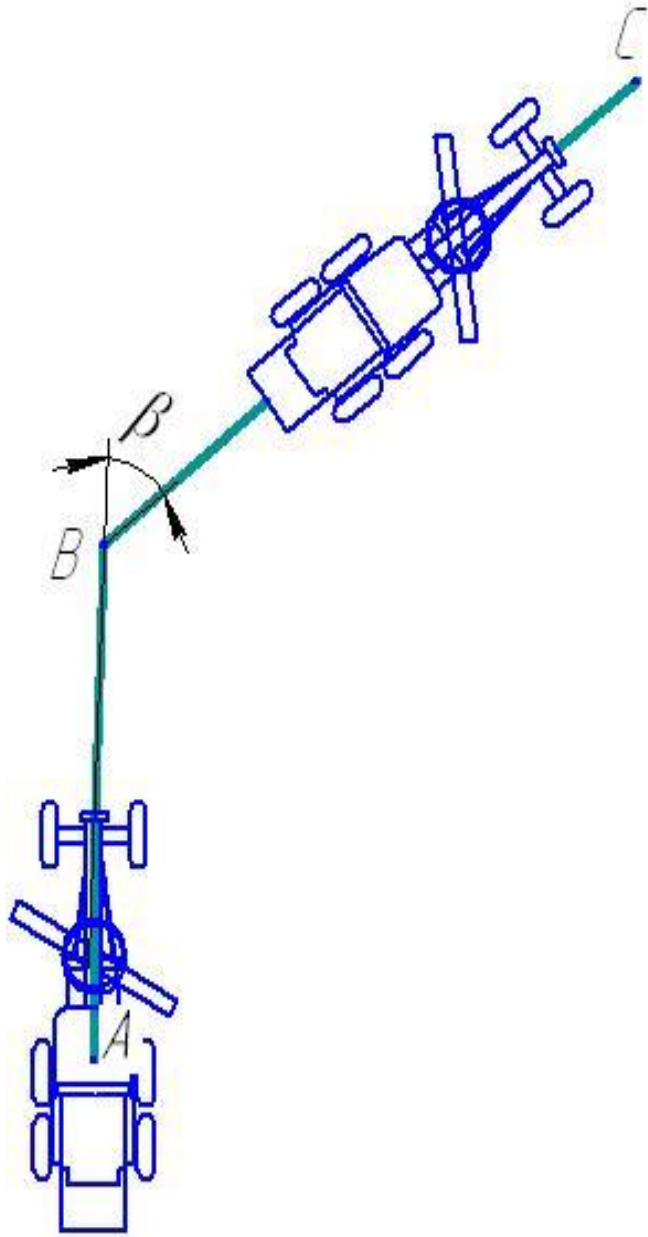


Fig.2 Motor grader path of motion

Machine turn is realized by means of wheels transversal motion. Herewith practically 100% of driving wheels spinning is registered. After turn the motor grader shifting along linear path of motion occurs. The given process may repeat further.

As the load on the operating equipment from the part of the developed medium may change in the function of motor grader misalignment for analytical studies of its path of motion it is necessary to consider the dynamic model taking into consideration the results of the experimental researches carried out.

In the process of compiling dynamic model the following simplifications were adopted:

- road cut is carried out on the horizontal location without top and side rakes;
- tractive efforts are developed by motor grader balance truck. Herewith the front axle is driven. This arrangement is characteristic for 70% of motor graders produced;

- cut soil homogeneous and possesses isotropy properties. This simplifications permits to use the determined dependencies for resistance forces description.

While developing motor grader's dynamic model the authors were coming to conclusion that the formation process of the path of motion may be described objectively by means of two different dynamic models:

1. at the initial stage of motion motor grader may be considered as the body performing plane motion along surface (fig. 3);
2. at the moment of barring operating equipment (blade) the application coordinate of resultant vector external impedances may be considered as unique point of attachment. Herewith motor grader perform rotating motion around this point (fig. 4).

Fig.3 calculation model corresponds to the plane motion of motor grader. As all the forces acting in the system are functions $x, y, \varphi, \dot{x}, \dot{y}, \dot{\varphi}$, then the path of motion can be determined in terms of shell's equation [10, 11]:

$$\begin{cases} m\ddot{x}_c = \sum_{k=1}^n F_{kx}^e \\ m\ddot{y}_c = \sum_{k=1}^n F_{ky}^e \\ m\ddot{\varphi}_c = \sum_{k=1}^m m_c(F_{kx}^e) \end{cases} \quad (4),$$

where m - motor grader's mass; y_c - motor grader inertia about axis passing over its mass center C; $\sum_{k=1}^n F_{kx}^e$ - the sums of projections of all external forces on the axis Ox; $\sum_{k=1}^n F_{ky}^e$ - the sums of projections of all external forces on the axis Oy; $\sum_{k=1}^m m_c(F_{kx}^e)$ - the sums of torques of all external forces in relation to C.

So, to describe path of motion three generic coordinates are used: misalignment along axis x, y and turn φ around machine mass center.

We receive the following system of the second power differential equations:

$$\begin{cases} m\ddot{x}_c = (T_1 + T_2 - W_{f1} - W_{f2} - W_n - W_{fn}) \cdot \cos(\varphi_0 + \varphi) - (P_{a1} + P_{a2} + W_s - P_{an}) \cdot \sin(\varphi_0 + \varphi) \\ m\ddot{y}_c = (T_1 + T_2 - W_{f1} - W_{f2} - W_n - W_{fn}) \cdot \sin(\varphi_0 + \varphi) + (P_{a1} + P_{a2} + W_s - P_{an}) \cdot \cos(\varphi_0 + \varphi) \\ m\ddot{\varphi}_c = (-T_1 + T_2 + W_{f1} - W_{f2}) \cdot \frac{l_a}{2} - (P_{a1} + P_{a2}) \cdot l_1 + W_s \cdot l_2 + W_n \cdot l_3 - P_{an} \cdot l_3 \end{cases} \quad (5),$$

where T_1, T_2 - tractive efforts developed by right and left sides correspondently; W_{f1}, W_{f2} - the forces resisting the rolling of the right and left balance truck; W_{fn} - the forces resisting the rolling of the front axle wheels; P_{a1}, P_{a2}, P_{an} - the forces resisting the skidding of the right and left balance truck wheels as well as front axle; φ_0 - start angle of motor grader longitudinal axis.

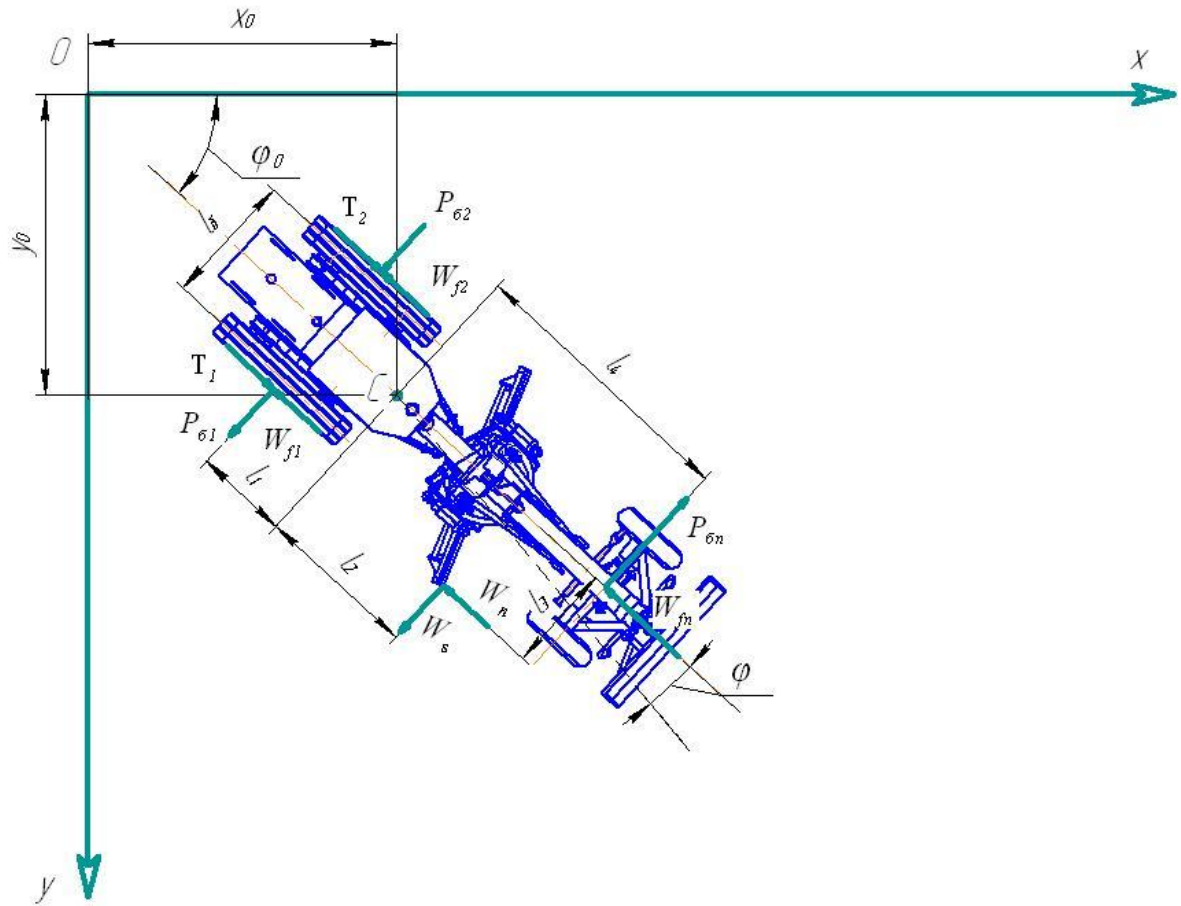


Fig.3 Calculation model for the case of motor grader motion at the initial stage.

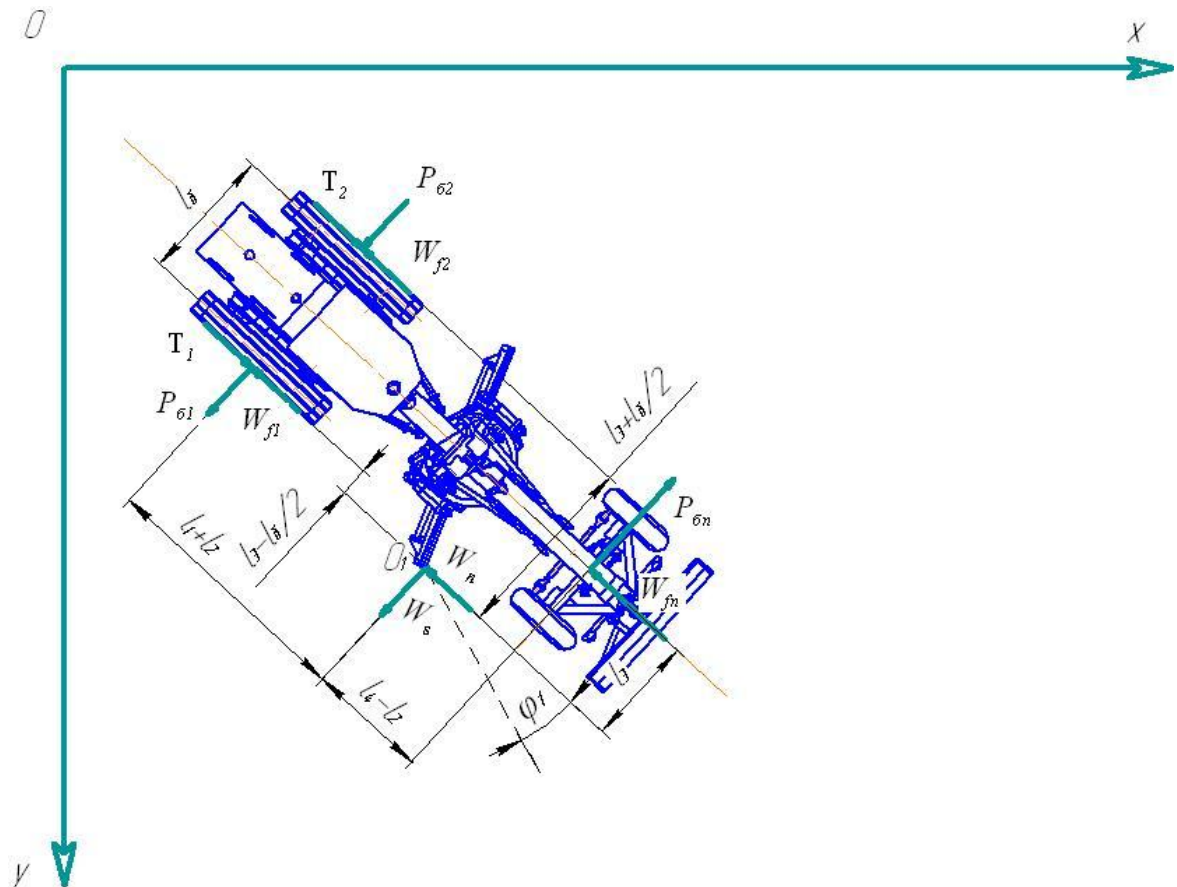


Fig.4 Calculation model for the second stage of motor grader motion (turn around O_1)

At the second stage of motion while crossing over motor grader in the 100% mode of skidding the turn of machine in relation to blade O_1 blocking point may start. In this case the equation of motion is described by the equation:

$$I_{O_1} \cdot \ddot{\varphi}_1 = \sum_{k=1}^m m_{O_1} (F_k^e), \quad (6)$$

Or after transformations

$$\left[I_c + m \cdot \left(\frac{l_a^2}{4} + l_2^2 \right) \right] \cdot \ddot{\varphi}_1 = (T_1 - W_{f1}) \cdot \left(l_3 - \frac{l_a}{2} \right) + (T_2 - W_{f2}) \cdot \left(l_3 - \frac{l_a}{2} \right) - (P_{a1} + P_{a2}) \cdot (l_1 + l_2) - P_{an} \cdot (l_4 + l_2) - W_{fn} \cdot l_3 \quad (7).$$

Transition from equations system (5) to the dependence (7) occurs in the case when the total force of traction $\sum T = T_1 + T_2$ will be equal tractive force according to the conditions of greater wheeled move with s.

Each of the forces compelling equations (5) and (7) depends upon are the velocity or motor grader acceleration [12]. In the process in machine motions this parameters will change. In the context of problem decide sold by us the estimations of the possibility of misalignment of the motor grader real path of motions from the planned one remains current.

The study cases of the comp roost dynamic models to needs to put down the conditions of motor grader road-holding ability loss:

at the first stage of motion

$$k_1 = \frac{T_1 \cdot \frac{l_a}{2} + W_{f2} \cdot \frac{l_a}{2} + (P_{a1} + P_{a2}) \cdot l_1 + P_{an} \cdot l_4}{T_2 \cdot \frac{l_a}{2} + W_{f1} \cdot \frac{l_a}{2} + W_n \cdot l_3 + W_s \cdot l_2} \leq 1; \quad (8)$$

at the second stage of motion

$$k_2 = \frac{(P_{a1} + P_{a2}) \cdot (l_1 + l_2) + W_{f1} \cdot \left(l_3 - \frac{l_a}{2} \right) + W_{f2} \cdot \left(l_3 + \frac{l_a}{2} \right) + P_{an} \cdot (l_4 - l_2) + W_{fn} \cdot l_3}{\left[I_c + m \cdot \left(\frac{l_a^2}{4} + l_2^2 \right) \right] \cdot \ddot{\varphi}_1 + T_1 \cdot \left(l_3 - \frac{l_a}{2} \right) + T_2 \cdot \left(l_3 + \frac{l_a}{2} \right)} \leq 1; \quad (9)$$

As causations when wraith wield performed technological operating by the motor grader it is necessary to carry out their recalculation during the whole operating period.

Conclusions

In terms of the carried out researches one can conclusions:

1. For the period of technological operating realization motor graders path of motion can be described by means of two dynamic models: plane motion of machine in the surface plane and rotary motion in relation to blade blocking point;

2. The calculus of the numerical values of motion stability coefficient k_1 and k_2 permits on the basis of analytical calculation determine if would occur the misalignment of motor grader real path of motion from planned one

References

1. Устойчивость колесных машин при заносе и способы ее повышения / [Подригало М.А., Волков В.П., Доброгорский М.В., Степанов В.Ю.]. – Харьков: Изд-во ХНАДУ, 2006. – 335 с.
2. Литвинов А.С. Автомобиль: Теория эксплуатационных свойств [учебник для вузов]/Литвинов А. С, Фаробин Я.Е — М.: Машиностроение, 1989. – 240 с.
3. Артемов Н.П. Повышение устойчивости движения пихотного агрегата при изменении технических параметров системы управления : автореф. дис. на здобуття наук. ступеня канд. техн. наук : спец. 05.05.11 «Машины и средства механизации сельскохозяйственного производства» / Н.П. Артемов. – Х., 2006. – 179 с.
4. Севров К.П. Автогрейдеры. Конструкции, теория, расчет / К.П. Севров, Б.В. Горячко, А.А. Покровский. – М. – Машиностроение, 1970. – С. 95–121
5. Дорожные машины. Машины для земляных работ / [Алексеева Т.В., Артемьев К.А., Бромберг А.А. и др.]; [Изд. 3-е, перераб. и доп.]. — М.: Машиностроение, 1972. — 504с.
6. Коваль А.Б. Визначення умов забезпечення курсової стійкості універсальних землерийних машин : автореф. дис. на здобуття наук. ступеня канд. техн. наук : спец. 05.05.04 «Машины для земляних, дорожніх і лісотехнічних робіт» / А.Б. Коваль. – Дніпропетровськ, 2014. – 21 с.
7. Чаплыгина А.М. Экспериментальное оценка показателей курсовой устойчивости автогрейдера/ А.М Чаплыгина // Вестник НУВГП. – Рівне: Изд-во НУВГП, 2015. – № 2(70) – С. 342 – 353.
8. Chaplygina O. Methods to determine measures providing a motor-grader road-holding ability/ O. Chaplygina, V. Shevchenko, Zh. Beztsennaya // "Machines, Technologies, Materials "INTERNATIONAL JOURNAL, issue 12/2015, ISSN 1313-0226 – Sofia, Bulgaria: Publisher scientific technical union of mechanical engineering, 2015 p.78-83
9. Chaplygina A.M. Road-holding ability of the motor grader in the process of performing work operations / A.M.Chaplygina, V.O.Shevchenko, Zh.P. Beztsennaya // VIII International Conference. Heavy Machinery-HM 2014 Proceedings – Zlatibor, 2014 – С. 59–67.
10. Курс теоретической механики. Том 2. Динамика (2-е издание). / [Бутенин Н.В., Лунц Я.Л., Меркин Д.Р.] – М.: Наука. Физматлит, 1979. – 544 с.
11. Бать М. И. Теоретическая механика в примерах и задачах: в 3 т./ М. И. Бать, Г.Ю Джанелидзе., А.С. Кельзон/. Изд. 9. – М.: Наука, 1990. -1309 с.
12. Shevchenko V. The analitical research of the process of forming the motor-grader motion path at implementation of working operations / V. Shevchenko, A. Chaplygina, Zh. Beztsennaya // International scientific journal trans & motauto world, issue 2/2017, ISSN 2367-8399 – Scientific technical union of mechanical engineering industry-4.0, Sofia, Bulgaria, 2017 – С. 81–84.

DESIGN AND ANALYSIS OF THE PROTECTIVE STRUCTURE OF AN INTERCITY BUS DURING A ROLLOVER ACCIDENT

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Abstract: Vehicles, such as buses which are massive and have a very high centre of gravity, they have a lower resistance to overturning than other vehicles. The studies have shown that deformations can especially occur in the body structure. Some deformations that can occur in carrier elements during an accident make the vehicle a vital danger area for drivers and passengers. The aim of this study is to examine the protection of the passengers in the bus by means of constructive developments to be made within the body structure. ECE R66 legal regulations which are issued by the European Union (EU) and (Economic Commission for Europe Regulation 66- Provisions on the Approval of Major Passenger Vehicles for Resistance to the Construction of the Skeleton) for the buses were developed to protect passengers' habitats in overturning accidents. This work focuses to reach constructive solutions for costing, manufacturing and, safety which provided conditions for the body structure during rollover behaviour of the vehicle. Computer simulations and analysis have been performed to examine the strength of the cross-section of the body structure. The methods specified in the standard for calculating the rollover behaviour of the vehicle have been implemented and concluded. The results obtained from all these analyses produced constructive solutions and optimizations for the design of intercity buses.

Keywords: BUSES, ROLLOVER, ECE R66, DESIGN OPTIMIZATION

1. Introduction

The fact that they have a large mass and that the center of gravity is located at a very high point on the ground significantly reduces the resistance of the buses and similar vehicles against overturning. Especially considering that buses are used for passenger transportation, it is seen that the loss of life and the amount of damage that can happen in case of a possible accident are quite high. Turkey Statistics Institute (TUIK) when the road traffic accident statistics are examined, it emerges outstanding data related accidents. For example, in 2013, a total of 1207354 casualties lost 3685 people's lives and 274829 people were injured. When we look at the distribution of these accidents by vehicle types, it emerges that 7230 of them were built by buses [1]. Tipping accidents usually take place in the form of step / roll. The wheel interrupts the lateral forces that interact with the object to create the stage, causing it to roll on the axis of that object. Sidewalk edges, ramps, contact with stones make up 90% of the overturns in this category [2]. It may, however, follow an accident such as a frontal collision [3].

In this study, a study was carried out to contribute to the protection of the passengers in a bus by means of constructive developments to be carried out in the body in case of an accident that occurred during the overturning and overturning of these conditions. The carrying elements of the vehicles were subjected to the overturning test specified in the legal regulation by simulation and various reinforcements were made in the sidewall columns, ceiling width wraps, and infrastructural connections in order to provide the determined living area in the calculation.

2. ECE R66 STANDARD AND DESIGN REQUIRMENTS

ECE R66 regulation was first published by the United Nations Economic Commission for Europe in 1986, with the aim of preventing the consequences of overturning and protecting the living area of passengers. Many countries take the bus rollover test as a mandatory certification program of the imported bus, requiring the superstructure of the bus have sufficient strength [4]. The ECE R66 regulation has been issued to prevent the consequences of overturning and to protect the living space of passengers and offers five ways to detect the superstructure strength when the bus rollovers: (1) rollover test; (2) rollover test using body sections; (3) quasi-static loading test of body sections; (4) quasi-static calculation based on testing of components; (5) computer simulation of rollover test of complete vehicles [4].

ECE-R66-02, It entered into force on August 19, 2010. The scope has been expanded to include minibuses (M2). Application to other vehicles in the M2 and M3 categories (e.g. double-decker bus) is optional. The requirements of R 66-01 apply. Valid from 9 November 2017 for all vehicles on transit in the class specified in this standard. TSE ECE R66 was issued by TSE (Turkish Standards Institute) on 01.01.1996 and TSE ECE R 66

(Revision 1) on 31.12.2008 issued the "Provisions on approval of large passenger vehicles on the strength of skeleton structure" standards. However, these standards were removal on 10.08.2016.

Requirements of ECE R66

"The worst situation case" describes the type of vehicle that at least fulfills the ECE R 66 requirements for superstructure strength within a vehicle type. The three parameters that define the worst case are structural strength, reference energy, and residual space. "Empty vehicle mass" (M_k) is the mass calculated with the weight of the vehicle in addition to the empty weight of 75 kg, weight of the fuel tank when 90% full, refrigerant gas, oil, spare wheel if the vehicle is used. For "total vehicle mass" (M_t) passenger and hostess weights are added to empty vehicle weight. The weight of the seated passengers is assumed to be 34 kg, the weight of the standing passengers is 68 kg, assuming that the seats are connected with the seat belt.

$$E_R = M \cdot g \cdot h_1 = M \cdot g [0.8 + \sqrt{h_0^2 + (B \pm t)^2}] \quad (1)$$

The reference energy is calculated as follows; Figure 1 shows the starting position of the vehicle, the moment it begins to topple, and the positions of the final center of gravity. The parameters to be used in the reference energy calculation are again shown on Figure 1.

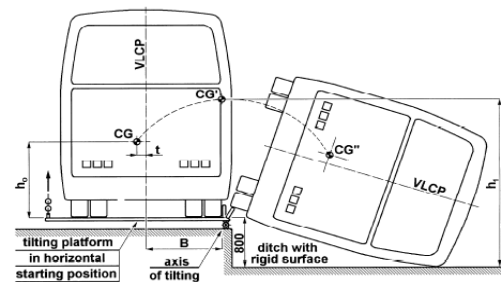


Fig. 1 The centre of gravity positions for rollover test in ECE R66 [4].

The application methods specified in the standard to calculate the rollover behavior of the vehicle are as follows (Figure 2). Basic approval method: Overturn of a completed vehicle under specified conditions and evaluation of the results. Equivalent validation method: Tilt test on trunk section, semi-static loading test on trunk section, semi-static calculation based on component tests, numerical simulation based on roll-over test the vehicle is placed on the tipping stand with the suspensions removed and slowly rotated to the axis of rotation of the stand until the equilibrium equilibrium point. The test begins with zero angular velocity at the equilibrium point and the rotation axis will be the wheel ground touch point. The energy of this vehicle is reference energy given in Eq. 1. The car is tilted to a dry and flat concrete floor over a step of 800 mm height.



Fig. 2 Rollover test of a passenger bus.

3. MODELING AND ANALYSIS OF THE STRUCTURE

The precise criterion for meeting the standard requirements is the protection of the criterion habitat. At this point; during the change of shape the bus superstructure carrier elements should be checked to see if they are attempting to this area which protects the passengers. The living area is defined between two boundary points (Figure 3). Reference point for these boundary points; the intersection of the inner surface of the side wall and the floor. The upper and lower limit points are determined from this reference point.

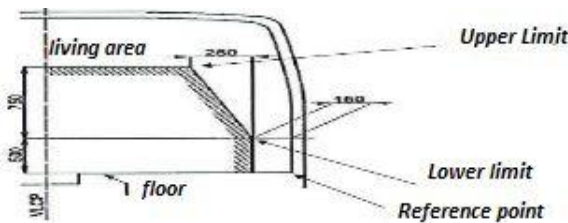


Fig. 3 Living area.

During the pre-processing fillets and small holes have been deleted in the modeling program (Catia and Siemens NX). After the profiles' middle surfaces were created, weld relationships were modeled, material and thickness information were processed and converted to model "step" (*.stp) file format (Figure 4). LS-DYNA was used to analyze the structure.

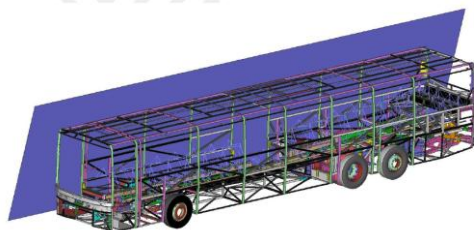


Fig. 4 A model of a three-axle interurban vehicle.

The same outer contour and the same loading direction but different constructions. In the following figures (Figure 5), three comparative examples are shown.

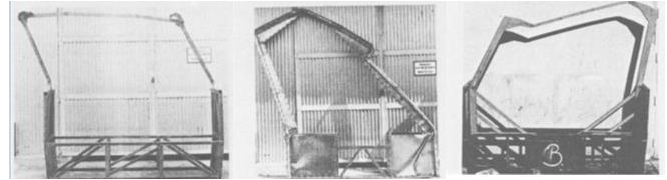


Fig. 5 Different profiles of structures after rollover.

The deformations determined in the reference model simulation are shown in Figure 6.

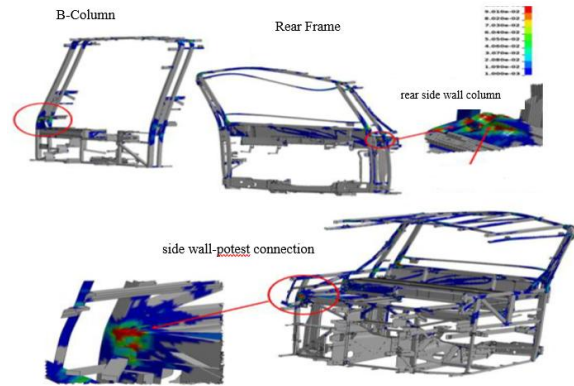


Fig. 6 Structure deformations.

4. RESULTS AND DISCUSSION

The main goal of the work is to reach constructive solutions for cost, weight and production optimizations, ensuring safety conditions within the body. Modeling is done in computer environment by using the data obtained from experimental studies focused on section and weight optimization. The methods specified in the standard were applied and finalized to calculate the rollover behavior of the vehicle. The results obtained by applying the rollover test specified in the legal regulations to the vehicle by simulation are calculated. Through these obtained data, the possibilities of developing different solutions have been searched and the protection of the residual space by supporting elements has been tried to be provided by strengthening the sidewall columns, roof cross bows and body connections. This results fulfill both ECE R66 requirements and keep weight increase on vehicle below the targeted level.

Below are examples (Figure 7) of retrofit studies made on a 14 m long 4 m high 3-axle intercity vehicle. Considering the standard requirements 30, the substructure is considered to be rigid. Vehicle weight is calculated with 50 passengers.

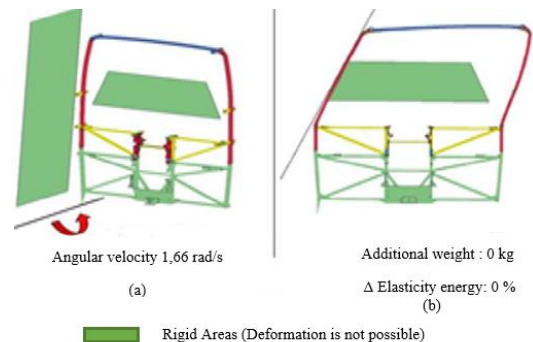


Fig. 7 a) Base model b) Reference deformation model.

Considering the weight and dimensions in the selection of the vehicle to be calculated, a three-axle interurban vehicle was first modeled and reinforcement studies were carried out on the reference model to produce solutions that would protect the living area in case of overturning (Figure 8).

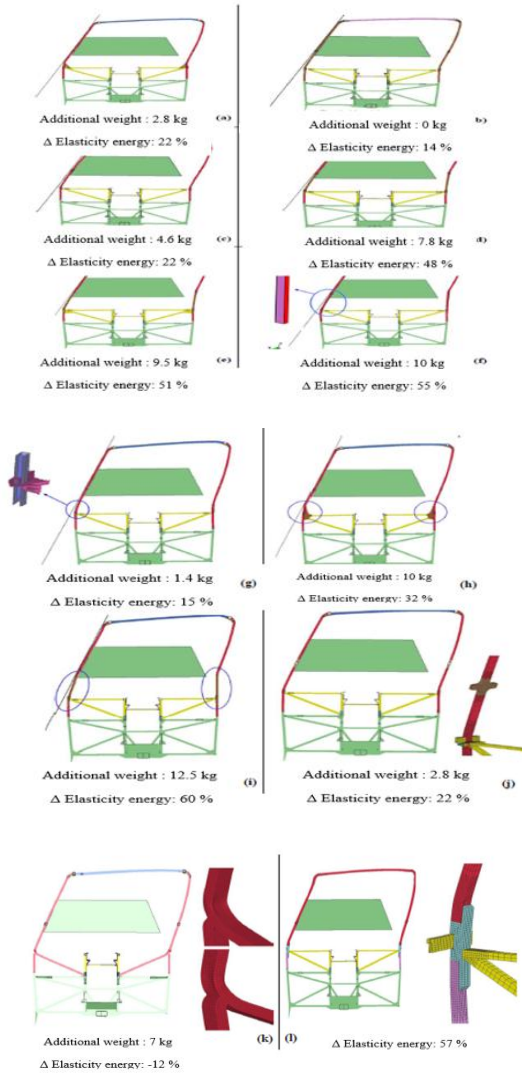


Fig. 8 The effects of different connection points, cross section and material change.

The explanations for Figure 8 are as follows:

- Additional triangular reinforcement piece in podest and side wall connection
- Use of high strength steel S500 MC in side wall pillar
- 70x30x2 curved support pieces between the ceiling sidewall
- Side wall column between bottom of window and top of luggage 6 mm wall thickness
- Side wall column between bottom of window and top of luggage 6 mm wall thickness + 2 mm bottom triangular reinforcements
- Side-wall column between the bottom of the window and the top of the luggage.
- 6 mm sheet metal support in the side wall pipe
- Cast parts connections
- 8 mm thick casting pipe piece on the side wall
- t reinforcement piece in the glassy tube
- Side wall - podest under coupling pipes
- 8 mm die casting on the side wall.

Energy time graph of the profiles in different cross sections shown in Figure 9. When evaluated the 60x50x4 mm sections shown in V19 of the circles with side wall column sections of 70x40x3 mm and 60x50x3 mm used in the reference model show about 40% less energy damped.

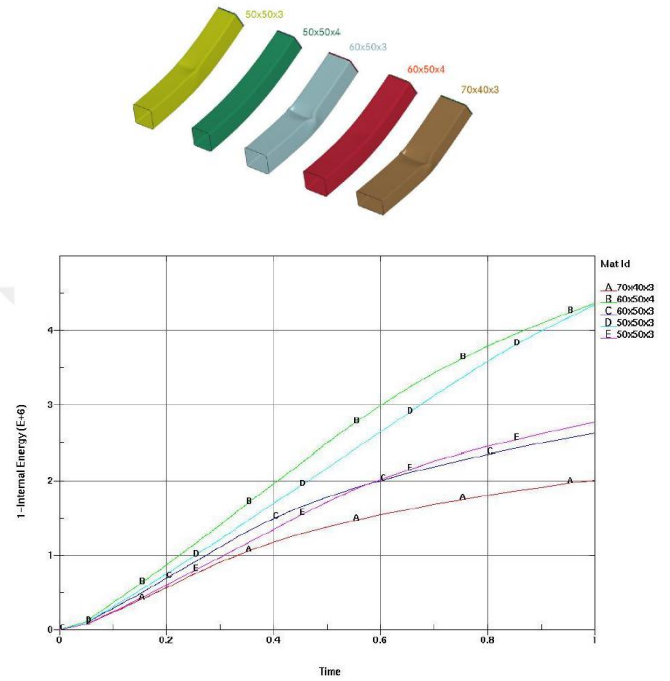
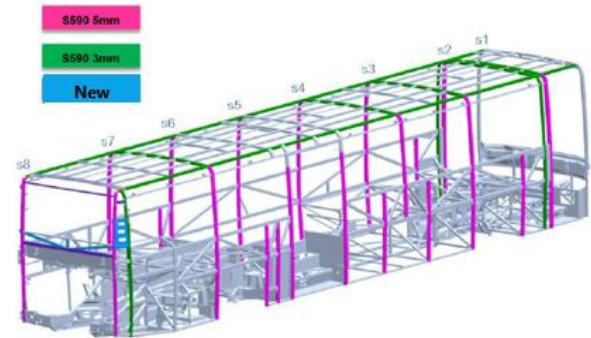


Fig. 9 Deformation behaviors under load of pipes in different sections.

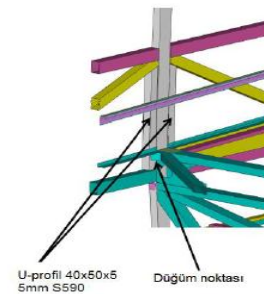
Examination of an intercity vehicle, it was observed that the first overturn test was not able to pass the test and reinforcement measures were investigated (Figure 10).



Right Overturn	c1	c2	c3	c4	c5	c6	c7	c8
Bottom Distance	100	38	30	7	9	-10	-15	-2
Top Distance	88	51	49	33	60	72	55	50

Fig. 10 The overturn test was not able to pass the test in some sections.

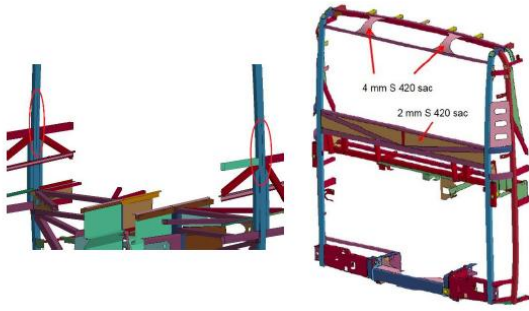
U-profilers (S590 MC 5mm) were placed on both sides of the column first to prevent interference in column 7 (Figure 11).



Right Overturn	c1	c2	c3	c4	c5	c6	c7	c8
Bottom Distance	100	40	32	11	14	-2	-22	4
Top Distance	88	51	49	33	60	72	55	50

Fig. 11 U profiles

In addition to the U-profiles, the sheet pieces shown in Figure 11, V8 (6 mm - S420) are added to the 7th column. Column 8 is reinforced with 4 mm sheet metal parts in the rear skeleton roof joint and 2 mm composite sheet under the glass (Figure 12).



Right Overturn	c1	c2	c3	c4	c5	c6	c7	c8
Bottom Distance	92	32	31	16	24	15	7	48
Top Distance	86	48	48	35	62	82	73	75

Fig. 12 The reinforced U profiles.

U-Profiler S 420 has been replaced with 6 mm sheets of steel and V8 parts have been canceled during the optimization work for manufacturing.

Right Overturn	c1	c2	c3	c4	c5	c6	c7	c8
Bottom Distance	85	18	25	12	35	11	2	45
Top Distance	84	32	44	28	48	78	70	74

Left Overturn	c1	c2	c3	c4	c5	c6	c7	c8
Bottom Distance	84	18	18	10	24	33	12	66
Top Distance	85	42	39	30	35	67	72	80

5. CONCLUSION

As a result of all these experimental studies, constructive solutions were produced with the data obtained. The results and optimizations obtained by applying all reinforcements to the vehicles are shown. In this way, solutions can be produced to contribute to the protection of passengers in buses resulting from rollover accidents.

12 different designs applied to the safety circle were analyzed and energy fading rates were taken as evaluation criterion. The different materials and sections were compared, the most suitable options were determined in terms of the amount of elasticity energy provided and the amount of additional weight added.

The applications in the vehicle safety circle were extended to two different intercity buses, and after the standard requirements were met, optimizations were made to ease manufacturing and reduce weight. At the end of the study, both the ECE R66 requirements and the vehicle weight difference were kept below the targeted 200 kg level.

5. REFERENCES

- [1] **Trafik kaza istatistikleri: karayolu 2013.** (2014). Ankara, Türkiye İstatistik Kurumu.
- [2] **Rahman, M. K., Johari, M. H., Abu Kassim, K., A. & Wong, S. V.** (2011). Body section analysis in bus rollover simulation, *Journal of the Eastern Asia Society for Transportation Studies*, 23, (Vol. 9, pp.1967-81). doi: 10.1007/s12206-009-0731-7.
- [3] **Martinez, L., Aparicio, F., Garcia, A., Paez, J., Ferichola, G.** (2003), Improving occupant safety in coach rollover, *Internationa journal of crashworthiness*, vol.8, no 2, pp. 121-132
- [4] **ECE-Regulation 66 Revision 1** (2006) Uniform provisions concerning the approval of large passenger vehicles with regard to the strength of their superstructure Corr.3, 13 June 2007, Amend. 02, 19 August 2010, United Nations Economic Commition for Europe

CONSOLIDATION OF COASTAL SHIPPING NETWORK IN MID-INSULAR CROATIA

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Abstract: Sea transport has always been the primary mode for both, passengers and cargo transport between the mainland and the islands along the Adriatic coast. The Liner shipping have had the central role in ensuring regular and affordable transport services in the region. Demand for a regular transport services is primarily derived from the need of goods' delivery and passengers traveling to/from islands. The demand is particularly intensive during the peak summertime season, due to a high level of tourists' mobility. Due to the affordable costs, taken from the users' perspective, the transport is of no commercial value for the transporter unless the state subsidizes part of the transport costs at the level of the concessions announced. This paper focuses on the analysis of transport costs and restructuring of the existing shipping lines in mid-insular Croatia, with the aim of developing a model that would reduce transportation costs and shrink total losses, thus lowering the burden on the state budget. The research points out that the specific reformation of the coastal shipping network would indeed lead to cost savings without compromising passengers/goods mobility among mainland and islands in Central Dalmatia.

Keywords: COASTAL SHIPPING, LINER SHIPPING, PASSENGERS' MOBILITY, COST SAVINGS

1. Introduction

After 2008, the world economy went into a period of cost reduction and the rationalization has become an essential element in the business entities.

When it comes to the liner shipping, i.e. connecting the mainland with islands, rationalization of costs can be achieved in several ways:

- in the technical sense with the ships of smaller capacity and lower engine power,
- in the economic terms by increasing the effective utilization of ships, i.e. by reorganizing the existing lines.

This paper focuses on the rationalization of the costs in economic terms, since the use of smaller capacity ships and/or lower engine power is not possible on most lines because of the distance of some islands from the mainland and primarily because of the seasonality i.e. the excessive difference between the number of passengers and goods transported through the seasons.

The costs of certain lines in central Dalmatia departing from the city of Zadar are analysed, and then the model that would reduce the total cost of transportation and reduce overall losses from the transportation of passengers and goods is designed.

The main source of data on which the survey is based are planned revenues and expenditures on lines, and statistical data on the number of passengers and vehicles on national lines 435 – Zadar/Bršanj (Iž), 405 – Zadar/Iž/Rava, 405a – Zadar/Sali/Zaglav (Dugi otok), 9404 – Zadar/Rivanj/Sestrunj/Zverinac/Božava/Brbinj (Dugi otok) and 9404a – Zadar/Iž/Rava.

Similar topics have also been dealt with by some other authors such as: Ceder. A., J. Varghese in Analysis of passenger-ferry routes using connectivity measures and Makkonen.T., M. Slaonen, S. Kajander in Island accessibility challenges: Rural transport in Finnish archipelago. Except in maritime affairs, similar problems arise in rail transport where the work of author Schlechte, T., Railway track allocation: Models and algorithms, show some of the possibilities of cost rationalization in public transportation.

2. Liner shipping on the Adriatic

Liner shipping represented, through history, the exclusive form of the intercontinental connections, as well as the transportation of passengers and goods between the coast and islands. Today that is not the case as it has often been substituted by some other transportation modes that are much faster and in certain conditions more functional, such as road or air transportation.

However, the importance of liner shipping has remained evident to date when it comes to linking the islands to the mainland and the

islands to each other. That is reflected, particularly in preventing the outflow of the living population from the islands and through the possibility of developing the economy and tourism on the islands.

The biggest problem of the liner shipping is in most cases seasonality, i.e. reduced demand for larger capacity ships during the winter period, when only a small number of locals use services, and the summer time when the number of passengers and cargoes increases up to several times due to the movement of tourists.

In addition to seasonality, there is furthermore the problem of insufficient utilization of the ships on certain lines with only 20% of time in navigation and the rest, moored alongside the shore.

Insufficient ships' utilization through the year, as well as seasonality in liner shipping, generates costs that multiply exceed the threshold of profitability and are serviced by the state through subsidies. In order to reduce these costs, i.e. to maximally approach the threshold of profitability, it is necessary to analyse the utilization of ships and the cost per line according to the current sailing schedule in order to find the methodology for rationalization through the analysis of the obtained data.

3. Analysis of utilization, costs and earnings

The basis of this research is of an economic nature and is based on reducing the costs of liner shipping and increasing the work performance of ships, so it is necessary first to analyse the current surveyed lines of navigation in order to determine the actual utilization of the ships.

According to the Law on Transport in Liner and Periodical Coastal Maritime Transport (Official Gazette 33/06, 38/09, 87/09, 18/11, 80/13 and 56/16) lines 435, 405, 405a, 9404 and 9404a are defined in the following way:

- state line 435 is categorized as a ferry line, where according to the timetable, 337 trips are performed annually, i.e. ferry spends 1110 hours at sea,
- state lines 405 and 405a are categorized as ship lines, where according to the timetable, 730 journeys are performed per year, i.e. ship spends 2972 hours at sea,
- state lines 9404 and 9404a are categorized as high-speed-craft lines on which catamaran performs 730 journeys per year or 2400 hours in navigation.

From the analysis of the sailing schedule on the lines 435, 405, 405a, 9404 and 9404a it can be seen that, from the total number of hours on an annual basis, the ferry on the line 435 performs 13% of the time in navigation, the catamaran on the lines 9404 and 9404a spends 27% in navigation and on the lines 405 and 405a ships navigate 34% of time, while the rest of the time are moored to the shore. If the effective utilization of ships is increased in a way to

run more lines a day, lying would fall to a lower level thus reducing the losses.

Speaking of the costs in liner shipping, it is necessary first to define what the costs are and how they are distributed. By definition, costs are the value-added expenses of the elements of the production process or service provision, resulting from the business activity of a company. Total costs (TC) can be divided into two basic parts, fixed and variable, due to the change in volume of work and the provision of services. The fixed part of the cost (FC) does not change with respect to the work process or the provision of services, while the variable part of the cost is variable, as it stems from the costs of navigation and is subject to environmental impacts.

For state lines 435, 405, 405a, 9404 and 9404a, fixed costs are: costs of materials, spare parts, maintenance costs, insurance premiums, amortization, workers' compensation, wages and salaries (net), taxes and surtaxes, and other fixed costs which, according to Table 1, amount to 13,752,690.24 HRK.

Table 1: Current fixed costs per line (HRK).

Line	435	405/405a	9404/9404a
Fixed costs			
Cost of materials	200,066.70	61,200.00	135,362.03
Spare parts	177,853.10	204,000.00	495,008.89
Maintenance costs	1,280,127.10	357,000.00	509,332.36
Insurance premiums	250,911.60	122,400.00	154,899.97
Amortization	23,826.10	107,100.00	386,413.74
Workers' compensation	721,961.20	441,456.00	683,005.07
Wages and salaries (net)	1,895,954.80	965,752.00	884,757.37
Taxes and surtaxes	811,791.10	550,461.00	336,701.03
Contributions	544,142.30	345,963.00	254,026.92
Other	316,518.40	510,000.00	24,698.46
Total	6,223,152.40	3,665,332.00	3,864,205.84

Source: Made by the authors according to the data of the Agency for Coastal Maritime Traffic

Variable costs (VC) in liner shipping include: fuel costs, lubricant costs, port fees and other financial costs, among which are those related to banking interest rates and exchange rate differences.

The total variable costs on the observed lines amount to 9,188,787.50 HRK, and the elements of the variable costs are given in Table 2.

Table 2: Current variable costs per line (HRK).

Line	435	405/405a	9404/9404a
Fixed costs			
Fuel costs	2,334,193.00	1,659,845.00	4,213,826.77
Lubricant costs	51,549.60	72,100.00	72,592.87
Port fees	353,288.80	168,300.00	95,461.80
Other	119,511.10		48,118.56
Total	2,858,542.50	1,900,245.00	4,430,000.00

Source: Made by the authors according to the data of the Agency for Coastal Maritime Traffic

The analysis of the structure of fixed and variable costs, given in Tables 1 and 2, on the observed lines shows that the overall costs (TC=FC+VC) reach the amount of 22,941,477.74 HRK, while the total planned feasible revenue according to the data of the Agency for Coastal Maritime Traffic is around 3,550,000.00 HRK (see Table 3).

Table 3: Planned feasible revenue by lines (HRK).

Line	435	405/405a	9404/9404a
Planned feasible revenue	1,500,000.00	800,000.00	1,250,000.00

Source: Made by the authors according to the data of the Agency for Coastal Maritime Traffic

4. Possibility of cost rationalization

Rationalization generally speaking means a better organization and management of a system. Economically, rationalization can be characterized as a measure to achieve changes in the organization of a work process, the use of system elements, human labour and their management tasks in order to reduce costs and increase work performance.

Rationalization of costs on lines 435, 405, 405a, 9404 and 9404a, can be observed through the use of smaller ships and reorganization of the existing lines.

However, it is almost impossible to hire smaller ships on these lines, primarily because of the number of passengers and vehicles transported in the summer months, but also because of the growth trend of nearly 10% per line per year. Since the opening of the passage "Mali Ždrelac" for public traffic and by relocating the public liner shipping through the same, travel time on lines 435, 405, 405a and 9404 decreased by almost 50%.

The reconstruction of the existing bridge Ugljan-Pašman and deepening of the canal enabled the passage of the ferry to the island of Iž. Until that time the ferry operated on the same route but through the passage "Veli Ždrelac" in which case the trip was longer by nearly 10 NM, that is one hour in time.

The following example also indicates that the bridge reconstruction and deepening of the canal have opened up savings' opportunities.

Namely, if the number of trips on the line 435 to the island of Iž is increased thus replacing the existing ship and high-speed lines, transportation costs would be considerably reduced. Due to the overlap with the ferry line, the ship line and high-speed line would be in that case redundant. There are several justified reasons for doing so. The travel time of a catamaran and a passenger ship with port call in every inhabited place on the island, compared with the ferry is slightly shorter, since the ferry port is located at the very beginning of the island of Iž and the transport of passengers from the ferry port to the final destination has been done by a bus, which is much faster but also far cheaper than the existing catamaran and the passenger ship. With the seasonal increase of passengers on lines 405 and 9404, travel time is extended with regard to boarding and disembarkation possibilities of catamaran and passenger ship in relation to the ferry. Considering the possibilities of ferry transport to the island of Iž and the rearrangement of the existing lines as the only option that would achieve savings, while retaining the same number of trips to the observed islands, is the reorganization of the existing lines which would keep the same number of trips to the islands while the duration of travel would not be significantly changed.

In order to achieve savings on the lines, the reorganization should be carried out in the following way:

- On the state line 435 out of season two trips per day should be introduced at 11.00 and 16.30, and three trips during the period from 01 July to 01 September with departures at 10:30, 16:30 and 20:00, where in both cases the first morning departure at 06:15 would be from the port of Bršanj (Iž). The number of trips per year would increase to 795 and the ferry would spend almost 32% of the time on the voyage.
- Cease the state line 9404a on the line Zadar – Iž – Rava due to overlap with the ferry line. Instead it would replace the existing line 405a that runs on the Zadar – Sali – Zaglav route with extension to the Vela and Mala Rava, which would keep the costs in equal boundary values due to almost identical distances of 22 NM in each direction likewise on line 9404a.
- Extend the route on the state line 9404 from the port Brbinj to the ports of Mala and Vela Rava which would further increase the effective use of the catamaran, that is reduce the idle sailing.
- Cease state lines 405 and 405a due to overlapping with other lines according to reorganized sailing schedules. Passengers

from lines 405 and 9404a, which would be taken by the ferry on line 435 to the island of Iž, would drive a local bus to the place of their final destination. The annual subsidy, i.e. the cost of the island's shuttle bus according to the data of the current concessionaire "Liburnija Zadar" varies around 135,000.00 HRK per year which, with the employment of another driver and by carrying out two more daily lines on the route from ferry port Bršanj – Mali Iž to Veli Iž, would be doubled and reach almost 270,000.00 HRK per year.

In order to realize that the reorganization of the lines and the increase in effective utilization can make savings possible it is necessary to analyse the costs that would be generated by the proposed reorganization model. When it comes to fixed costs, in this case they would not change since the travel time for the reorganized sailing schedule in no case exceeds 8 hours, which means that the fixed costs remain unaffected (Table 1.). Those costs, such as the cost of the material, spare parts, maintenance costs and amortization are not voyage-sensitive.

5. Results and discussion

The analysis showed that the assumed fixed costs, after the reorganization of the lines, amount to 10,087,358.24 HRK, which in relation to the current fixed costs of 13,752,690.24 HRK represents a saving of 3,665,332 HRK at the annual level.

The value of variable costs according to the model varies considerably from the current variable costs (see Table 2). Because of the greater number of trips per line, the variable costs have been considerably increased. Based on the costs generated by ships in navigation, according to the model, assumed variable costs would amount to 8,378,734.54 HRK (Table 4).

When the current variable costs are compared with the costs according to the reorganization model, it can be clearly seen that the potential savings on the annual level is 810,052.96 HRK, from which the bus transportation of passengers on the island Iž should be taken away. Thus, the annual savings would be reduced by 270,000.00 HRK and the final amount would be 540,052.96 HRK per year.

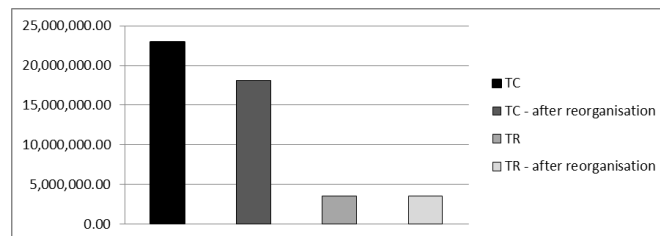
Table 4: Variable costs per line after reorganisation (HRK).

Line	435	9404/9404a
Fixed costs		
Fuel costs	3,011,005.00	4,571,526.77
Lubricant costs	101,549.60	78,272.91
Port fees	353,288.80	95,461.80
Other	119,511.10	48,118.56
Total	3,585,354.50	4,793,380.04

Source: Made by the authors according to the specifications of propulsion and auxiliary engines and data of the Agency for Coastal Maritime Traffic

Reorganized lines should also be analysed through the number of passengers carried and the revenue per line. According to the proposed model, based on the annual statistical data for several years of the Port Authority of Zadar, the anticipated number of passengers carried on the line 435 that would replace lines 405 and 9404a would reach almost 100,000 which would be an increase in the number of passengers on the line of 120%.

The planned revenue on the line with regard to the assumed number of passengers, based on the analysis of statistics on the passengers throughput, would amount to nearly 2,000,000.00 HRK. The number of passengers would be increased on the line 9404 to around 10%, thus assumed total planned revenue from passenger transportation amounted to approximately 1,500,000.00 HRK.



*TC – total costs, TR – total revenue.

Fig. 1 Relation of the cost and profit before and after reorganization of lines (HRK).

Comparing overall planned revenue before reorganization and assumed total revenue according to the proposed model (Figure 1), would eventually be reduced by 50,000.00 HRK since the 9404a high-speed line would be replaced by a ferry where the cost of transport (tickets) is considerably cheaper. However, if the lines were viewed individually, the planned revenue according to the reorganization model would be higher, due to the larger number of passengers per line, which would automatically result in an increase in revenue, which would amount to 500,000.00 HRK.

6. Conclusion

Liner shipping in Croatia as a country with over 1000 islands represents a very important factor, primarily in connecting but also in economic development and survival of life on the islands.

The seasonality but also the unprofitability of most of the lines generates significant losses, which, after the economic crisis in 2008, and the weakening of economic power on the global level, became even more pronounced problems for most coastal countries.

The purpose of this paper was to analyse the costs of liner shipping on individual lines connecting islands with the mainland in Croatian Central Dalmatia in order to develop a model of rationalization of existing costs. The analysis of the navigation schedule has shown that most of the generated costs arise specifically because of the inactivity of the vessels, i.e. their ineffective usability, thus opening up the possibility of reorganizing the lines, i.e. raising the effective usability of the vessels to the maximum values defined by the working time of the crew.

The rationalization model obtained on the basis of the calculated costs of the vessels according to the reorganized schedule of navigation indicates that it is possible to achieve significant savings while maintaining the same number of trips on all lines and at the same time periods.

From the cost analysis before and after the reorganization of the existing lines, and the conclusions drawn from the research, it is evident that this reorganization model represents the basis of rationalization of costs in liner shipping in the region of Central Dalmatia. In an analogous way it would be possible to rationalize even more lines in the broader area of the Adriatic and thus contribute to the future of the sustainable linking of the island with the mainland and the islands to each other.

References

1. Ceder A., J. Varghese, Analysis of passenger-ferry routes using connectivity measures, Journal of Public Transportation, Florida, US 2011,
2. Makkonen T., M. Slaonen, S. Kajander, Island accessibility challenges: Rural transport in Finnish archipelago, European Journal of Transport and Infrastructure Research, Netherlands, EU 2013,
3. Sandvik E., J. Odeck, How efficient are ferries in providing public transport services, The case Norway, Association for European transport and contributors 2007,
4. Schlechte T., Railway track allocation: Models and algorithms, Berlin, Germany 2006,

5. Toljanić. B, Management of Linear Maritime Transportation in the Republic of Croatia, (Croatian: Upravljanje linijskim pomorsko putničkim prometom u Republici Hrvatskoj), Rijeka 2013,
6. Vujević. K, M. Balen, Efficacy indices of a maritime transport firm (Croatian: Pokazatelji uspješnosti poslovanja poduzeća pomorskog prometa), Pomorstvo, Rijeka 2006,
7. Marine Development Strategy and Integral Maritime Policy of the Republic of Croatia for the period 2014-2020 (Croatian: Strategija pomorskog razvitka i integralne pomorske politike Republike Hrvatske za razdoblje od 2014 do 2020 godine), Zagreb 2014.,
8. Notice of Intent to Grant Concessions for lines 401, 433 and 435 (Croatian: Obavijest o namjeri davanja koncesije za linije 401, 433 i 435), from: http://www.agencija-zolpp.hr/Portals/12/doc/Obavijest_o_namjeri_davanja_koncesije-linije_401,_433_i_435_u_paketu.pdf, 15.03.2017,
9. Notice of Intent to Grant Concessions for Lines 405 and 405a (Croatian: Obavijest o namjeri davanja koncesije za linije 405 i 405a), from: http://www.agencija-zolpp.hr/Portals/12/doc/Obavijest_o_namjeri_davanja_koncesije_405_Rava-I-Zadar_i_405_a_Sali-Zaglav-Zadar.pdf, 15.03.2017,
10. Notice of Intent to Grant Concessions for Lines 9404 and 9404a (Croatian: Obavijest o namjeri davanja koncesije za linije 9404 i 9404a), from: http://www.agencija-zolpp.hr/Portals/12/doc/Obavijest_o_namjeri_davanja_koncesije_9404_Zverinac-Bozava-Sestrunj-Rivanj-Zadar_i_9404_a_Zadar-Iz-Rava.pdf, 15.03.2017.

APPLICATION OF THE THEORY OF INVARIANCE FOR NOISE-RESISTANCE ESTIMATION OF TRANSPORTATION INFORMATION SYSTEMS

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Abstract: *In the present paper is defined the functional stability of the communication systems for radio connection in the railway transport. It is associated with the possibilities for the realization of the principles of invariance within signal – noise environment altering itself.*

Keywords: INFORMATION SYSTEMS, TRANSPORT, FUNCTIONAL STABILITY, INVARIANCE, NOISE-RESISTANCE .

1. Introduction in the problem

Information systems in some important production sectors, such as transport, production and distribution of electricity, etc., are crucial for their correct and reliable functioning. They required providing for the relevant security level and functional safety.

The traditional methods, based on multiple reservations, bringing into use systems for “built-in” control, and elements with enhanced security level, are insufficient.

For instance, the mobile systems for radio contact in the railway transport are distinguished on the one hand by functioning under extremely arduous and complex conditions with complex influence exerted by strong fluctuative, concentrated, impulse disturbances [4] in the grid – circuit as well as the operation of multiple devices while on the other hand by utilizing high level of reliability of the information being transferred which is related to the traffic safety. In relation to that, the development of approaches and methods capable of providing for reliability assigned in advance and guaranteed level of jamming resistance respectively is of exceptionally high interest and special actuality.

In the present paper, the mobile communication systems’ capability of preserving characteristics’ qualities of the jamming resistance property within certain bounds, while altering static characteristics of the random parameters, as well as varying both shape and parameters of the signal and the disturbances, is defined as functional stability [1,2,3].

It means that the given quantity of the system functioning is achieved thanks to the independency (partial or complete) of the performance of the noise-resistance from reasons causing the non-stationary state of the channel of connection. This ability of the system to oppose resist against the disturbing actions is known as invariance [2,3].

In this paper the functional stability of the mobile systems for radio connection in the railway transport is associated with the possibilities for the realization of the principles of invariance within signal – noise environment altering itself.

2. Connection between functional stability of the communication system and theory of invariance

The problem of functional stability of the radio – communication systems for mobile radio connection establishment has been defined and given proof on in the [1,2]. Besides, as it has been mentioned in [1], the distinction between the problems of functional stability of the automatic control systems and suggested radio – communication systems must be emphasized in particular.

In the automatic control systems, both disturbances and control signals are spatially divided in main. This allows one to measure as well as estimate the disturbances regardless its random nature. Also, this allows one to utilize different compensational methods to realize their invariance regarding the disturbances distinguished by conditions and methods being employed in achieving the invariance [2].

In addition, it is also necessary to mention that the notion “invariance,” being the main component and the goal the functionally stable control is to achieve, requires refinement in

relation to which one of the control system’s numerical characteristics is an invariant as well as which transformations or influences the system is invariant towards.

In case of radio – communication systems, the disturbances themselves in a broad sense play a certain part as disturbances: the different kind of noise, superposing the received signal, as well as random alterations of characteristics and parameters of both the communication channel and the signal influencing the jamming resistance. In that case, the system’s characteristic that should be invariant to the disturbances is its jamming resistance being equalized quantitatively to the error probability during digital communications.

At the same time, it should be emphasized that in the communication systems, in contrast to the automatic control systems, the useful signal and the disturbance react upon the same point, i.e. the receiver input oftentimes, and could not be divided thoroughly. In the opposite case, it could be mentioned that the problem of struggling against the disturbances would not exist.

In the radio – communication systems, it is all about a composite between a signal and noise since the white noise is always available as additive. The parameters of the additive disturbance determine at first hand the jamming resistance of the communication system. If it were a non-stationary random process, the level of thrust-worthiness of the information transmitting process would be altered. For instance, if the disturbance power increased in time, the error probability of information transmitting would get increased as well. The non – additive disturbances lead to relevant alteration of the particular parameters of both signal and channel. Since the channel parameters alteration could be expressed through the relevant alteration of signal parameters, the non – additive disturbances exert influence on the jamming resistance while the receiving conditions are getting either deteriorated or improved, yet this alter the error probability.

This is why building functionally stable radio – communication systems with invariant, in relation to the disturbances complex influence, parameters and characteristics, requires for a variety of reasons another formulation and approach to be met as compared to the problem of functional stability of the automatic control systems.

Such a fundamental characteristic of the system for official radio contact with mobile objects, such as the jamming resistance, could not represent thoroughly the system’s qualitative functioning. For this purpose, it is necessary to introduce indicators that would allow the system’s ability to preserve characteristics’ qualities of the jamming resistance within certain bounds, while altering the parameters of the signals and disturbances.

On the present level of growth of the mobile radio – communication systems, operating under conditions of complex influence exerted by disturbances, development of methods for increasing the jamming resistance is related to usage of signals with complex structure, channels with adjustable feedback, and synthesis of special algorithms [1,3], minimizing the influence exerted by disturbances on the jamming resistance. On these lines, looking into algorithms of information being transmitted through noise – like signals with optimized structure, permitting warranty related to the working capability of the system in a variety of situations rendering into account the static characteristics of the signal, the channel, and

the noise environment, is topical in particular. This approach is related to two – dimensional (frequency – temporal) coding of each signal parameter: by means of either forming pseudo – stable switching between the operative frequencies or usage of pseudo – random sequences manipulating the signal's phase [5,6]. Using either of the mentioned complex signals allow one to increase significantly both the jamming resistance of the radio systems, at the expense of introducing multiple frequency – temporal surplus within the signal, and the relevant complication arising during the signal's processing by the receiver.

Under conditions of work of businesses radio communication systems for transmitting information with security reliability in the railway transport, the decisive factor is the influence of the impulse disturbances during signals receiving [2,3]. This influence reveals itself during spontaneous alteration of the dispersion as well as failures of the adaptive devices of spatial – frequency – temporal signals' processing which signals are generated assuming that the received mixture is quasi – stationary and Gauss one (in common sense) [7].

As a result of that, the efficiency of the radio system is getting vastly deteriorated under the influence of these signals. It must be borne in mind that the indicators of the jamming resistance (the weighted error of the signal's reproduction and the probability of wrong decision to be taken by the demodulator regarding the discrete message being transmitted) are not completely adequate to the real conditions the connection is established under. In the non – stationary channels of the systems for mobile radio connection establishment, the relation "signal/noise" is altered during the system's functioning process. Therefore, the determined in this way reliability is also getting altered. If these alterations could be neglected within the time interval of message transmitting, the channel is considered as locally stationary one. In addition to either the weighted error or the probability of wrong estimation of the jamming resistance, it is necessary one to determine what the trust probability that the values of these variables will not exceed the limit is. During the effect of impulse disturbances, the constancy of the ratio "signal/noise" is violated by powerful momentary peaks within the electromagnetic field of the disturbances. These peaks dramatically change the ratio and evaluation of the acquired specific resistance (jamming resistance) traits.

In radio channels, intended to establish connection to mobile objects, the probability of error is variable quantity (heterogeneous channel with variable characteristics). In this case, even if securing the average probability of error less than assigned limit were successful, the probability of error could be set greater than permissible value. Furthermore, regarding all mobile channels, reducing the average probability of error does not show clearly improving the quality of the system's functioning. For example, if the percentage of cases of error probability were getting greater than admissible value, along with reducing the average probability of error allowance, the jamming resistance of the system would get decreased. It follows that, in particular, optimization of the radio system, in accordance with the widely used criterion for the minimum average probability of error, does not provide the best quality of operation of the real system in the radio channel with variable parameters. To ensure an acceptable quality of functioning of the real system in the radio channel with variable characteristics, it is necessary to maintain the probability of error at a level not exceeding a preset limit. In essence, this means that the specified quality of the system functioning is achieved due to error likelihood independence (partial or complete) of causes for non-stationary nature of the communication channel.

This standard, known as the invariance, is a property of the system to oppose the disturbing effects.

In the most general case, if the initial system coordinate $y(t)$ for any point in time t does not depend on the disturbance $f(t)$, the system will be possessed by absolute invariance regarding $f(t)$, i.e:

$$y(t) = \text{invar}[f(t)]. \quad (1)$$

If this property is fulfilled roughly (in a certain sense) then the invariance will be accurate up to ε and the system will be relatively invariant, i.e:

$$y(t) = \text{invar}[f(\varepsilon)]. \quad (2)$$

The concepts of "invariance" and "functional stability" are interrelated. If one examined invariance of the jamming resistance characteristics, put in the form of functional dependence of the error probability of both the signal's and disturbances' parameters, in which case the system has characteristic of the jamming resistance being absolute invariance in relation to a definite class of disturbances, the study of functional stability would become futility. If the system has an invariant characteristic then the relative invariance and functional stability will be thought as concepts being largely equivalent.

3. Defining of conditions of invariance of the performance of noise-resistance

For a radio channel, the typical situation is the one where the performance of noise-resistance is determined by the presence of disturbances of several classes (fluctuating, spectrum-concentrated, impulse). The functional kind [3] of the expression of the error probability with receiving by elements depends on the sets of signal parameters, the disturbances and the interaction between them :

$$P = \left\{ \bar{h}_i^2 \right\} \left\{ \bar{h}_\zeta^2 \right\} \bar{G}_{ij}^2, \quad (3)$$

where $\bar{h}_i^2$ and $\bar{h}_\zeta^2$ express the mean statistical properties of the ratios between the energies of the i -th signal variant and the j -th disturbance variant and the white noise spectral density.

The part of parameters of interaction between the signal and disturbances is played by set $\{ \bar{G}_{ij}^2 \}$, $i=1 \div n$, $j=1 \div n_\zeta$, average statistical values of the coefficients of the reciprocal differences in the frequency-and-time area of their structures.

As the degree of the interaction between the useful signal and the disturbance on the frequency-and-time plane is analogous to their mutual correlation function, it is suitable to assume the average statistical value of the mutual difference coefficient in the position of interaction between them. This value is expressed in the kind of [3]:

$$\bar{G}_{ij}^2 = \left[\frac{K_0 K_\zeta}{2P_i T} \int_0^T \dot{S}_i(t) \Sigma_{\zeta_j}^*(t) dt \right]^2, \quad (4)$$

where K_0 , K_ζ , are the amplitude coefficients of the signal and disturbance, $T = \tau_0 N$ is the signal length, $\dot{S}_i(t)$ and $\Sigma_{\zeta_j}^*(t)$ are the complex functions of the i -th signal and j -th disturbance,

$$P_i = \frac{K_0^2}{T} \int_0^T s_i^2(t) dt \quad (5)$$

is the average power of the i -th signal variant.

The conditions of the invariance of the connection system are expressed in relation to a certain class of disturbances and in dependence with the metrics selected on the signal space.

If $n(t)$ and $\zeta(t)$ are random realizations of fluctuation noise $\{N\}$ and quasi-determined interferences $\{\Xi\}$ respectively, then the performance of noise-resistance is a function of both interferences:

$$P = P(N, \Xi). \quad (6)$$

The system of connection is absolutely invariant to $\zeta(t)$, if :

$$P(n, \zeta) = P(n, 0) = P(n) \quad (7)$$

is fulfilled.

When the noise-resistance characterization depends on interferences Ξ to a certain extent, e.g.:

$$|P(n, 0) - P(n, \zeta)| \leq \varepsilon, \quad (8)$$

then the system is relatively invariant (invariant to ε), where ε presents the given distance between $P(n, \zeta)$ and $P(n, 0)$:

$$\varepsilon = \max_{\zeta} |P(n, \zeta) - P(n, 0)|. \quad (9)$$

4. Conclusion

The functional stability is a broader concept which is associated with the investigation of possibilities opened up by the development of modern element base for the realization of the principles of invariance within signal – noise environment altering itself

References

- [1] Andonov, A. The Problem of System's Functional Stability for Mobile Radio Link Establishment, Higher School of Transport, Sofia, 1996 (into Bulgarian)
- [2] Cherneva G. Generation and Examination on Signals, Harmonized with Communication Channels. PhD Dissertation. S. 2007 (into Bulgarian)
- [3] Andonov A., G. Cherneva., Z. Hubenova. The Problem of Synthesis of Functionally Stable Information Systems in Railway Transport. Proceedings of the 5th International Scientific Conference „Theoretical and Practical Issues in Transport“ Pardubice, February 11th -12th, 2010, ISBN 978-80-7395-245-7, pp.298-301
- [4] Cherneva G., Dimkina E. Specific Aspects for the Electromagnetic Compatibility of the Railway Transport. Proceedings of papers of International Conference “Bultrans 2011”, pp.324-326 (into Bulgarian)
- [5] Gorskii, J. M., System Informational Analysis of the Control Processes, Science Publishing House, Moscow, 1998, p. 320 (into Russian)
- [6] Mashkov, O. A., Principles for Construction of Functionally Stable On-Board Information – Control Complexes, Symposium “Problems of Navigation and Control of Aeronautical Space Systems,” pp. 63 – 67, K., 1991 (into Russian)
- [7] J.Proakis. 2001. Digital Communications. Mc Graw Hill Series in El.Eng. Stephen W.

BY MANAGING THE REQUIREMENTS AND INTERNAL STANDARDS OF RENOWNED CUSTOMERS TO BETTER BUSINESS RESULTS IN THE MOTORCYCLE INDUSTRY

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Abstract: The effectiveness of the organization depends largely on the ability of managers, employee involvement in clear strategic orientations and its integrated culture. A successful management system of the organization is no longer dependent just on a process approach and continuous improvement. Increasingly, risk and opportunity management is at the forefront, taking into account the requirements of the business environment, particularly the requirements of the largest buyers of the company's products. It is very important for the organization to incorporate risk management into its operations, not only to reduce the negative consequences but also to increase its business opportunities. The paper presents the company's cooperation with one of the largest motorcycle manufacturers in the world - BMW Group, which took place while the company was introducing a new steel frame for the BMW F 800 S motorcycle in global markets. Due to the right approach including a positive risk, compliance with the requirements of the SPQM (Supplied Part of Quality Management) and last but not least our ardent desire to cooperate with BMW, the company has been given the opportunity to become the supplier of complex components for BMW and other large manufacturers in this industry.

Keywords: NOMINATION, FUNCTIONAL PROTOTYPE, SPQM, PFMEA

1. Introduction

The organizations that use their quality management systems to good advantage have a head start over others in the phase of the introduction of new standards, and later the certification and internal and external evaluation processes. Continuous changes require adjustments and new ways of designing and developing products and services. Therefore, the design and development of products and services are of vital importance to each organization as the very existence of the company depends on how successful they are.

In September 2015, the fifth edition of the ISO 9001: 2015 Quality Management System was published, giving a new strategic orientation to the standard by taking into account the fact that more and more quality management systems are used together and integrated with the business processes of the organization, that priority is given to the effectiveness and the results of the management system and that the requirements of the system need to be adapted to current and future business circumstances and requirements. Increasingly, risk management and opportunities are at the forefront, taking into account the requirements of all stakeholders. The quality management system should become a tool for the realization of strategic decisions and the fulfillment of the mission of the organization¹. Among the seven principles of quality management, there is no longer an explicitly stated systemic approach that is covered by the process approach, and the principle of a mutually beneficial supplier relationship has spread to all stakeholders.

A brief summary of the principle of planning and improving could be that preventive measures are no longer there because organizations have to assess and manage risks. Organizations must prevent key risks or at least reduce unwanted impacts in order to ensure that the quality management system achieves the expected results and actualizes the identified opportunities for improvement. The chapter explicitly sets out requirements for quality objectives and planning for achieving them. In addition, organizations are expected to plan and manage change. The principle of improvement deals with inconsistencies, corrective actions and improvements, but no longer speaks of preventive measures, which are now covered by requirements in the planning chapter (risk management). When measuring, the identified risks and opportunities must be taken into account.

Entrepreneurial action is full of uncertainty, which can be the result of changes in the business environment, possible changes in

the company, the perception of opportunities, or the lack of information. Therefore, the goal is to identify the potential effects of the uncertainties and take appropriate action. Contrary to crisis management or problem management, risk management is characterized by a distinct focus on the future. With persistent measures, effective and efficient risk management will contribute to the prevention of crises and problems in line with the motto: "Good managers manage risk, poor managers manage problems."

The paper presents a practical example of opportunity search and project uncertainty in the nomination phase and industrialization of the complex product for BMW.

2. Requirements of the customer BMW

The cooperation between a prominent motorcycle factory, Slovenian company Tomos, and the world-renowned motorcycle manufacturer BMW date back to the late 1990s.

The value of the successful supplier increased when BMW entrusted Tomos the task to enter the competition with other companies in the segment of complex welded components. Project team was entrusted with the management of the project named BMW K71 with a large format drawing containing dimensional and technological requirements. The product is the rear frame of the motorcycle BMW F 800 S/ST made from steel structure, as indicated in the figure 1.

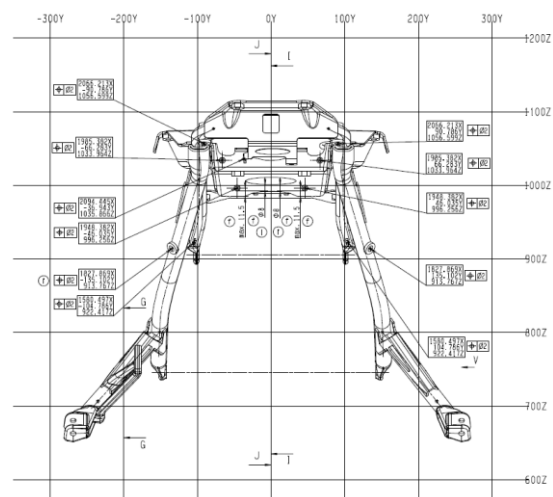


Fig. 1 Drawing of rear frame BMW F 800 S/ST.

With competitiveness in the manufacturing and supply of welded components for BMW, Tomos gained advantage over other companies, which enabled the growth of the company and its new owner Hidria, not only in the segment of welded components but also in the segment of smaller aluminium castings.

With good present cooperation, we entered the nomination process with the rest of other major companies whose aim was similar to ours: to become manufacturers and suppliers of the complex welded product. The deadline for making the calculation was predetermined by BMW. BMW's development department in Munich acceded to our request and soon we acquired a 3D model of the product, made in the program Catia 4.0.

The product was disassembled to single elements and the indicative value for each of them was determined. The calculations of technological processes of welding, painting, inspection and delivery were followed by the final price and its entry into the BMW system. Our manufacturing costs turned out to be interesting to BMW auditors and we came to a shortlist of suppliers.

The project team was given a month to prepare for the visit and assessment by BMW, in the areas of development, industrialization, quality and logistics. Assessment is carried out using SPQM system Supplied Parts Quality Management.

2.1 From the prototype through the challenging SPQM assessment to the winning of the nomination

The BMW engineering and production of quality parts after calculation process, starts with the nomination of suppliers. During the selection process, we must prove that we meet the demanding requirements of BMW Group. The BMW Group Purchasing Division is responsible for the satisfactory completion of all supplier selection and contracting activities. Purchasing is supported by the engineering, parts quality and logistics departments. Supplier selection is performed in different project phases, depending on the type of suppliers and the responsibilities they take.

The relationship between BMW and suppliers is based on partnership and trust. In the supplier selection process, potential BMW suppliers successfully convince our teams that their concepts will meet the requirements in terms of specifications, innovations, quality, and cost. Having signed a contract as a supplier to BMW Group, suppliers together with BMW engineers share responsibility for achieving challenging goals.

SPQM is predestined to develop the questionnaire. At the end of each question assessors appropriately labeled the adequacy of the response to the "traffic lights". Figure 2 shows the initial preparatory form SPQM for carrying out quality management assessment in the field of development, supply, logistics and product quality.

BMW Group Qualitätsmanagement Kaufteile		SPQM Massnahmen pro Umfang				Name: Hans-Jürgen Dülkewitz Datum: 28.08.2004 Postleitzahl: U1-T-13 Telefon: +49-30-3095-2359	
Projekt		K-T1		RE		Status: Freigegeben	
Verantwortlicher		Guido Hofbauer - U1-M-1					
Umfang		Lieferant: 101822-10		Modul: 84		NAEL	
Hintergrund		Tomas		NAEL		Risiko: hoch	
		Verantwortlicher: Wolfgang Rentschler - U1-M-2 Bernhard Kötter - U1-E-3 Hans-Jürgen Dülkewitz - U1-T-13 Robert Tappener - U1-T-3488		FIBNRID: 2091021490			

Fig. 2 SPQM questionnaire, free form BMW2.

We received the SPQM questionnaire at the same time as other nomination candidates. The group had a month to prepare for the external evaluation of BMW experts according to the SPQM questionnaire. Each individual area of audit consists of a large number of questions, which enable the auditors to provide the criteria for the selection of the best among all candidates at the end of the audit. While waiting for the arrival of the auditors from the company BMW, the project team decided to manufacture the first

prototype of the 3D model, which we had received from the R&D department in Munich.

We decided to take a risk and while preparing for the assessment SPQM, we invested additional effort into the production of the first prototype. We were well aware of the complexity of all the areas of the audit, and the advantages of our business functions as well as our weaknesses. Having enough experts as well as knowledge in the field of rapid prototype technology, we recognized the production of the first prototypes as one of our advantages. Looking back on the then quick decisions, and on today's cooperation with BMW, we can conclude that we acted well.

In its first phase, the future plan included the purchase of the material, all the tubes and sheets of suitable dimensions, and also the material on the basis of the drawing of the frame. Simultaneously with the acquisition of all the materials, from which we had to manually manufacture the individual frame components, we focused on components manufacturing via prototyping technologies.

According to the technologies of rapid prototyping known and available at that time in Slovenia, we decided on the technology of laser sintering, DMLS – direct metal laser sintering, to manufacture both pedals and the exhaust bracket. The device for direct metal sintering of metal powders was owned by the company RTCZ Izlake, which agreed to manufacture all three components. The device enabled a good shape accuracy and mechanical property of the sintered products, which were later welded together. And what was then the most important; we received all three parts three days after sending 3D models to the company RTCZ. The remaining four, production components – pressed parts – were manufactured on a lathe and a milling machine in the tool workshop in Tomos.

A lot of knowledge and experience were invested in the manufacturing of the complex metal sheet components. There are many ways to manufacture a product by reading a drawing. However, due to the time limit, we decided to develop all sheet metal components in 2D shape using the program Catia. This was followed by the cutting of sheet metal with a water-jet technology, which, unlike the technology of laser cutting, maintained the cutting edge without excessive heat load and consolidation of the material. Consolidation of the material could later in the prototype workshop complicate the process of bending and adjusting the products to the requirements of the steel frame drawing.

We managed to purchase and manufacture all the subassemblies needed to build the frame in time. In the prototype workshop a colleague manually shaped all prepared sheet metal parts and other profiles into elements according to the accompanying drawings. Figure 3 shows the process of manufacturing the element, support steel sheet from 3D model to 2D cutting, welding and shaping into the required structure.



Fig. 3 Process of prototyping the complex element.

This was followed by the required phase of adjustment and welding of all components to get the final product. The frame was welded manually using MIG procedure, with 3.5 m of welded joining parts between all the elements. Prototype required a lot of knowledge in the different welding processes between the different materials that we use. Construction of such prototypes is a unique process. Masters of producing such prototypes need a lot of experience, ingenuity and knowledge of modern technologies.

Figure 4 shows the first prototype, successfully and timely implementable with the project team.



Fig. 4 First prototype BMW K71 rear frame.

The first prototype was manufactured in good time just before the arrival of BMW's external auditors. BMW's external auditors' assessment lasted for three days. The supplier selection process aims at appointing the best available suppliers in the world, in terms of product quality, lifetime costs, product innovation, project management and delivery process capability and supply performance. Figure 5 shows the completed SPQM form by the BMW auditors with the decisions shown in the right-hand traffic light of each individual condition of the audit.

BMW Group		SPQM				Name: Stefan Ganten	
Quality management		Variable report				Date: 28.11.2005	
Project:		K71	TOP		01.03.2008	Prozess: UV-T-54	
Responsible:		Reto Raggli - UV-T-55				Phone: +49-30-3355-2010	
Supplier: 101822-10		Module: 84		Risk: high		Status:	
Volume: Tomos		Responsible: Wolfgang Rottler - UV-T-52				Date: 203/18/12/07	
Measures:		Responsible: Bernhard Dierker - UV-T-67					
		Note: Liefermenge Differenz: UV-T-13					
		Liefer: Ganten - UV-T-54					
Comment: Datum letzte Aupak: 28.11.2005 Status: Gels IQ gelb LEM grün -> PS nicht noch erfüllt und Abgleich Messverfahren: Progress GWS: Anlaufzeit: PZ3 durchgeführt: Wiederholung PS-Seite							
K06 51-02-09: EMPB-Termin: Bauteil erstellt in Bemessung: nächster Reibschritt: Ende Januar 2009							
Checkpoint: RET: Prozessentwicklung und Anlaufleistungsprozess (2)				MS/OP: 0		Term: 01.03.2005	
Headline: Prozessentwicklung / Prozessoptimierung						G1/G2 a: G	

Fig. 5 SPQM questionnaire, example in Tomos², 2003.

After the selection procedure from BMW Tomos factory and our team has been nominated the main product supplier. Contracting is the next step. The objective of the supplier contracting process is to create the best supply contract for the component, in terms of clearly stated requirements, agreed targets, achievable objectives and compatible terms and conditions. Tomos as the nominated supplier takes great responsibility for the overall quality management.

Immediately after the nomination by BMW, the production of three functional prototypes was one of the indicative priorities. All three prototypes were demanded to meet the requirements of the drawing, regional European and internal technical standards of BMW, among which the following can be mentioned: BMW N 11369.0; BMW N 11399.0; BMW N 11221.0; BMW N11329.0; GS 96003; GS 90006; GS 90011; GS 90013; GS 97010.

Figure 6 shows the process of manual welding of a functional prototype on a massive steel table. The steel table is made by a fine grinding process and to tight tolerance, which enables very precise manufacturing of the first prototypes. All three functional prototypes were made using CNC milling technologies, cutting all sheet metal with a water jet, complex manual design of semi-manufactured products and finally welding individual parts into a whole.



Fig. 6 Functional prototype.

All the nominated suppliers were required by BMW to manufacture three functional prototypes according to their technical requirements and standards. In this way, three motorcycles were assembled, ready to be tested on different continents. Due to different temperature conditions and consequently different road loads, BMW was able to perform vehicle sustainability and dynamics testing and received the results that influenced subsequent modifications in individual motorcycle parts.

Since all functional prototypes had to be precisely designed according to the dimensions and allowed tolerances in the drawing, each prototype had to be measured on a 3D measuring machine before being shipped to Munich. Figure 7a shows the measurement of the functional prototype on the 3D measuring machine DEA. Figure 7b shows the partial results of the measurements of some important points when assembling the sub-assembly.

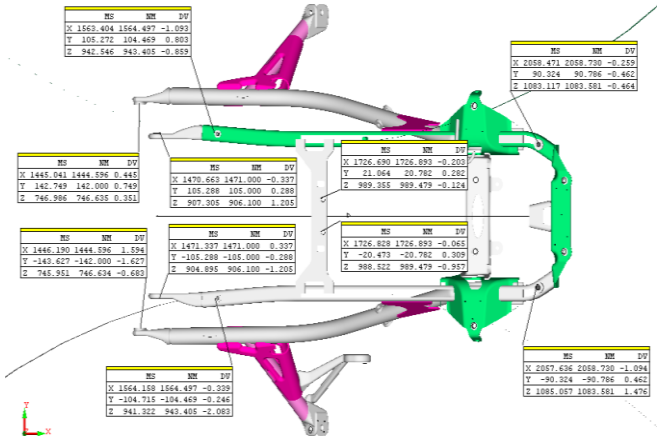


Fig. 7 Measuring protocol and measuring results.

3. FMEA analysis

After the functional prototypes were successfully manufactured, the planning and design of individual processes followed, including the acquisition of materials and sub-assemblies, the complex industrialization of the product, and the shipment of the product to Berlin, where the BMW motorcycle is installed.

The planning and management of implementation processes included the planning of the realization, capacities, resources and materials, and the associated integration of external suppliers and partners. The quality manager at Tomos understood the importance of planning the operation and risk analysis and was well aware and capable of managing the opportunities for creating a product value through the FMEA quality system.

The FMEA Failure Mode and Effects Analysis system, or the analysis of methods of cancellation and consequences, enables the use of specific process methods for managing processes of creating a process network.

Process Failure Mode and Effects Analysis (PFMEA) looks at each process step to identify risks and possible errors from many different sources. The sources most often considered are people, methods, material, machinery, measurement, and environment. All the steps in risk assessment and business impact analysis using the PFMEA method are shown in Figure 8 below.

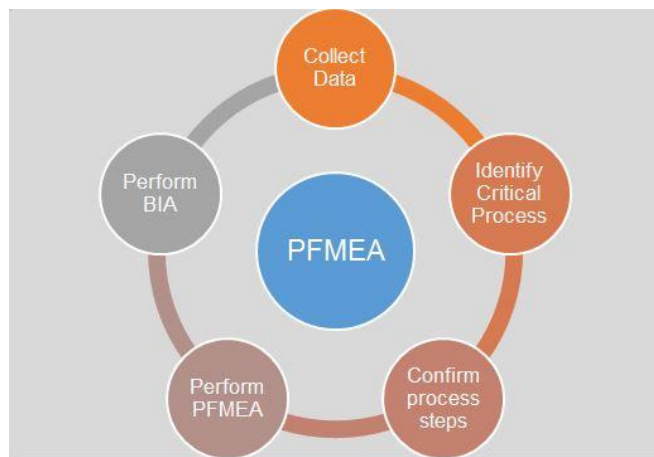


Fig. 8 Steps to conduct Risk assessment and Business Impact Analysis³.

A number of people participated in the PFMEA process, including the coordinator of FMEA - the director of quality, the project leader, the sheet metal processing technologist, the welding and surface protection with varnishing technologist, the quality assurance technologist, the purchasing and logistics technologists and the production manager. When manufacturing the BMW frame, the working group identified possible causes of a possible defect and the corresponding sequence of errors (what could happen?).

Figure 9 shows the form into which we entered identified and collectively received information about the process of manufacturing the BMW frame. For each function, we determined the possible method of failure, the potential consequences of errors, and the probability of detecting the cause of errors.

TOMOS		PROCESS FMEA										Datei: "Cm"		Datum: 01.07.2019	
Change	Item	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
1	Change	Item	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
2	Change	Item	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
3	Change	Item	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
4	Change	Item	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
5	Change	Item	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
6	Change	Item	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
7	Change	Item	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
8	Change	Item	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
9	Change	Item	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
10	Change	Item	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
11	Change	Item	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
12	Change	Item	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
13	Change	Item	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
14	Change	Item	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
15	Change	Item	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
16	Change	Item	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
17	Change	Item	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
18	Change	Item	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
19	Change	Item	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
20	Change	Item	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
21	Change	Item	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
22	Change	Item	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
23	Change	Item	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
24	Change	Item	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
25	Change	Item	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
26	Change	Item	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
27	Change	Item	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
28	Change	Item	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
29	Change	Item	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
30	Change	Item	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
31	Change	Item	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
32	Change	Item	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
33	Change	Item	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO

Fig. 9 PFMEA obrazec, Tomos, 2004.

PFMEA is a methodical approach used for identifying risks on process changes. The Process FMEA initially identifies process functions, failure modes their effects on the process. If there are design inputs, or special characteristics, the effect on end user is also included. The severity ranking or danger of the effect is determined for each effect of failure. Then, causes and their mechanisms of the failure mode are identified. The assumption that the design is adequate keeps the focus on the process⁴.

A high probability of a cause drives actions to prevent or reduce the impact of the cause on the failure mode. The detection ranking determines the ability of specific tests to confirm the failure mode / causes are eliminated. The PFMEA also tracks improvements through Risk Priority Number (RPN) reductions. By comparing the before and after RPN, a history of improvement and risk mitigation can be chronicled.

Risk is the substitute for failure on new processes. It is a good practice to identify risks for each process step as early as possible. The main goal is to identify risk prior to tooling acquisition. Mitigation of the identified risk prior to first article or Production Part Approval Process (PPAP) will validate the expectation of superior process performance. Risks are identified on new technology and processes, which if left unattended, could result in failure.

4. Conclusions

People who work in organizations, in the private or public sector, must be aware of the quality policies and their own contribution to effectiveness, including better quality of implementation. The introduction of a quality management system is, of course, the strategic decision of each organization. In order to achieve high customer satisfaction, customer expectations must first be met even when they are not precisely defined, presumed or binding. The challenge is to recognize these requirements, as the expectations of customers change over time. Requirements are today becoming defined expectations. By this, in addition to clearly defined requirements and the application of standards, undefined and unspoken expectations are also referred to. This change of perspective is interpreted by successful organizations as a trend, a direction of development, and a larger focus on customers.

A few years before the new ISO 9001: 2015 standard was issued, our project team was already well aware of the fact that risk and uncertainty can only be the result of perceiving the opportunity. At that time, we managed to obtain the nomination for the manufacture of a complex BMW product because of our desire, ingenuity and knowledge that was then more competitive than that of the others. The product – the first prototype – made with different technologies of rapid prototyping was presented to a group of BMW auditors. The effort we had invested into creating the prototype and the successful completion of the assessment SPQM and PFMEA brought us BMW's assurance and official nomination for the serial production of the steel frames BMW F 800 S and BMW F 800 ST. The nomination for the manufacturing of this complex product still guarantees the company the serial production of complex steel components and welded components made from aluminium alloys not only for BMW but also for other well-known motorcycle manufacturers.

5. References

1. Koubek, A. Priročnik ISO 9001:2015, Hanser Verlag Munchen, Ljubljana, 2016
2. Tomos, Project documentation BMW K71, 2003
3. www.linkedin.com/pulse/how-conduct-bia-risk-assessment, january 2018
4. <http://asq.org/learn-about-quality/process>, january 2018

AN APPLICATION OF A NETWORK SCIENCE TOOL FOR EXAMINING AND ANALYSING THE STRUCTURE AND TOPOLOGICAL PROPERTIES OF PUBLIC-TRANSPORT NETWORKS: A CASE STUDY

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Abstract: More than one century network science (NS) has been extensively used in numerous studies of different research fields, including public transport (PT). This work presents an application of a NS tool enabling to explore complex public-transport networks (PTNs). This tool explores networks for small-world, scale-free and random network characteristics, in a case study to examine and analyze, by using NS concepts, two PT systems - Washington DC's Metro Network (WMN) and Oslo's Metro Network (OMN). The performed analyses focused on the structure and the topological properties of the examined networks. As the networks have longer average path lengths, compared with random networks, and because of not being clustered, these metro networks demonstrated they are not small-world networks. The analyses also show that in contrast to the OMN the WMN has certain characteristics associated with scale-free networks; that is, a small number of highly connected nodes (hubs) and node degree distribution that can be represented by a power-law function. Nevertheless, it still cannot be considered as a pure scale-free network because of its empirical distribution which is better approximated by an exponential rather than a power-law function. The metro WMN cannot be considered a random network because of having hubs. Thus, it is concluded that the examined WMN is an evolving complex network.

Keywords: NETWORK SCIENCE, PUBLIC-TRANSPORT NETWORK, NETWORK TOPOLOGICAL PROPERTIES, NETWORK ANALYSIS, NODE-DEGREE DISTRIBUTION, AVERAGE SHORTEST PATH LENGTH, NETWORK'S EFFICIENCY

1. Introduction

Network science [1] or the science of networks has revealed more opportunities for researchers and scientists who work in different research areas. One of the first attempts for application of network science as a tool is made by Euler [2] in the 18th century in resolving the well-known Koenigsberg seven bridges problem and De Solla Price [3] who pictured the network of scientific papers through linking each published paper to the papers that are directly associated with it. While network science is based on graph theory, it is also comprised of methods and approaches rooted in other research fields. Basically, network science is a result of the convergence of many fields, such as network analysis [4], social network analysis [5,6,7,8] as well as physical [9] and biological sciences [10]. Thus, by providing new tools, mechanisms, and improved methods, NS has enabled exploring, examining, analyzing, modelling and simulating the existing variety of complex networks through evaluating their characteristics and properties in different ways. Recent findings show that NS made it possible to understand complex networks' structure, topological properties and dynamics [11,12]. In this way, by revealing networks' strengths and weaknesses, and thereafter, establishing directions to improving networks' structure, NS has facilitated overcoming problems that have yet to be solved by applying existing methods. Theories related to NS and the findings of complex systems are a good foundation for practical studies of the structure of real-world networks (including PTNs) through an evaluation of topological properties such as average network clustering coefficient (appearing below only as clustering coefficient, CC), average network shortest path length (appearing below as an average path length APL), node degree distribution (NDD) and network efficiency (local and global) in different research fields, including public transport network design and operations [13,14].

2. Prerequisites and means for solving the problem

The limitations of the existing approaches and tools for analyzing real-life complex networks, such as PTNs, place a number of new challenges for researchers and scholars in terms of the data required, methods to be applied, and software to be used. Recently Dimitrov and Ceder [15] developed a method enabling to examine and analyse complex public-transport networks (PTNs) incorporating computer programming, large-scale network- and statistical data analysis techniques. The method was tested on a case study.

The objective of this study, which is practically oriented, was to examine and analyse the structure and topological properties of real-world public-transport networks on a case study by using an existing NS tool which uniquely combines computer programming techniques, implementation of known algorithms, network- and data analysis. A network-science perspective was applied, while seeking to reveal network strengths and weaknesses.

In order to achieve the objective, the following essential tasks have been completed:

- (i) Collecting, processing and analyzing data on a comparative basis of a case study;
- (ii) Examining the structure of the observed PTNs and evaluating their topological properties and characteristics by performing network- and statistical data analysis using the NS tool;
- (iii) Drawing reasonable conclusions and outlining the possibilities for a further research work for improving public-transport networks' operation.

A flow-chart of the tool applied for processing the general transit feed specification (GTFS) [16] data used, the calculations made, further data processing as well as all types of analyses performed, is shown in Fig. 1.

3. Solution of the examined problem

3.2. Data collection and data processing

The objects of examination in this case study were the subway (metro) networks in Washington DC (USA) and Oslo (Norway). The first of the observed public-transport metro networks in Washington DC, WMN, (Figures 2a and 2b) is composed of 91 metro stations serviced by six lines traveling between the terminal stations. The second of the observed metro networks in Oslo, OMN, also known as T-bane or Oslo Tunnelbane (Fig. 3) is composed of 101 metro stations serviced by five lines traveling between the terminal stations. It is interesting to mention that only 17 out of 101 of the stations in the Oslo's metro network are underground or indoors.

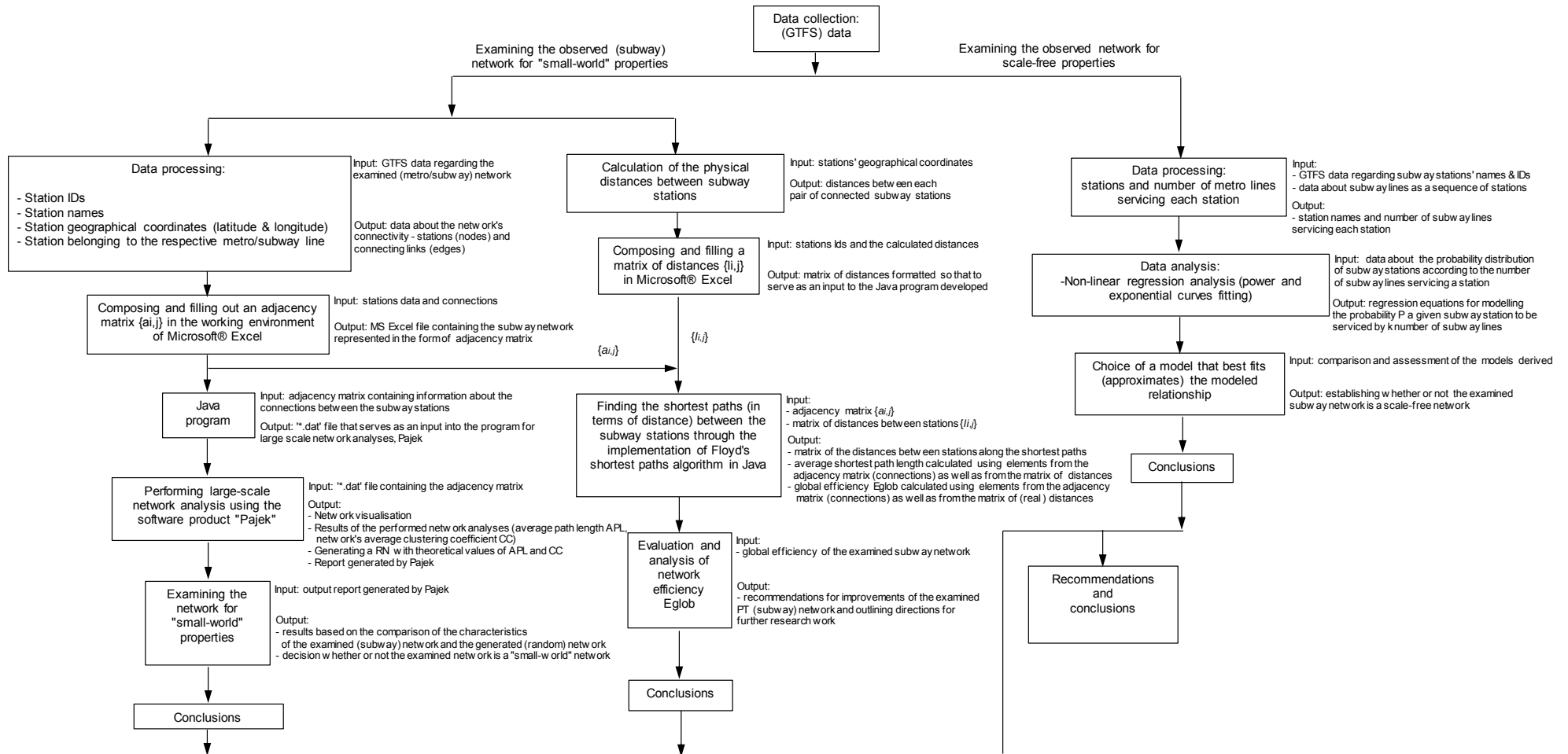


Fig. 1. Flowchart representing the sequence of steps outlining the logic of the proposed tool for examining and analysing PT (subway/metro) networks

3.3. Examining the subway network for small-world properties

Because of differences in data formats and descriptions used by the public transport operators within the GTFS feeds [17], in contrast to Dimitrov and Ceder (2016) who extracted and processed the required GTFS data by means of a Java program, in this work the data feeds in the form of text (*.txt) files. The GTFS data [18,19], provided by the Washington Metropolitan Area Transit Authority as well as by Ruter – the management company that plans, coordinates, orders and markets public transport in Oslo, was directly imported and further processed within the Microsoft Excel® working environment. As a result, useful information regarding the subway stations has been extracted, such as station names, codes (an identifying number), geographical coordinates (latitude and longitude) and the sequence of stations along each of the metro lines in the examined networks. Then, the data about the connections between each pair of stations have been further used to assign values in the Excel adjacency matrix $\{a_{i,j}\}$ showing the connectivity between each two nodes within the network, i.e., between each two subway stations. For example, if station i is directly connected by link (railway section) to station j , then the matrix element $a_{i,j} = 1$, otherwise $a_{i,j} = 0$. As a result, the subway network examined is represented as an undirected, unweighted graph within which each node represents a subway station (in this network the number of stations in both directions is the same and these stations are located opposite one another) and the edges (having length 1) represent the connection between two stations. The presence of a link between two stations means that there is at least one subway line servicing these stations.



Fig. 2a. Washington DC Metro system map, adapted from Washington Metropolitan Area Transit Authority [20]

3.3.1. Evaluation of the average network's shortest path length and the average network's clustering coefficient

The information extracted from GTFS files and saved in a MS Excel file is thereafter imported into a developed Java software program automating and accelerating the processing of the data. Within the Java program, the imported adjacency matrix data is then processed, transformed, and as a result exported and saved into a (*.dat) file that served as an input into the software program for large scale network analyses Pajek [23,7,8] which was used to visualize the network and perform further analyses. By using Pajek, topological properties of the examined network, such as average

path length (APL), clustering coefficient (CC) and average network's node degree (ANND), have been computed. Alternatively, apart from Pajek, the average shortest path length for undirected graphs was calculated within the developed Java software program by using the following formulae [24]:

$$(1) L = \frac{2}{N(N-1)} \cdot \sum_{i=1}^N \sum_{j=i+1}^N d_{i,j},$$

where:

L – APL;

N – number of nodes (stations) in the network;

$d_{i,j}$ – the shortest path (in terms of number of sections) between any two pairs of nodes i and j , and $d_{i,j} = d_{j,i}$.

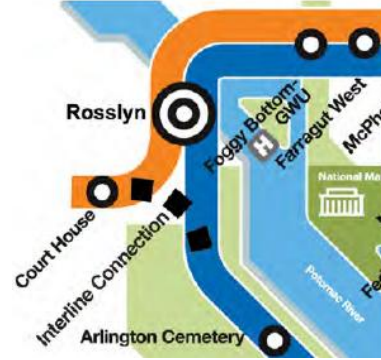


Fig. 2b. Washington DC Metro system map, Planned improvements, adapted from Momentum [21]



Fig. 3. Oslo Metro system map [22]

Formula (1) was incorporated within the Java program not only to calculate the average network shortest path length as a number of consecutive route sections, but also in kilometers by substituting in $d_{i,j}$ the distances between stations along the shortest paths computed through the Java implementation [25] of Floyd's shortest path algorithm [26]. To verify the output results of the software program developed, the value of the APL (in number of sections) calculated with the Java program was compared with the APL computed by using Pajek.

In order to discover whether the examined public-transport metro networks exhibit small-world characteristics, their properties, as shown in Table 1 and Table 2, have been compared to those of random Bernoulli/Poisson [8] networks that were generated with Pajek using the same number of nodes and average network node degree as an input, as did Watts and Strogatz [27].

Table 1. Washington DC's metro network compared with a random network generated using the software product Pajek

Public transport mode	Networks	Network properties				
		Nodes	Edges	ANND	CC	APL
Subway/ Metro	Examined subway/ metro network	91	93	2.044	0.0000	11.51
	Generated random (Bernoulli/Poisson) network		95	2.088	0.0156	5.06

Table 2. Oslo's metro network compared with a random network generated using the software product Pajek

Public transport mode	Networks	Network properties				
		Nodes	Edges	ANND	CC	APL
Subway/ Metro	Examined subway/ metro network	101	101	2.000	0.0000	14.68
	Generated random (Bernoulli/Poisson) network		105	2.079	0.0718	5.80

Based on the comparison made between the empirical (calculated) and the theoretical (generated) values of the topological properties, it can be concluded that examined metro networks (Washington DC's and Oslo's), characterized with average path lengths of 11.51 and 14.68 sections, respectively, which exceed more than twice the APL for the generated random networks, and both having clustering coefficient equal to 0, cannot be considered small-world networks. This is because the derived values differ from what is given as a definition for small world graphs [28]: "A small-world graph is a large- n , sparsely connected, decentralized graph ($n \gg k_{max} \gg 1$) that exhibits a characteristic path length close to that of an equivalent random graph ($L \approx L_{random}$), yet with a clustering coefficient much greater ($C \gg C_{random}$)."

3.3.2. Evaluation of network efficiency

In contrast to Watts and Strogatz [27], examining real life networks by using average path length (as a global property) and clustering coefficient (as a local property), Latora and Marchiori [29] introduced the concept of network efficiency – global and local – in their work, measuring the communication between the nodes within a network. In this way, they examined networks' local and global behavior with local efficiency E_{loc} and global efficiency E_{glob} instead of using CC and APL. In other words, E_{loc} and E_{glob} replace CC and APL. It is known [29] that small-world networks have both high E_{loc} and E_{glob} .

As the efficiency $\varepsilon_{i,j}$ between nodes i and j is inversely proportional to the shortest path $d_{i,j}$ between these two nodes [30]:

$$(2) \quad \varepsilon_{i,j} = \frac{1}{d_{i,j}},$$

the global efficiency E_{glob} was calculated via the following formulae implemented in the Java program developed:

$$(3) \quad E_{glob} = \frac{2}{N \cdot (N-1)} \cdot \sum_{i=1}^N \sum_{j=i+1}^N \varepsilon_{i,j} = \frac{2}{N \cdot (N-1)} \cdot \sum_{i=1}^N \sum_{j=i+1}^N \frac{1}{d_{i,j}},$$

where E_{glob} takes values within the range $0 \leq E_{glob} \leq 1$ [29], i.e., $E_{glob} \in [0; 1]$. Ideally, the global efficiency, considered [30] as the efficiency of the whole network, would have the value of $E_{glob} = 1$, which could be valid in complete graphs in which there is an edge between each pair of nodes connecting them.

The results showing that the global efficiencies for both the metro networks having values $E_{glob} = 0.14$ (Washington DC) and

$E_{glob} = 0.12$ (Oslo) means that these networks have only 14% and 12% of the efficiency of the ideal one ($E_{glob} = 1$), the latter having a direct line from each station to the others. The obtained low values are an indication of poor global efficiency of the networks, lacking direct connections between their stations. The low global efficiency values only show that possible network improvements could be achieved in network's topology (and not by the level of service it provides) through the construction of new links (sections), as long as it is proven that the cost incurred for this would be justified.

Since the network analyses, performed with the software program Pajek for the metro networks studied, established that they are not clustered at all ($CC = 0$), the alternative topological property of the clustering coefficient (which is the local network's efficiency E_{loc}) was not evaluated. Again, the value 0 of CC means that there are no metro stations within the networks having neighbouring stations connected to one another. Therefore, it can be concluded that the networks examined are not fault tolerant in the context that each disruption (disconnected stations) would significantly affect the transport service as there are no alternative connections between the stations. This leads to the conclusion that the higher the number of connections in the networks, the greater the fault tolerance of the networks. This can be achieved by increasing connectivity between stations in the network through constructing more sections linking important subway (transfer) stations – hubs.

The Washington Metropolitan Area Transit Authority's (WMATA) strategic plan [21] for 2013-2025 discusses constructing a rail track (section) that would serve as a connection between the Blue and Orange/Silver metro lines (see the Blue line's Arlington Cemetery station and the Silver/Orange Court House station as shown in Fig. 2b), as one of two potential alternatives. This would be a new edge within the existing subway network enabling passengers to make one seat (non-transfer) trips between Dulles Airport, Tysons Corner, Ballston, The Pentagon, National Airport, and the Alexandria metro stations, thus avoiding the need to travel through the core of the network. Both alternatives would result in an increase of train frequency with five more trains per hour, thus leading to an increase in the vehicle carrying capacity provided for up to 4000 passengers per direction per hour. People from WMATA expect the above measures to reduce the average passenger waiting time by an average of three minutes for around 16000 trips.

To explore how the above constructive changes planned for the subway network would affect the APL, CC, and the network's (global) efficiency, the newly created link was added as an edge into the adjacency matrix $\{a_{i,j}\}$, then the approach described in sections 3.3.1 and 3.3.2 was applied. As a result, the following values of the evaluated topological properties of the network examined were identified: APL = 11.32 sections in the proposed network as opposed to 11.51 for the existing network, and clustering coefficients, 0.0252 as opposed to 0, respectively. The network efficiency remains unchanged (0.14). Even after the expected changes, the network is still not a Small-world network (SWN) as it has a clustering coefficient ($CC_{ESP} = 0.0252$) commensurate to that of the Random network (RN) ($CC_{RN} = 0.0156$) and still quite long APL (11.32 sections) compared to that value for RN (5.06 sections). Thus, as expected, the structural change above (only one new link added) does not globally affect network connectivity. The positive effect on the network can be felt locally as the increased value of CC from 0 to 0.0252 means that the network would become more faults tolerant. This means that in an event of a breakdown (a disconnected link in the triangle Arlington Cemetery, Court House and Rosslyn), the network would still be functioning because of the presence of an alternative (a newly constructed) connection.

3.4. Examining the subway network for scale-free properties.

3.4.1. Data analysis

Based on the GTFS data processed regarding the metro stations and the metro lines in the two networks (see Figures 4 and 5) it turned out that the majority of the stations (76 stations) in the first (Washington DC's) network are serviced by only one metro line (48 stations) or two metro lines (28 stations). There are also 13 more stations serviced by three lines. On the other hand, there are only two stations serviced by four and five subway lines, respectively, that can be considered hubs. Thus, the network topology of the metro network examined resembles the topology of scale-free networks in which most of the nodes have a small number of links, with only a small number of nodes (called hubs) having multiple connections [31], which is in contrast with the second examined metro network in Oslo. Similar to the Washington's metro network, the majority of the stations in the Oslo's metro network (89 stations) are also serviced by one metro line (61 stations) or two lines (28 stations). However, Oslo's network does not have small number highly connected stations (hubs). Instead, it is characterized with 3 stations serviced by 3 lines, another 3 stations serviced by 4 lines, and 6 more stations serviced by 6 metro lines. For the sake of clarity, the 5th line of the Oslo's metro network (in green) can be considered as composed of two separated lines as it runs twice through nine stations and follows two separate routes. That is, when a vehicle runs in the direction from Vestli to Sognsvann (see Fig. 3), it can either pass through the station "Ullevål stadion" and continues to station Nydalen (the first route), or continues in the direction station Berg.

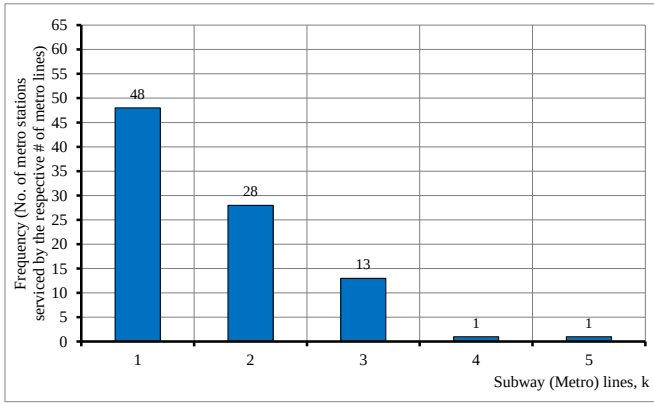


Fig. 4. Distribution of the Washington DC metro stations according to the number of lines k servicing a station

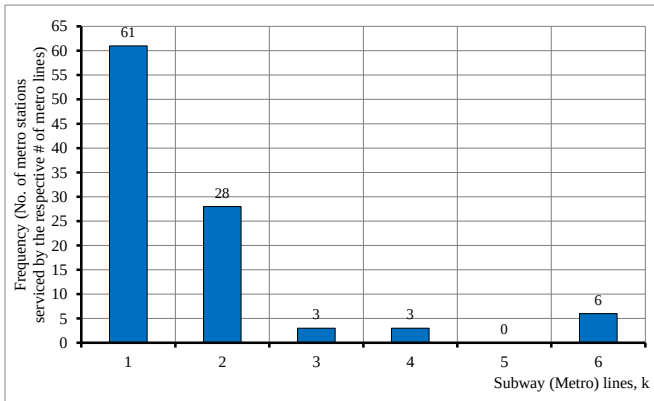


Fig. 5. Distribution of the Oslo's metro stations according to the number of lines k servicing a station

With the intention of confirming or falsifying the above supposition, in order to estimate the probability $P(k)$ with which a randomly selected station is being serviced by k lines, two types of functions – a power-law [32,33] and exponential – were approximated through performing a statistical data analysis [34] as shown in Table 3 (for Washington DC's network) and Table 4 (for Oslo's network) below. It is obvious (from Table 3) that the coefficient A in the power function has value which is close to 1, i.e.: $A = 0.948 \approx 1$. Therefore, it can be accepted that the formula $P(k) \sim k^{-B}$ satisfactorily represents the established statistical relationship between P (the dependent variable) and k (the

independent variable), i.e., $P(k) \sim k^{-2.61}$ in which the scaling factor B falls within the range $2 < B < 3$ [31]. Based on this result, it can be accepted that the network examined exhibits characteristics of scale-free networks. On the other hand, as shown in Table 3, the results of the least squares fitting procedure performed for the empirical values also revealed that the observed nonlinear relationship between P and k is better fitted by means of an exponential ($R^2 = 0.902$) rather than a power-law function ($R^2 = 0.813$). In contrast to the Washington DC's metro network the low R-square value ($R^2 = 0.69$) in Table 4 clearly shows for the Oslo's network that the probability $P(k)$ is not satisfactorily fitted by a power-law function $P(k) \sim k^{-B}$ describing scale-free networks, which means that this network does not exhibit the specific characteristics for scale-free networks. Therefore, it does not appear that the studied metro network of Oslo is a scale-free network.

Table 3. Derived regression equations with their estimated parameters, metro network Washington DC

PT network	Method	Function	Type	Parameter	Value	R-square
Subway lines	Least squares fitting	$P(k) = A \cdot k^{-B}$	Power	A	0.948	0.813
				B	2.610	
		$P(k) = A \cdot e^{-B \cdot k}$	Exponential	A	2.149	0.902
				B	1.100	

Table 4. Derived regression equations with their estimated parameters, metro network in Oslo

PT network	Method	Function	Type	Parameter	Value	R-square
Subway lines	Least squares fitting	$P(k) = A \cdot k^{-B}$	Power	A	0.505	0,69
				B	1.656	

Regardless of the fact that for the Washington DC's metro network examined the presence of a small number of highly connected nodes (considered hubs) was established, and that a power-law function satisfactorily describes the node degree distribution of that network, it still cannot be considered a purely scale-free network. The fact that the examined network is better described by an exponential rather than a power-law function supports this statement. As Barabási and Albert [35] wrote, "a common feature of the ER and WS models is that the probability of finding a highly connected vertex (that is, a large k) decreases exponentially with k ; thus, vertices with large connectivity are practically absent." Accordingly, "such networks are called the exponential networks" [36]. It is known [37] that in RNs, each node has approximately the same number of links, which means that the node degree k_i of each node i is close to the average network's node degree $\langle k \rangle$, i.e. $k_i = \langle k \rangle$. In the case study, the network was presented as of bus-station network which "retains the basic topological features of public transportation networks" [38]. In this network the average node degree having a value of 1.67 lines servicing each node is on the average 2.4 and 3.0 times less than the degree of the two highly connected nodes in the network (serviced by four and five subway lines, respectively). Therefore, due to the presence of hubs, the network also cannot be considered as an entirely random network. According to Albert and Barabási [39] who wrote that "if all processes shaping the topology of a certain network are properly incorporated, the resulting $P(k)$ often has a rather complex form, described by a combination of power laws and exponentials", it can be expected that the network examined should have a complex form, which shows that the PTN examined can be considered a complex network. The latter is not valid for the metro network in Oslo as the $P(k)$ is neither good fitted by an

exponential nor by a power-law function. In accordance with Albert and Barabási who wrote that the “evolving networks can develop both power-law and exponential degree distributions” [39] as the network examined can satisfactorily be described by a power-law as well as by exponential functions, it can be expected for it to be an evolving network.

4. Conclusion

The results of the examination of two real-life metro networks and the analyses performed as part of this case study, by using the proposed network science tool, have led to a few general conclusions that can be summarized as follows:

The network analysis performed in exploring the topological properties of the Washington DC's and the Oslo's metro networks showed that when represented in an L-space network topology [40], the networks examined do not exhibit small-world properties, and hence, they are not small-world networks.

The examination of the Washington DC's metro network and its analyses also showed that the network is neither a scale-free nor random network; this is based on the consideration of network's node degree distribution, the number of the metro lines servicing each station and representing the network as a bus station network. In contrast to the Oslo's metro network, the metro network in Washington appears to be a complex network.

The analysis considering the networks' global efficiency, performed by using network science concepts and findings, showed that both the metro networks examined appear not to be faults tolerant. In case of a railway section's breakdown, this would significantly affect the quality of the transport service provided, because of the lack of alternative connections linking the disconnected metro stations. These results illustrate connectivity weaknesses, thus indicating that there is a room for improving the connectivity between the stations within the networks.

This case study does not only examine real-world metro networks with their topological properties, but also performs network's reconstruction analysis for the Washington DC's network. That is, it considers a hypothetical construction of a section connecting two stations within the Washington DC's network to show that a new link would not sensibly improve the global network's efficiency; this is explicated by measuring the presence of direct connections between the metro stations of the network.

It turned out that both the metro networks examined have low valued global network's efficiencies. This global efficiency does not take into account the routes of the operational metro lines and the passenger trips. Thus, the above statement does not necessarily mean that these networks are inefficient in serving passengers and covering the existing PT demand.

References

- [1] Börner, K., Sanyal, S., & Vespignani, A. (2007). Network science. *Annual review of information science and technology*, 41(1), 537-607.
- [2] Euler, L. (1953). Leonhard Euler and the Königsberg bridges. *Scientific American*, 189(1), 66-70.
- [3] De Solla Price, D. J. (1965). Networks of scientific papers. *Science*, 149(3683), 510-515.
- [4] Boissevain, J. (1979). Network analysis: a reappraisal. *Current anthropology*, 20(2), 392-394.
- [5] Wasserman, S., & Faust, K. (1994). *Social network analysis: Methods and applications* (Vol.8). Cambridge university press.
- [6] Wasserman, S. (1980). Analyzing social networks as stochastic processes. *Journal of the American statistical association*, 75(370), 280-294.
- [7] De Nooy, W., Mrvar, A., & Batagelj, V. (2005). *Exploratory Social Network Analysis with Pajek*, Cambridge University Press, New York.
- [8] De Nooy, W., Mrvar, A., & Batagelj, V. (2011). *Exploratory Social Network Analysis with Pajek: Revised and Expanded Second Edition*. Cambridge University Press.
- [9] Barabási, A. L. (2013). Network science. *Philosophical Transactions of the Royal Society of London A: Mathematical, Physical and Engineering Sciences*, 371(1987), <http://rsta.royalsocietypublishing.org/content/roypta/371/1987/20120375.full.pdf>.
- [10] Lewis, T. G., (2009). *Network science*, John Wiley & Sons.
- [11] Boccaletti, S., Latora, V., Moreno, Y., Chavez, M. & Hwang, D.U. (2006). Complex networks: Structure and dynamics. *Physics Reports*, 424(4), 175-308.
- [12] Newman, M. E. (2003). The structure and function of complex networks. *SIAM review*, 45(2), 167-256.
- [13] Ceder, A. (2016). *Public transit planning and operation: Modeling, practice and behavior*. 2nd ed. Boca Raton, FL: CRC Press.
- [14] Ceder, A. (2007). *Public transit planning and operation: Theory, modeling and practice*. London: Elsevier, Butterworth-Heinemann.
- [15] Dimitrov S. D., Ceder, A., (2016). Method of examining the structure and topological properties of public-transport networks, *Physica A: Statistical Mechanics and its Applications*, 451(1), 373-387.
- [16] <https://developers.google.com/transit/gtfs/>
- [17] <https://developers.google.com/transit/gtfs/#overview-of-a-gtfs-feed>
- [18] <http://transitfeeds.com/p/wmata/75>
- [19] <http://transitfeeds.com/p/ruter/240>
- [20] http://wmata.com/pdfs/pocket_guides/english.pdf
- [21] <https://www.wmata.com/momentum/momentum-full.pdf>
- [22] <https://ruter.no/globalassets/rutetabeller/oslo/t-banen-linjekart-03042016.pdf>
- [23] <http://Pajek.imfm.si/doku.php?id=pajek>
- [24] Prettejohn, B. J., Berryman, M. J., & McDonnell, M. D. (2011). Methods for generating complex networks with selected structural properties for simulations: a review and tutorial for neuroscientists, *Frontiers in computational neuroscience*, 5,11.
- [25] Lau, H. T. (2006). *A Java library of graph algorithms and optimization*. CRC Press.
- [26] Floyd, R. W. (1962). Algorithm 97: shortest path. *Communications of the ACM*, 5(6), 345.
- [27] Watts, D. J., & Strogatz, S. H. (1998). Collective dynamics of 'small-world' networks. *Nature*, 393(6684), 440-442.
- [28] Watts, D. J. (1999). Networks, Dynamics, and the Small-World Phenomenon 1. *American Journal of sociology*, 105(2), 493-527.
- [29] Latora, V., & Marchiori, M. (2001). Efficient behavior of small-world networks. *Physical review letters*, 87(19), <http://link.aps.org/doi/10.1103/PhysRevLett.87.198701>.
- [30] Latora, V., & Marchiori, M. (2002). Is the Boston subway a small-world network? *Physica A: Statistical Mechanics and its Applications*, 314(1), 109-113.
- [31] Barabási, A. L., & Bonabeau, E. (2003). Scale-free networks. *Scientific American*, 288(5), 50-59.
- [32] Adamic, L. A. (2000). Zipf, Power-laws, and Pareto - a ranking tutorial. *Xerox Palo Alto Research Center, Palo Alto, CA*. <http://www.hpl.hp.com/research/idl/papers/ranking/ranking.html>. Accessed August 2015.
- [33] Newman, M. E. (2005). Power laws, Pareto distributions and Zipf's law. *Contemporary physics*, 46(5), 323-351.
- [34] Kirkup, L. (2002). *Data analysis with Excel®: an introduction for physical scientists*. Cambridge University Press.
- [35] Barabási, A. L., & Albert, R. (1999). Emergence of scaling in random networks. *Science*, 286(5439), 509-512.
- [36] Chen, Q., & Shi, D. (2004). The modeling of scale-free networks. *Physica A: Statistical Mechanics and its Applications*, 335(1), 240-248.
- [37] Albert, R., Jeong, H., & Barabási, A. L. (2000). Error and attack tolerance of complex networks. *Nature*, 406(6794), 378-382.
- [38] Lu, H., & Shi, Y. (2007). Complexity of public transport networks. *Tsinghua Science & Technology*, 12(2), 204-213.
- [39] Albert, R., & Barabási, A. L. (2002). Statistical mechanics of complex networks. *Reviews of modern physics*, 74(1), 47.
- [40] Sienkiewicz, J., & Hołyst, J. A. (2005). Statistical analysis of 22 public transport networks in Poland. *Physical Review E*, 72(4), 046127.

LOGISTICAL RISKS OF MARITIME TRANSPORT PROCESSES

ЛОГИСТИЧЕСКИЕ РИСКИ МОРСКИХ ТРАНСПОРТНЫХ ПРОЦЕССОВ

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Abstract: Risk exists objectively in any marine enterprise, since the human presence of a person on the sea is accompanied both by circumstances caused by the irresistible forces of nature and directly by activities in the sphere of trading navigation. Risk management in the logistics supply chain is a complex multidimensional problem addressed in the process of identifying and assessing the risks and taking measures of protection against them.

In logistics, risk refers to the likelihood of an insured event occurring, as well as the possible damage caused by this event. Risk and an insured event can be described by using methods of the reliability theory. In this case, reliability is the probability of operation of the logistics system with failure or with no failure.

In order to identify rational methods and techniques for insurance, it is advisable to construe the logistics system as the process of movement of material resources.

KEY WORDS: RISK MANAGEMENT; SOURCES OF RISK; LOGISTICS SYSTEM RELIABILITY.

1.Introduction

An increase in cargo-turnover has been recently observed in water transport, the functioning of which is influenced by numerous factors of the external and internal environment and involves risks that arise at different stages of the logistical transport process. Risk exists objectively in any marine enterprise, since the human presence of a person on the sea is accompanied both by circumstances caused by the irresistible forces of nature and directly by activities in the sphere of trading navigation. Negative events can occur when a ship is in the sea or in a port, but risks also exist at the decision-making stage on the choice of sea traffic, freight rates, etc. Reliability of the carriage and, consequently, risks, while adhering to the logistical principles "just in time", "in a cost-effective manner" and "necessary qualities and quantities" become problematic issues. Accordingly, if the activities of transport as an object of increased danger were not subjected to various negative impacts, including risks, the transport component in the price of the goods, taking into account logistical technologies, could be significantly reduced.

Risk management in the logistics supply chain is a complex multidimensional problem addressed in the process of identifying and assessing the risks and taking measures of protection against them. As a result of its solution, it is possible to balance potential losses and benefits, avoid costly mistakes and ensure the stable operation of the logistics chains involving maritime transport.

Transport and logistical risks in the field of the carriage of goods by sea represent a combination of conditions and factors posing a real and potential threat (challenge, risk) to the sea logistics cargo supply chain. Unfortunately, at present, practical activities on revealing, identifying and assessing risks are not been expanded as they should be. At the same time, risk management and their minimization can be ensured on the basis of the logistical approaches, which allow fore diminishing the danger of choosing poor decision at the time of its adoption, as well as for mitigating the possible negative consequences of making decisions at the stage of their implementation.

The so-called "logistical" specification is considered as an important indicator of transport and logistical risks, that is, their

belonging to the specific types of flows, by means of which the links are established and implemented in the system. Moreover, the main components of the marine logistics supply chains will be the channels of trade, supplies, logistics and their corresponding information, financial and cargo flows.

2. Preconditions and means for resolving the problem

Researchers make distinction between four main sources of risk in the supply chain involving maritime transport:

- Environment (natural, regional-geographical factors, as well as terrorism threats);
- Regulatory and political sphere;
- Networking environment – interaction of the organizations in the supply chain (relationships between suppliers and customers, the influence of their problems on the counterparties);
- Internal (organization) environment (inadequate preparation of a ship and cargo for the carriage, defects in a ship and equipment, labor troubles, curtailment or stoppage of production by the supplier).

The least manageable risk factors arise in the environment and in the regulatory and political sphere. Natural factors are often combined with regional-geographical factors or are conditioned by the latter. For example, because of insufficient depth, the Georgian Black Sea ports are unable to receive tankers with tonnage larger than 130-150 thousand tons, the similar restrictions exist in many European ports; also, on busy routes of the intercontinental seas, the use of large tankers is undesirable from the environmental standpoint, since the probability of accidents in such water areas is considerably higher than on ocean voyages. More commonly, such factors can be controlled out only by way of operational and strategic adjustments in the shipping business itself.

The dangerous natural risks (risks of the sea itself and other natural disasters) are generally insured, but this does not solve the problem for the logistics system, since insurance only compensates for

losses once the timeliness and the quality of supply have already been violated. Therefore, risk management in the context of logistics should be oriented towards comprehensive control and prevention.

Another external source of risk is represented by the regulatory and policy decisions taken unilaterally, and which are beneficial to companies in one country or region. So, in order to ensure its own environmental safety, Turkey has set limits on the passage of the ships across the Bosphorus; in particular, tankers over 200 m long or the with dangerous types of cargo are permitted to pass through the straits only in daytime.

Consequences of such restrictions for transportation of Caspian oil and oil products from Georgian ports through these straits are unfavorable, especially considering that the volume of Caspian oil is expected to grow [1].

Risks caused by regulatory and political factors are generally not insurable, and their management tools should be methodologies for analyzing and reviewing the decisions, changes in business processes and structural changes that are carried out with the most efficient use of the competencies, knowledge and ties that the company has.

The phenomenology of the third ("networking") source of risk in the supply chain has been studied the least to date, despite its critical nature in creating the risk situations. The main problem is the complexity of risk assessment, since risk factors are rooted in the complex organizational and business interrelationships. Until recently, the issues of risk assessment and control in transport systems were addressed mostly in the context of individual organizations, but not in a systemic, "networking" context. Attention to this context is strengthened due to the following circumstances [2].

The increasing complexity of infrastructure and processes in transport logistics systems inevitably leads to a weakening of attention to their quality and control. In the maritime transport systems, the consequence of this the increased number of catastrophes with large damages and strengthened factors threatening life and health of people at sea.

In logistics, risk refers to the likelihood of an insured event occurring, as well as the possible damage caused by this event. Risk and an insured event can be described by using methods of the reliability theory. In this case, reliability is the probability of operation of the logistics system with failure or with no failure.

In general, insurance constitutes a justified system of ensuring the interests of natural or legal persons with a particular risk.

In order to identify rational methods and techniques for insurance, it is advisable to construe the logistics system as the process of movement of material resources in the spheres of production and circulation. Considering this, a logistics system would consist of two subsystems. These are:

- 1) Commercial subsystem, that is, the movement of material and financial flows in the spheres of circulation.
- 2) Production subsystem, that is physical movement or change of material and supplies immediately before receiving finished products in the production, and all kinds of logistics equipment (vehicles, transshipment machinery, etc.).

The commercial subsystem comprises the following operations or elements: procurement, sale, transportation, storage, production and information services and so on.

The production subsystem comprises the basic and support technological operations of the creation and movement of finished products. Multiplicity of links of the logistics system is what

creates the possibilities of failures. In a broader sense, these cases are called risks.

Multiplicity of links is also associated with the infinity of the logistics system, which can be measured by initial entropy

$$H = -\sum(p_i \log p_i + q_i \log q_i),$$

where n – number of operations of the logistics system or chain;

p_i – probability of failure-free performance, or reliability of operations to be carried out;

q_i – probability of failure, or risk of operations to be carried out;

The formula $p + q = 1$ shows that the logistics system is characterized by a high level of potential risks, which is significantly decreasing, first of all due to the reasonable management of material flows, or in order to maintain the minimum level of entropy for the purpose of influencing adequately on the operation of the logistics system.

Computer-aided management by highly qualified personnel can increase reliability of the logistics system and bring it closer to 1. Sound management requires a lot of information, which complies with the following condition

$$1 = H_{pr} - H_{cir} \quad \text{when } H_{cir} \rightarrow 0,$$

where H_{pr} and H_{cir} – are initial and final entropies. This circumstance defines information as a risk to eliminate or minimize the risk.

For the participants of logistics process, particularly for the suppliers (sellers), consumers (buyers), consignors and consignees, wholesale intermedia, transporters, etc. First of all, there is need for information on the situation existing in the market and in its separate segments, where the given logistical process is implemented. In addition, there is also need for current and predictable information on the specific situation of material flow.

At present, the seaports represent a set of disparate business entities (in fact, competitors) that do not have organizational unity and body coordinating their joint activities. Their uncoordinated actions result in decreasing the port's capacity. In this regard, a new logistics mechanism is needed that allows for coordinating the interests of all participants in the transport process, as well as the body that brings together their efforts [3].

3. Conclusion

The ability to manage the risks, that is, to reduce, compensate and prevent losses, is determined after identifying the nature of the risk of obtaining its quantitative and qualitative estimates. When assessing the risks, there are used several basic approaches and numerous methods [5].

According to the theoretical approach, the risk is calculated as follows:

- based on the logical reasonings, empirically - by extrapolating the past situations, and predicting them for the future;
- based on statistics - by studying statistics on losses, with establishing the frequency of the occurrence of the certain loss levels;

- expertly - based on the assessments and information received from experts;
- calculative-analytically - by constructing the loss probability distribution curve.

4. References

1. Korezin A.S. Корезин А.С. Risks of the logistics system and approaches to their mitigation in the context of sea traffic. «Transport of Russian Federation», No 3-4 (16–17) 2008.
2. Tyrtyshtny N. Management of logistical risks during the carriage of goods by maritime transport. The Author's Abstract of the Doctoral Thesis Nominated for Academic Degree of Candidate of Economics. Rostov-on-Don – 2013.
3. Legostayeva N.V. Risk management in freight forwarding companies. The Author's Abstract of the Doctoral Thesis Nominated for Academic Degree of Candidate of Economics St. Petersburg, – 2011.
4. Logistics – Eurasian bridge: Proceedings of 10th International Scientific-Practical Conference (14-15 May, 2015). Krasnoyarsk, 2015.

APPLICATION OF RISK FACTORS EVALUATION METHOD FOR ASSESSMENT OF VOYAGE EFFICIENCY IN TRAMP SHIPPING

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Abstract: The present article outlines the risk factors affecting voyage efficiency in tramp shipping operations. The influence of factors of time and costs parameters is identified. The voyage revenue is formulated and studied according to variances of time and costs elements. For the evaluation of efficiency of voyage operations an approach based on value-at-risk method is proposed and voyage statistics in short sea shipping are studied. The results presented prove the applicability of the method for efficiency evaluation of tramp shipping operations and voyage planning.

Keywords: TRAMP SHIPPING, RISK FACTORS, VOYAGE EFFICIENCY, RISK ASSESSMENT

1. Introduction

Maritime transportation demand is derived demand as it depends mainly on the demand for certain commodities or products. Considering that the fee for transportation by sea is represented by freight rates (in general) same are affected both market factors (ration between supply and demand in the freight market) as well as the costs structure of transport activities. Tramp shipping is considered as highly risky business activity as freight rates and prices of bunker are characterized by volatility against the increasing costs for shipowners and maritime operators. The revenue and profit of shipowners and maritime operators are influenced by a number of factors that pertain to the external (market) parameters and internal (cost) parameters. The said uncertainty of tramp shipping operations can be attributed to the state of the freight markets, economic activity for a certain group of commodities, political events and economic cycle. The market risk for shipowners and operators is an object of analysis and measurement in view of its potential impact on revenues and profits. The purpose of the present article is to study in detail the main risk factors affecting voyage efficiency in tramp shipping. The income and costs structure of voyage implementation is presented along with details of each element thereof. Consequently, the risk factors for efficient voyage implementation are identified as cost and time parameters which value depends on the duration of the voyage and market prices of bunker fuel. The value-at-risk (VaR) approach is applied to evaluate the expected losses due to a prolonged voyage and/or increase of bunker prices. The results show that the proposed method serves as an applicable tool in controlling and evaluating the voyage efficiency in tramp shipping.

2. Voyage efficiency in tramp shipping and risk factors

Tramp shipping is generally characterized by volatile demand. Being an industry of high commercial risk, shipowners and maritime operators strive to apply new approached for evaluation of transportation efficiency. There are several studies for assessment of the market risks effect on voyage efficiency [4]. However, a few are focusing on voyage efficiency from an operational point of view. Policy implications for risk averse shipowners with a choice of employing ships between the spot and time charter markets, point to preferring the lower risk time charter market over the spot market in general [2].

The objective of this article is to develop a conceptual model for analyzing the effect of the market risks on the results of vessels' operations and to quantify the deviation of planned results versus actual results in voyage operations. As a first stage the most important market risks are identified and their impact on the voyage results. The system approach allows for structuring a conceptual model for evaluation of voyage efficiency under the effect of

market risks (Figure 1). The empirical analysis concerns the actual performance of voyages thus all the commercial factors are constants including freight rate, loading and discharging rates at ports, commissions and the cargo quantity margins. According to the established practice all elements of the voyage implementation are planned in advance via voyage estimating. Due to the latter we can assume with a high level of probability that the expected result will be close to the planned. The latter refers to the time and costs parameters as well. The time components (parameters) include: steaming time between ports (laden and ballast legs), port stay time (cargo handling operations and unplanned delays) as well as unplanned delays during the passages between ports.

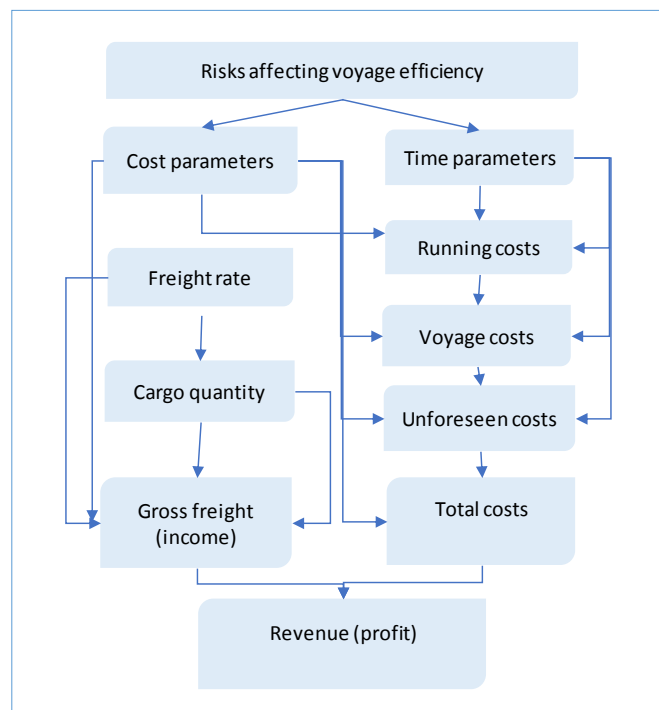


Figure 1. Conceptual model for evaluation of risk factor impact on voyage efficiency

The time components can be formalized as follows:

$$T_v = T_s + T_p + T_u \quad (1)$$

Where T_v represents the total voyage duration (number of days), T_s the steaming time both vessel being laden and in ballast, T_p represents the duration of time in port (number of days) and T_u is the duration of unforeseen delays (number of days).

The costs components (parameters) include the costs of disbursement accounts in ports, bunker costs, costs for passing canals as well as the running costs of the vessel. The costs for

bunkers, disbursements and costs related to cargo operations (in case same are for owners account) form the variable (voyage costs). The voyage implementation is also related to running costs, i.e. all costs that are incurred regardless of vessel's employment during the operational period. The level of voyage costs will depend mainly on the fuel prices, the current level of disbursement accounts in ports, etc. Running costs are also affected by the duration of all time components of the voyage as well as by the set budget of daily running costs. As voyage (variable) costs are mainly determined by time and costs parameters of the voyage depending on the bunker prices, disbursements and canal tolls. Thus we can assume that the most important parameters in evaluation of vessels' efficiency are the cost and time values given the agreed value of gross freight income. Therefore we can define the total costs of the voyage as follows:

$$T_v = VC + FC \quad (2)$$

The gross income basis the agreed freight is based on the total quantity loaded multiplied by the freight rate plus the due demurrage (if any).

$$R = Q \cdot f + dm \quad (3)$$

where R represents the gross voyage revenue, Q is the Bill of Lading weight of the cargo, f – freight rate and dm – the gross amount of demurrage due to the owners.

The net voyage revenue can be represented as follows

$$R_n = (Q \cdot f + dm) - \frac{(Q \cdot f + dm) \cdot K}{100} - ds \quad (4)$$

where R_n is the net voyage revenue, K – total amount of commissions agreed and ds – the amount of dispatch (if any). Commissions are due on gross freight, deadfreight and demurrage.

As an efficiency indicator the voyage revenue is used that can be presented as the difference between the net voyage revenue and total voyage (variable costs):

$$R_v = \left[(Q \cdot f + dm) - \frac{(Q \cdot f + dm) \cdot K}{100} - ds \right] - VC_v \quad (5)$$

where R_v is the voyage gross profit and VC_v are the variable (voyage costs) of the voyage.

On the basis of the net result of the voyage the daily financial results can be derived as follows:

$$TCE = \frac{\left[\left[(Q \cdot f + dm) - \frac{(Q \cdot f + dm) \cdot K}{100} - ds \right] - VC_v \right]}{T_v} \quad (6)$$

where TCE is the timecharter equivalent for the voyage.

The timecharter equivalent characterizes the profitability per day for a specific voyage and a specific ship. This indicator allows to perform comparison between different options of voyage employment of ships. As a rule, the planned timecharter equivalent should be higher than the rate of the daily running costs thus ensuring for a certain percentage of profit taking into account the pertaining risks during the voyage implementation.

The actual circumstance for implementation of the voyage as well as the risk factors may lead to the change of the time and cost parameters and thus to a change of the planned profit level. In practice, the planned result differs from actual result in a negative interrelationship, i.e. voyage revenue is lower than planned. Tramp shipping operations are affected by a number of external factors and risks [4]:

- change of bunker prices

Bunker prices are closely related to the state of the freight market. In the case of high market conditions the freight rates increase more slowly than the bunker prices. Conversely, the freight rates decrease sharply following the decrease of bunker prices

which shows a lower state of the freight market. Figure 2 presents the dynamics of bunker prices (IFO 380 cst) at Bosphorus for the period November, 2017 to April, 2018. As evident, the bunker prices can vary by more than 25% within a month only;

- delays in ports of loading and discharging

These refer to issues of discrepancies regarding cargo delivery in port, lack of cargo documents preventing customs clearance, etc. The latter can directly affect the port stay time and thus the overall duration of the voyage. Also these factors include the delays due to servicing of the ships in ports (activities of ship agents, pilots, tug companies, port authorities, etc.);

- change of port disbursements

These refer to the local price policy of port tariffs, most valid for larger ships performing longer voyages due to the longer time span between sailing from load port until arrival at discharge port. This factor affects the cost parameter in terms of voyage costs;

- weather conditions during the voyage

These factors refer to the weather conditions during sailing time and during port stay time. These may affect the safety condition of the ship and thus incur additional costs and time loss for unplanned repairs and/or supplies;

- human error

These refer to omissions of the crew that can affect negatively the operation of the ship and lead to loss of time due to incidents and delays. On the part of shore personal, with reference to the ship management activities, human errors can be related to improper and untimely decisions to/not to supply the ship or to decisions leading to loss of time due to unavailability of cargo, cargo documents, delayed formalities at ports, etc.

Factors described above can affect the time parameters of the voyage in terms of increase of steaming and port stay time.

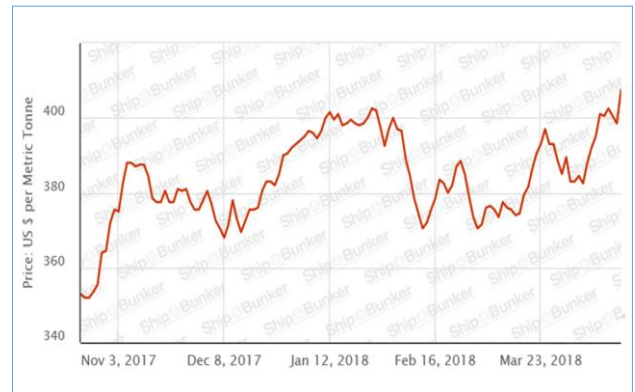


Figure 2. IFO 380 cst prices for bunker supplied at Istanbul [6]

As a result of the costs change (increase of bunker prices and/or port disbursements) and time parameters (increase of steaming time and port stay time) the voyage costs increase. It should be noted, however, that apart from the bunker prices and port disbursements, the weather delays are considered extreme external factors that are not liable to initial evaluation. The increase of voyage duration leads to increase of the running costs. The increase of running costs is often related to crew errors, ship management errors and delays of ships in ports. Therefore, when a voyage is planned, the entire system of affecting factors must be taken into account in order to evaluate correctly the expected voyage efficiency. Moreover, the decrease of daily revenue is due not only to the cost increase but also to the decrease of daily income.

Bunker consumption is planned in advance according to empirical evidence from ship's operation and to the technical specification of ship's engine. They are set separately for the sailing

period and for the port stay. It should be noted that the relationship between speed and bunker consumption is not linear therefore careful considerations should be made for the trade-off between time saved and bunker costs saved as concerns speed management.

Bunker costs will increase due to the increase of sailing time or time in port as well as due to the increase of bunker prices. As concerns disbursement accounts some of their elements are dependent on the duration of port stay – for example berth dues, anchorage dues, agency fee, etc.

3. Evaluation of risk factors impact on voyage efficiency

For the purposes of risk factor evaluation, we assume the commercial elements of the voyage, i.e. the charter party terms, are constant. The latter refers to the cargo quantity, freight rate and agreed brokerage. The margin of voyage elements values has been ascertained via statistical study of voyage implementation of a 5300 mts DWAT general cargo vessel performing contract voyages between Constanta and Ravenna for the period April, 2017 to April, 2018 (Table 1).

Table 1. Characteristics of 5000 mts DWAT general cargo vessel

Vessel type	general cargo
DWCC (bulk grain cargo)	5000 mt
Freight rate [7]	36 \$ per mt (net)
Service speed (average)	10 knots
Voyage rotation	Constanta – Ravenna
Distance (nm)	1312 nm
Total sailing time (incl. ballast)	10,93 days
Total time in port	5 days
Bosporus passage (one way)	1 day
Total voyage duration	16,93 days
Price of IFO 380 cst [6]	430 \$/mt
Price of MGO [6]	670 \$/mt
Total D/As and canal fees	26000\$
Daily running costs	3500\$/day

Models for estimation of market risks are of the purpose to predict potential losses as an outcome of external factors changes. One of the best-known and most widely used of risk measurement tools is value at risk (VaR) [5]. The findings of the present study can be applied in vessel's operations for short sea shipping in the Black Sea and the Mediterranean region particularly for the financial risk management in shipping.

A main concern for the market risk manager is the choice of the most appropriate market risk measurement method amongst a number of alternative models developed in the literature [3]. Value-at-risk method (VaR) is the maximum amount of loss that can be sustained with a given probability over a certain period of days. It is typically calculated within a 95% or 99% confidence interval. VaR is defined as the dollar (or percentage) loss to be exceeded with a certain probability (known as confidence level) over a given time horizon [1]. For the purposes of this study we strive to understand the overall risk factors structure for tramp shipping. The values of VaR measures are calculated for above mentioned period. The realized α -level VaR measures are computed as the $1-\alpha$ quantiles of the past n observations of X_t , as in the following equation [5]:

$$\text{VaR}(\alpha) = \text{Quantile}^{1-\alpha}(\{X_t\}_{t=1}^n) \quad (7)$$

VaR method is based on the determining of certain deviations (losses) at given probability. In order that the application of this method is correct it is necessary that the studies values of the cost and time parameters are random values with normal distribution. For the purposes of the latter we have conducted statistical study of the bunker prices and duration of port stay for a sequence of voyages performed by a general cargo vessel as described in Section 2 of the present article. Figure 3 presents the hypothesis test of the random value distribution type as concerns port stay in ports – as evident it is subject to normal distribution. The Pearson's test confirmed the on-contradiction to the initially adopted hypothesis of normal distribution with χ^2 with value 4,0655 and p with value 0,0678 which is acceptable for such analysis.

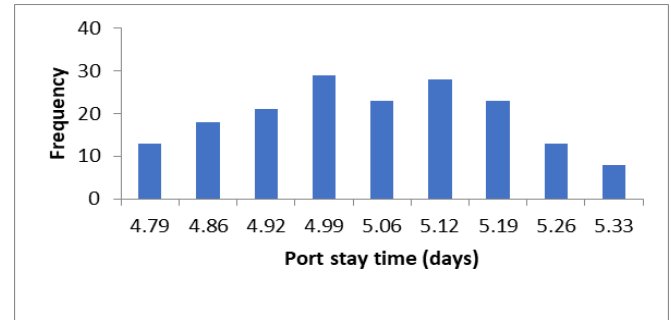


Figure 3. Statistical analysis of port stat time (number of days)

As a result it has been ascertained that the mean value of port stay time is $T_p = 5.06$ days that can be assumed as planned value. In accordance with (7) we have calculated with 99% and 95% probability the potential losses on case of deviation of the port stay time from the mean value. The results are presented in Table 2.

Table 2. Voyage VaR for a 5300 DWAT general cargo vessel (Constanta-Ravenna) for increase of port stay time

Increase of days in port	99% VaR	95% VaR	Total costs per voyage (USD)	Profit/Loss per voyage (USD)
4%	0.196	0.112	\$ 174,084	\$ 5,916
8%	0.201	0.115	\$ 178,557	\$ 1,443
12%	0.206	0.118	\$ 183,059	\$ - 3,059
16%	0.211	0.121	\$ 187,589	\$ - 7,589
20%	0.216	0.123	\$ 192,146	\$ - 12,146
24%	0.222	0.126	\$ 196,732	\$ - 16,732
28%	0.227	0.129	\$ 201,346	\$ - 21,346
32%	0.232	0.132	\$ 205,987	\$ - 25,987
36%	0.237	0.135	\$ 210,657	\$ - 30,657
40%	0.243	0.138	\$ 215,355	\$ - 35,355

It should be noted that the assumed losses in terms of increase total costs of the voyage will lead to incurring of loss for the implementation of the voyage. The latter is a direct result of the increased port stay time. Vessel operators are able to evaluate efficiently the direct impact of delays of port stay and plan in advance.

The evaluation of VaR in case of changes of MGO bunker prices for the presented voyage rotation are presented in Table 3. As in this case MGO consumption is limited only to port stay time the sensitivity of this factor is low as compared to the time parameter of prolonged port stay time. Planning of bunker supply is also considered as important element of vessel operations and therefore should be planned well in advance taking into account both the price of bunker, additional costs for bunkering and time loss thereof. It should be also noted that bunker prices can be extremely volatile within a short period of time and there is a large variance of

prices between different ports/regions, even for the same standard type of bunker fuels.

Table 3. Voyage VaR for a 5300 DWAT general cargo vessel (Contanta-Ravenna) for increase of MGO price

Increase of MGO price	99% VaR	95% VaR	Total costs per voyage (USD)	Profit/Loss per voyage (USD)
3%	0.195	0.111	\$ 172,900.67	\$ 7,099.33
6%	0.198	0.113	\$ 176,163.33	\$ 3,836.67
9%	0.202	0.115	\$ 179,426.00	\$ 574.00
12%	0.206	0.117	\$ 182,688.67	\$ - 2,688.67
15%	0.209	0.119	\$ 185,951.33	\$ - 5,951.33
18%	0.213	0.122	\$ 189,214.00	\$ - 9,214.00
21%	0.217	0.124	\$ 192,476.67	\$ - 12,476.67
24%	0.221	0.126	\$ 195,739.33	\$ - 15,739.33
27%	0.224	0.128	\$ 199,002.00	\$ - 19,002.00
30%	0.228	0.130	\$ 202,264.67	\$ - 22,264.67

The proposed VaR method allows for realistic conclusions about the expected deviations of the cost and time parameters for certain voyages implementation given the expected variations in MGO prices and port stay time duration. It should be noted that this method, although being straightforward, has certain drawbacks as larger losses (beyond the ones computed) are being ignored. Nevertheless, the application of the VaR method in voyage planning and operations, especially for shorter sailing distances, is a valuable tool for assessment of voyage efficiency.

4. Conclusion

Tramp shipping market, being highly volatile, required metrification of risk and evaluation of vessel operation methods. The present paper has analyzed the applicability of the VaR method for evaluation of voyage efficiency in tramp shipping. The findings have proved that time and cost parameters of the planned voyage and their variations can lead to significant loss in voyage revenue and profit. We have ascertained the system of risk factors that affect the voyage results such as prolonged port stay time, changes in bunker prices, human errors in ship management, weather conditions, omissions in vessel's servicing in ports, delays of cargo delivery in ports, etc. It has been proved that the abovementioned factors can affect directly the cost and time parameters of the voyage. The deviations of the latter lead directly to deviations between planned and actual result of the voyage. The analysis has been conducted on the basis of empirical study of data for actual voyages on the Black Sea and the Mediterranean region for a short sea shipping transportation. The total costs of the voyage and the profit/loss have been calculated. For the purposes of evaluation of the probable deviations of the port stay time and MGO process we have applied the VaR method in order to determine the maximum level of deviation of port stay time and MGO process at a given probability. For the purposes of the correctness of the study statistical analysis has been carried and its results proved the applicability of the VaR method for the evaluation of voyage efficiency. The results can be further used for evaluation of vessel operation activities based on the probabilistic nature of the cost and time parameters as part of the vessel's voyage on the basis of the proposed method for evaluation of vessel's voyage efficiency.

5. References

- [1]. Angelidis, T., Skiadopoulos, G., 2008, Measuring the market risk of freight rates: a value-at risk approach, *International Journal of Theoretical and Applied Finance*, Vol. 11, No. 5, pp. 447–469
- [2]. Kavussanos, M.G., 2003, Time varying risks among segments of the tanker freight markets, *Maritime Economics and Logistics*, Vol. 5, No. 3, pp. 227–250
- [3]. Kavussanos, M.G., D. Dimitrakopoulos, 2011, Market risk model selection and medium-term risk with limited data: application to ocean tanker freight markets, *International Review of Financial Analysis*, Vol. 20, No. 5, pp. 258–268
- [4]. Onyschenko, S., Vyshnevskaya O., Evaluation methods for voyage results deviation under risk factors, 2016, *NTU Annals*, 7(1179), pp. 25-31
- [5]. Unal, G. et al, Revealing the freight market risk in Istfix shipping area, 2014, *International Journal of Shipping and Transport Logistics*, 6 (6), pp. 593-610
- [6]. <https://shipandbunker.com>
- [7]. <https://metalexpert.com>

COMPARISON OF FUEL COSTS BETWEEN COGES AND DIESEL-ELECTRIC PROPULSION SYSTEMS FOR CONVENTIONAL PASSENGER CRUISER PROPULSION

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Abstract: The paper presented a comparison of fuel costs between COGES and Diesel-electric propulsion systems for large conventional cruise ship. COGES propulsion system installed on the analyzed cruise ship saves ship's space in comparison with Diesel-electric propulsion system. Diesel-electric propulsion system uses much more fuel for additional steam production and therefore, the additional fuel costs of this propulsion system are much higher in comparison with COGES system. Net profit of 50 additional cabins cannot compensate the difference in COGES system total annual fuel costs throughout the observed time period when compared to Diesel-electric propulsion system. The COGES propulsion system has much lower exhaust gas emissions in comparison with equivalent Diesel-electric system and therefore, in presented comparison, COGES could become profitable in the future if the emission regulations become more rigorous.

KEYWORDS: FUEL COSTS, COGES, DIESEL-ELECTRIC, PROPULSION, PASSENGER CRUISER

1. Introduction

Advanced marine propulsion systems which combine several prime movers at the same ship were investigated by many authors so far, from the various different aspects.

Geertsma et al. [1] presented a complete review about the design and control of hybrid power and propulsion systems. Techno-economic and environmental risk analysis for advanced marine propulsion systems was investigated by Doulgeris et al. [2]. The method comprises several numerical models which simulate the life cycle operation of marine gas turbines installed on marine vessels. The economic model predicts net present cost over the operating life of the vessel by using stochastic analysis.

The different propulsion systems used on board vessels for the transport of Liquefied Natural Gas (LNG) were described and analyzed by Fernández et al. [3]. The analysis describes main characteristics of the propulsion systems used on LNG carriers along with its advantages and disadvantages, from its very beginnings up to the systems installed to date. The described propulsion systems include gas and steam turbines, combined cycles, two and four stroke internal combustion engines, as well as re-liquefaction plants, while encompassing mechanical, electrical and Dual Fuel (DF) technology systems.

Marine electric propulsion system was investigated by Yutao et al. [4]. Investigation of a tanker with twin podded propulsion was presented by Taskar et al. [5]. The effect of various factors that influenced ship propeller is quantified. Propeller performance in waves in terms of cavitation, pressure pulses, and efficiency is compared with the performance in calm water.

Fuel efficiency study based on the overall ship propulsion model was investigated by Zhao et al. [6]. An overall ship propulsion plant involves marine engine, propeller and ship dynamic model, which are completely included in the presented analysis. The whole ship voyage model was used to predict fuel consumption and exhaust emissions under different sailing conditions.

Unlike above, in this paper was presented an economic and profitability aspect of two complex and advanced marine propulsion systems - COGES and Diesel-electric systems which can be used for propulsion of a large conventional cruise ship. Comparison of annual fuel costs and additional fuel costs provides an insight into the proper selection of propulsion system. Total annual fuel costs were calculated for both propulsion systems and for thirteen different fuel prices in the period from 07.11.2016. up to 07.11.2017. In calculation was also taken the real saving of ship's space when COGES propulsion system was selected.

2. Description of COGES propulsion system installed on passenger cruiser

Passenger cruise ship Celebrity Millennium is one of several cruise ships which use COGES (COmbined Gas and Steam Electric) propulsion system [7]. Most of other passenger cruise

ships use Diesel-electric propulsion systems due to its several advantages.

Celebrity Millennium COGES propulsion system is equipped with a pair of General Electric aeroderivative gas turbines with power of 25 MW each and a single steam turbine with a power of 8 MW. Each of those three prime movers drives an AC (Alternating Current) electric generator. Produced electric power is directed into two electrically driven podded propulsion units' Rolls-Royce/Alstom Mermaid azimuth thrusters with a power of 19 MW each. As each pod can be rotated horizontally through 360° if required, the need for rudder shaft lines, stern thrusters, steering gear bossing and brackets is eliminated. Gas turbines are the main propulsion devices and the steam turbine is used to produce additional electricity if needed. A steam turbine recovers heat from both gas turbine exhausts to produce steam. Electricity produced with steam turbine is not used only for additional drive of azimuth thrusters; it is also used for heating and cooling throughout the ship as well as for several other purposes. Depending on the amount of steam required for the electricity production, the entire COGES propulsion system has efficiency between 45 % and 50 %.

Gas turbines use clean distillate fuel (Marine Gas Oil - MGO) what significantly reduce exhaust emissions. The used propulsion technology has been a factor that Millennium is the first ship built to Det Norske Veritas' voluntary class notation, Clean Design. In year 2000 ship was awarded with ISO14001 certificate.

General specifications and characteristics of Celebrity Millennium, which are not related to the propulsion system, are presented in Table 1.

Table 1. General specifications and characteristics of Celebrity Millennium

Builder	Chantiers de l'Atlantique
Owner/Manager	Celebrity Cruises
Length	294 m
Breadth	32.2 m
Draught	8.3 m
Deadweight	8500 t
Gross Tonnage	90228 t
Passenger Capacity	2449

3. Fuel costs comparison between Celebrity Millennium COGES and equivalent Diesel-electric propulsion system for the year 2000. (the year when Celebrity Millennium was launched)

Fuel cost comparison between COGES propulsion system installed on Celebrity Millennium can be performed in relation to equivalent Diesel-electric propulsion system. So, COGES propulsion system installed on Millennium with the total electrical power output of 58 MW is compared with Diesel-electric propulsion system. Comparable Diesel-electric propulsion system

consists of five medium-speed diesel engines along with the corresponding generators and electric motors with total electrical power output of 61 MW. These two propulsion systems are compared from the basis of annual fuel costs firstly for the cruiser launch year, 2000.

Author [8] proposed the correct way of comparison in the annual fuel cost calculation for these two systems and also appropriate load scenario of cruise ship Celebrity Millennium. Annual fuel cost calculation is based on a typical weekly load scenario of 60 hours per week in ports (electrical power requirement 10 MW) with one medium-speed diesel engine in operation, which is equivalent to the operation of one gas turbine along with a steam turbine from COGES system. Proposed scenario includes 3840 working hours per year for each of the five diesel engines or 6150 working hours for each of the two gas turbines from COGES system. It should be noted that COGES system operates with MGO (Marine Gas Oil), while medium-speed diesel engines operates with IFO 380 cSt (Intermediate Fuel Oil with a kinematic viscosity of 380 cSt). For these two propulsion systems and for described load scenario, calculation of fuel consumption is performed in [9] and the results of that calculation are presented in Table 2.

Table 2. Comparison of annual fuel consumption between COGES and equivalent Diesel-electric propulsion system

Annual fuel consumption for COGES (58 MW) and Diesel-electric (61 MW) propulsion systems	COGES	Diesel-electric
Fuel	MGO	IFO 380 cSt
Fuel consumption, ton	45120	39540
Additional fuel for steam production (17 ton/h), ton	1000	7050

Average fuel prices for the year 2000, from the Rotterdam bunker market were 300 USD per ton of MGO and 145 USD per ton of IFO 380 cSt [10]. Based on those prices, for the year 2000 were calculated annual fuel costs for each of two propulsion systems and presented in Table 3.

Table 3. Comparison of annual fuel costs between COGES and equivalent Diesel-electric propulsion system

Annual fuel costs for COGES (58 MW) and Diesel-electric (61 MW) propulsion systems	COGES	Diesel-electric
Fuel	MGO	IFO 380 cSt
Annual fuel cost, million USD	13.54	5.73
Annual fuel cost for additional fuel, million USD	0.3	1.03
Total annual fuel cost, million USD	13.84	6.76

At the moment when cruiser Celebrity Millennium was launched the difference in annual fuel cost between COGES and Diesel-electric propulsion system was approximately 7 million USD. The appropriate question is how is intended to compensate such big difference in the annual fuel cost between COGES and Diesel-electric propulsion systems.

The COGES propulsion system needs less ship's space than Diesel-electric system, so the selection of COGES on cruiser Celebrity Millennium allow installation of 50 additional double-passenger cabins on lower cruiser decks, which will not be installed if the Diesel-electric system were selected for propulsion. The selection of COGES propulsion system arises from the idea that additional cabins will compensate the difference in total annual fuel cost in comparison with equivalent Diesel-electric propulsion system.

If assumed that 90 % of capacities in 50 additional cabins are continuously sold out 50 weeks a year and if it is taken the real price of accommodation of about 200 USD per person per day, income from additional cabins will be approximately 7 million USD annually. Based on a practical experience [11], the net profit of 7 million USD income can be estimated on about maximum of 35 % or approximately 2.5 million USD. The remaining 65 % are costs

for additional cabins building and furnishing, cost of food, staff, cabin cleaning, laundry, taxes, etc.

In the year 2000 when the Celebrity Millennium was launched, it is obvious that annual fuel cost of COGES propulsion system cannot be compensated with additional cabins.

In general - if the difference in annual fuel cost between COGES and Diesel-electric propulsion systems is 2.5 million USD or less, additional cabins compensate the higher COGES fuel cost. If not, additional cabins cannot compensate the higher COGES fuel cost.

The comparison in this paragraph was made for the year 2000. The authors of this paper were interested how this comparison will look nowadays.

4. Fuel costs comparison between Celebrity Millennium COGES and equivalent Diesel-electric propulsion system for a period between 07.11.2016. and 07.11.2017.

The same calculation and comparison of annual fuel costs between COGES and equivalent Diesel-electric propulsion system is provided for the period between 07.11.2016. and 07.11.2017.

It should be noted that annual fuel consumption and additional fuel consumption of both propulsion systems remain the same as presented in Table 2. The changeable variable is the fuel price between observed periods.

4.1. The change in fuel prices between 07.11.2016. and 07.11.2017.

The change in fuel prices between 07.11.2016. and 07.11.2017. is presented in Fig. 1 (IFO 380 cSt) and in Fig. 2 (MGO). Fuel price in the Rotterdam bunker market was taken as relevant (red curve in Fig. 1 and Fig. 2). It is important that both fuel prices in the Rotterdam bunker market are lower throughout observed period than average price in 20 the most important worldwide trading ports (gray curve in Fig. 1 and Fig. 2).

Fuel price for both observed fuels increases in average during the observed period and in 07.11.2017. the price of both fuels was the highest.

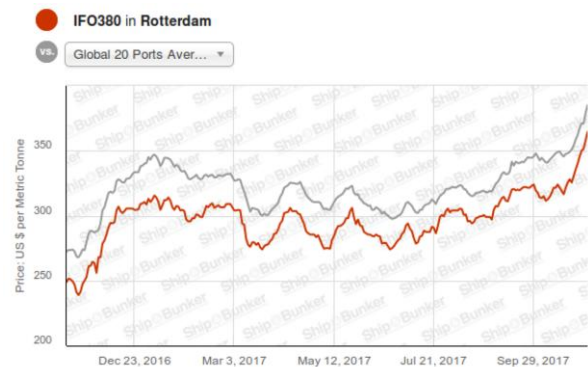


Fig. 1. IFO 380 cSt price change between 07.11.2016. and 07.11.2017. in the Rotterdam bunker market [12]

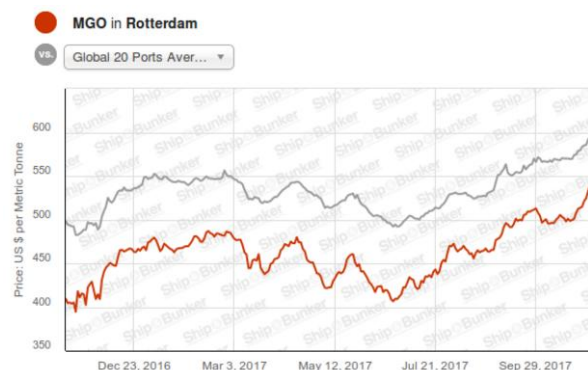


Fig. 2. MGO price change between 07.11.2016. and 07.11.2017. in the Rotterdam bunker market [12]

4.2. Annual fuel costs comparison between COGES and equivalent Diesel-electric propulsion system for thirteen randomly selected dates in the period between 07.11.2016. and 07.11.2017.

From the period between 07.11.2016. and 07.11.2017. was randomly selected one day in every month, and it was read the fuel prices for that day from Fig. 1 and Fig. 2. Randomly selected dates and fuel prices on that day at the Rotterdam bunker market was presented in Table 4.

Table 4. Randomly selected dates and fuel prices for every month between 07.11.2016. and 07.11.2017. - Rotterdam bunker market

Date	IFO 380 cSt	MGO
07.11.2016.	249.0 USD/ton	409.5 USD/ton
27.12.2016.	305.0 USD/ton	466.5 USD/ton
24.01.2017.	307.0 USD/ton	467.0 USD/ton
21.02.2017.	308.0 USD/ton	484.0 USD/ton
20.03.2017.	277.5 USD/ton	453.0 USD/ton
13.04.2017.	303.5 USD/ton	473.0 USD/ton
22.05.2017.	298.0 USD/ton	454.5 USD/ton
20.06.2017.	276.5 USD/ton	415.0 USD/ton
19.07.2017.	287.5 USD/ton	434.0 USD/ton
24.08.2017.	299.5 USD/ton	464.5 USD/ton
22.09.2017.	322.0 USD/ton	506.0 USD/ton
20.10.2017.	316.5 USD/ton	498.0 USD/ton
07.11.2017.	364.5 USD/ton	539.0 USD/ton

To make appropriate annual fuel price comparison between COGES and Diesel-electric propulsion systems, it was calculated total and partial annual fuel prices for each date presented in Table 4. That calculation allows comparison of annual fuel prices based on fuel prices for each month. The final intention of this analysis was to calculate can the COGES propulsion system can be cost effective in comparison with Diesel-electric propulsion system.

Change in annual fuel costs for COGES and Diesel-electric propulsion systems for randomly selected fuel prices from Table 4 is presented in Fig. 3. From Fig. 3 it can be seen that COGES annual fuel cost at any selected calculation date is much higher than the annual fuel cost of Diesel-electric propulsion system. During the observed period, annual fuel costs of COGES propulsion system are higher for approximately 9 million USD in average.

It is important to note that at the last observed date (07.11.2017.) annual fuel costs of both propulsion systems are the highest in comparison with the previous calculated ones. This fact arises from the fact that on the last observed date prices of both fuels was the highest, Table 4.

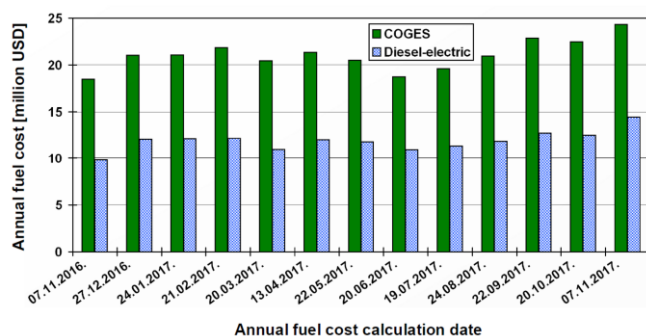


Fig. 3. Change in annual fuel costs for COGES and Diesel-electric propulsion systems

Change in annual fuel costs for additional fuel (fuel for steam production, Table 2) of COGES and Diesel-electric propulsion systems are presented in Fig. 4. According to Table 2, Diesel-electric propulsion system uses much more fuel for additional steam production and therefore, the additional fuel costs of this propulsion system are much higher in comparison with COGES system. Throughout the observed period, annual fuel costs for additional

fuel of Diesel-electric propulsion system are higher for approximately 1.7 million USD in average.

Annual costs of additional fuel for steam production represents smaller part of total fuel costs; therefore they cannot have a significant influence on total annual fuel costs in presented comparison. Again, the highest values of additional fuel annual costs for both COGES and Diesel-electric propulsion systems are the highest for the last observed date (07.11.2017.) due to the highest fuel prices from the Rotterdam bunker market on that day.

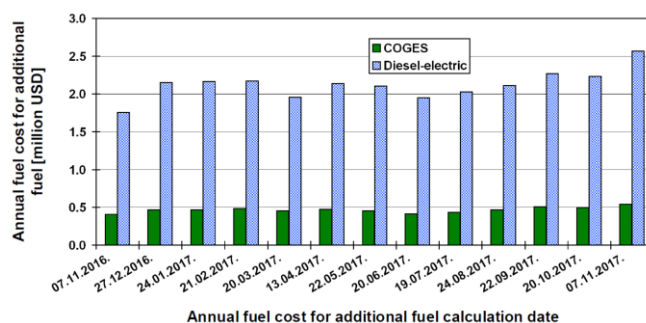


Fig. 4. Change in annual fuel costs for additional fuel of COGES and Diesel-electric propulsion systems

Total annual fuel costs change of COGES and Diesel-electric propulsion systems are presented in Fig. 5. Data presented in Fig. 5 were obtained by summing annual fuel costs, Fig. 3, and annual fuel costs for additional fuel, Fig. 4, for each observed propulsion system and for every observed calculation date, Table 4.

Fig. 5 presents that total annual fuel costs in the observed period amounts in average 21.5 million USD for COGES propulsion system and 14 million USD in average for Diesel-electric propulsion system.

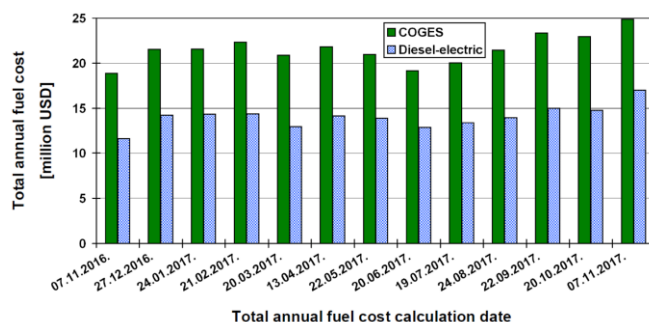


Fig. 5. Change in total annual fuel costs of COGES and Diesel-electric propulsion systems

The differences in total annual fuel costs of COGES and Diesel-electric propulsion systems, for all calculation dates (Table 4) are presented in Fig. 6. The fuel costs differences between those two systems amounts from approximately 6 million USD up to 8.5 million USD.

50 additional cabins mounted on Celebrity Millennium with COGES propulsion system bring an annual net profit of approximately 2.5 million USD. Net profit of 50 additional cabins cannot compensate the difference in COGES and Diesel-electric propulsion system total annual fuel costs not only for a year 2000 (when the Celebrity Millennium was launched) but also throughout the observed time period (from 07.11.2016. to 07.11.2017.). The COGES propulsion system at the analyzed cruiser can be profitable only if total annual fuel cost difference, in relation to Diesel-electric propulsion system, amounts 2.5 million USD or less.

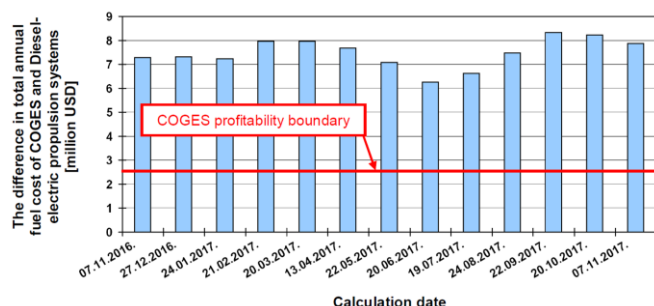


Fig. 6. The differences in total annual fuel costs of COGES and Diesel-electric propulsion systems

5. Conclusion

In the paper was presented comparison of fuel costs between COGES and Diesel-electric propulsion systems for large conventional cruise ship, based of known fuel consumption comparison between these two propulsion systems.

COGES propulsion system installed on the analyzed cruise ship saves ship's space in comparison with Diesel-electric propulsion system, so the selection of COGES system allows installation of 50 additional double-passenger cabins on lower cruiser decks. The intention of such propulsion system selection was that additional cabins will compensate the difference in total annual fuel costs in comparison with Diesel-electric propulsion system.

Annual fuel costs of COGES and Diesel-electric propulsion systems were calculated for randomly selected fuel prices at each month during the period between 07.11.2016. and 07.11.2017.

COGES annual fuel costs in any selected calculation date is much higher than annual fuel costs of Diesel-electric propulsion system. During the observed period, annual fuel costs of COGES propulsion system are higher for approximately 9 million USD in average.

Diesel-electric propulsion system uses much more fuel for additional steam production and therefore, the additional fuel costs of this propulsion system are much higher in comparison with COGES system. Annual fuel costs for additional fuel of Diesel-electric propulsion system are higher for approximately 1.7 million USD in average throughout observed period.

Total annual fuel costs in the observed period amounts in average 21.5 million USD for COGES propulsion system and 14 million USD in average for Diesel-electric propulsion system.

Net profit of 50 additional cabins cannot compensate the difference in COGES and Diesel-electric propulsion systems total annual fuel costs throughout the observed time period (from 07.11.2016. to 07.11.2017.).

It should be noted that COGES propulsion system has much lower exhaust gas emissions in comparison with Diesel-electric system. Therefore, COGES propulsion system could become profitable in the future (in comparison with equivalent Diesel-electric propulsion system) if the emission regulations become more rigorous.

6. Acknowledgment

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7. References

- [1] Geertsma, R. D., Negenborn, R. R., Visser, K., Hopman, J. J.: *Design and control of hybrid power and propulsion systems for smart ships: A review of developments*, Applied Energy 194, p. 30–54, 2017. (doi:10.1016/j.apenergy.2017.02.060)
- [2] Doulgeris, G., Korakianitis, T., Pilidis, P., Tsoudis, E.: *Techno-economic and environmental risk analysis for advanced marine propulsion systems*, Applied Energy 99, p. 1–12, 2012. (doi:10.1016/j.apenergy.2012.04.026)
- [3] Fernández, I. A., Gómez, M. R., Gómez, J. R., Baaliña Insua, A. A.: *Review of propulsion systems on LNG carriers*, Renewable and Sustainable Energy Reviews 67, p. 1395–1411, 2017. (doi:10.1016/j.rser.2016.09.095)
- [4] Yutao, C., Fanming, Z., Jiaming, W.: *Integrated Design Platform for Marine Electric Propulsion System*, Energy Procedia 17, p. 540 – 546, 2012. (doi:10.1016/j.egypro.2012.02.133)
- [5] Taskar, B., Steen, S., Eriksson, J.: *Effect of waves on cavitation and pressure pulses of a tanker with twin podded propulsion*, Applied Ocean Research 65, p. 206–218, 2017. (doi:10.1016/j.apor.2017.04.005)
- [6] Zhao, F., Yang, W., Wan Tan, W., Kiang Chou, S., Yu, W.: *An Overall Ship Propulsion Model for Fuel Efficiency Study*, Energy Procedia 75, p. 813 – 818, 2015. (doi:10.1016/j.egypro.2015.07.139)
- [7] <http://www.ship-technology.com>, (accessed: 03.11.17.)
- [8] Koehler, H. W.: *Diesel Engines and Gas Turbines in Cruise Vessel Propulsion*, presentation at The Institution of Diesel and Gas Turbine Engineers, London, February, 2000.
- [9] Mrzljak, V., Mrakovčić, T.: *Comparison of COGES and diesel-electric ship propulsion systems*, Journal of Maritime and Transportation Sciences, 1, p. 131–148, 2016. (doi:10.18048/2016-00.131)
- [10] <http://www.bunkerworld.com>, (accessed: 04.11.17.)
- [11] Haglind, F.: *A review on the use of gas and steam turbine combined cycles as prime movers for large ships. Part II: Previous work and implications*, Energy Conversion and Management 49, p. 3468–3475, 2008. (doi:10.1016/j.enconman.2008.08.004)
- [12] <https://shipandbunker.com>, (accessed: 08.11.17.)

RESEARCHING BIOFUELS IN PRIMARY SCHOOL LABORATORY

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Abstract: The aim of the article is to show how to encourage students to deepen their knowledge, creativity and their enthusiasm for research. In this way we can also promote the popularization of science and technology as well as the identification of students talented in specific research areas. This article presents an example of writing a research assignment undertaken by students in the final year of primary school (class 9, i.e. age 14-15). We live in the age of diminishing supplies of fossil fuels and consequently a growing interest in the renewable energy sources, including biofuels. Through research assignment, we wanted our students to learn more about the characteristics of biofuels which we haven't discussed in detail in class. Biofuel is a solid, liquid or gaseous fuel, obtained from a relatively recently deceased biological substance. For the production of biofuels, we use various plants and substances of plant origin, which are known under the term "biomass". In addition to looking for information in literature and electronic resources, we conducted experiments in which we measured how many degrees a particular quantity of water heats up by the burning of various fuels, and the amount of residue left after burning. The biofuels we used were: pellets, briquettes, olive pulp, cherry stones, biodiesel, ethanol and sawdust.

We established that different types of fuel emit, when burnt, different amounts of heat. Water heated up the most when burning ethanol, while it heated up the least when using biodiesel. Experiments showed that different fuels burn for different amounts of time, leaving a residue which depends on the type of fuel

Keywords: RESEARCH ASSIGNMENT, BIOFUELS, EXPERIMENTAL WORK

1. Introduction

1.1 Alternative energy sources

Renewable energy sources are sources of energy we obtain from constant natural processes such as the wind, solar radiation (solar power stations), water current in rivers or streams (hydroenergy), Earth's heat fluxes (geothermal energy), the tides and waves of the seas and oceans (tidal energy and wave energy), photosynthesis by which plants build biomass (wood, vegetable oils that we convert into bioethanol, biodiesel, biogas).

The majority of renewable energy sources, with the exception of geothermal energy and tidal energy, come from regular solar radiation. The Sun is constantly sending into space a heat flux which we call solar radiation. Solar radiation is heating up our planet and changing into other forms of energy. A few tenths of 1 percent of solar radiation are used for photosynthesis, and this is how organic material, biomass is made. We turn solar radiation into heat and electricity using various technologies.¹

The main characteristics of renewable energy sources include the fact that their use reduces the emissions of greenhouse gases; these energy sources are also free, they are durable and have a great potential.

Renewable energy sources cannot be stored in nature except in the form of biomass and the heat of oceans. Thus we have to use various devices for storing the energy of renewable resources, which lessens their efficiency and makes their exploitation more expensive.²

This decade of the 21st century is a favourable time for further development of technologies linked to renewable energy sources. The European Union decided to pursue the objective of reducing greenhouse gases emissions by 40 percent by the year 2030. Using the existing technologies, this can be achieved through greater use of the energy from nuclear power plants or by expanding the use of renewable sources of energy in all forms: direct solar radiation and the energy of water, wind and biomass. In recent years, wood, other solid biofuels and renewable waste have presented the crucial part of renewable energy sources.^{3,4}

1.2 Biomass

According to the Directive on renewable energy resources, biomass derives from different kinds of organic materials: energy crops (oil plants; plants containing sugar), wood,

forest waste and agricultural waste, and biodegradable waste from households, fishery and industry⁵.

Biomass can be used for heating, for generating electricity and producing biofuels. Both plant biomass and substances formed in the process of its decomposition contain elements that burn in presence of oxygen and at high temperature.

We distinguish between four procedures used to convert biomass into fuels:

- combustion in which combustible substances in biomass burn into carbon dioxide and water, emitting heat;
- biological transformation such as anaerobic fermentation, fermentation and composting;
- heat and chemical transformation such as pyrolysis;
- liquefaction or gasification.

Fuels produced from biomass with the described procedures can be classified into three groups:

- solid biomass (wood biomass, agricultural crops);
- liquid biofuels (bioethanol, biodiesel) ;
- gases from biomass (biogas, wood gas, landfill gas).¹

1.3 Advantages and disadvantages of using biomass

It is a renewable energy resource – its quantity is not infinite, but with the right use it is relatively quickly renewed (in contradistinction to fossil fuels). This is one of the greatest strengths of biomass, beside reducing pollution, contributing to the cleaning of forests and a positive effect on the development of agriculture. However, there are also disadvantages to it: the high price of the developing technology and the low level of people's awareness about its use, there is also a possibility of harmful ecological effects (excessive deforestation, degradation and contamination of fertile soil, reduced biodiversity ...). Total replacement of fossil fuels with biofuels is at the moment therefore unattainable. Energy is needed to produce biofuels, too.¹

Interestingly, many scientists believe that the best natural source of biomass are algae, single cell water organisms, since they grow in waste water, including the sea, and only need light and carbon monoxide to flourish.^{6,7}

1.4 Types of biomass and biofuels

Bioethanol is an alcohol which is nowadays produced by sugar fermentation, especially from corn and sugar cane, but also from corn stalks, prairie grasses, fast-growing trees, sawdust and algae.

By using bioethanol we can reduce emissions of greenhouse gases by 22-56 percent (and even by 91 percent, by using cellulose ethanol – a fuel barely known to date). However, production of corn ethanol leads to a great consumption of fossil fuels and releases a lot of CO₂, so many scientists are currently in double mind as regards the processing of corn into fuel. For the time being it is mostly used as a complement to petrol.

Biodiesel is a methyl ester produced from biomass. It is formed through the esterification of vegetable oils and animal fats (usually canola, soya and oilseed rape). High quality biodiesel can be used in normal diesel engines, independently or in mixtures with diesel. Its use can reduce carbon dioxide emissions by 68 percent.

Olive pomace (pulp) is one of the more interesting biofuels, which can be completely dried and compressed into blocks that can be then used for heating. While olive pomace remains nearly unknown as a fuel in Slovenia, it is already being used as an energy resource in the Near and Middle East and some other parts of the world (Spain, Turkey).

Wood biomass is an ancient, but at the same time modern, environmentally friendly and familiar source of energy. If we want to keep waste gas emission below the permissible level, wood biomass needs to be treated in a suitable way and the heating devices (stoves) should be in working order.

The source of wood biomass are forests. Slovenia is rich with forests, considering that 56 percent of its surface is covered in them. The wood industry in Slovenia uses almost all wood waste for the production of heat and steam, and only to a small extent also for electricity. Briquettes or pellets made of compressed wood are used as modern solid fuels produced from forest biomass or agricultural yields. Pellets are made of sawdust and are of a cylindrical shape, with a diameter of 5-15 mm and up to 30 mm in length. Wood briquettes are produced in a similar manner as wood pellets, but they are larger, with a diameter of 20-120 mm and a length of up to 400 mm. Only high pressure and steam are needed in the manufacturing process. Briquettes are made of bark, sawdust and dry wood dust.^{1,8}

2. Experimental part

This article presents an example of writing a research assignment undertaken by students in the final year of primary school (age 14-15).

During school lessons, we did not discuss biomass as a fuel in detail, but we found the topic very interesting, which is why we decided that we would focus on it in our research paper. We decided to use olive pomace because we live in a region which is known for the production of olive oil and the locals use the leftovers of the process of pressing olives also at home as a fuel in central heating appliances. Cherry stones can also be used as a fuel. In the applied part we tried to answer the following questions:

- how many °C do various fuels heat up a particular amount of water,
- what amount of residue is left after the burning of solid fuels.

2.1 Hypotheses

Before the experimental work we have set the following hypotheses:

First hypothesis: Different fuels emit different amounts of heat.

Second hypothesis: Burning time varies depending on the type of fuel.

Third hypothesis: There is no residue left after the burning of liquid fuels, while there is some after the burning of solid fuels.

Fourth hypothesis: Solid fuels emit more heat during burning than do liquid ones.

Fifth hypothesis: The quantity of residue left after the burning of various solid fuels varies.

2.2 Fuels that were used

The fuels we used during our experimental work were the following:

- pellets,
- briquettes,
- sawdust,
- olive pomace (undried and dried for one hour at 105°C),
- cherry stones (undried and dried for one hour at 105°C),
- biodiesel,
- ethanol,
- fuel oil.

Figure 1 shows olive pomace and cherry stones we used as biofuels.



Fig. 1 Olive pomace (left) and cherry stones (right) (Photo: Marzi)

2.3 Laboratory equipment

For our experiments we needed: an empty spirit burner, a laboratory balance, a stand and a gauze, a beaker, a holed aluminium container, a thermometer, a measuring cylinder and a stopwatch.

2.4 The work procedure

We investigated the amount of heat emitted during the burning of various fuels. We observed this indirectly, through measuring the temperature of water heated by the release of heat during the burning of a specific fuel.

On a piece of paper we weighed 20 g of solid fuel; we measured out 20 ml of liquid fuel with the help of a measuring cylinder. We put some old newspaper (0,9 g) and a combustion tablet (3 g) into the aluminium container, while the liquid fuel was poured into the empty spirit burner. On the lower stand we put a container with a solid fuel, or the burner with a liquid fuel, while we put a gauze and a beaker containing 50 ml of water on the upper stand. (see fig. 2)



Fig. 2 Burning of biodiesel (Photo: Marzi)

With the thermometer we measured the initial water temperature and noted it down. Then we ignited the combustion tablet and watched the burning process and the changes in water temperature. Temperature was read every 5 minutes. After all of the fuel burnt out, we noted the final water temperature and the total burning time. We also weighed the mass of the residue.

2.5 Results of experiments

2.5.1 Final temperature of water after the burning of various fuels

The experiments done gave us the following results:

Table 1: The final water temperature

Fuel	Initial water T [°C]	Final water T [°C]
Biodiesel	21	42
Ethanol	22	92
Fuel oil	22	70
Pellets	22	71
Briquettes	15	90
Sawdust	17	72
Undried cherry stones	21	90
Dried cherry stones	22	65
Undried olive pomace	17	80
Dried olive pomace	21	90

Ethanol gave off the most heat during burning (the final water temperature being 92°C), while biodiesel produced the least heat (the final water temperature being 42°C). (Table 1)

During the burning of ethanol temperature rises until the end (see fig. 3), while the temperature of biodiesel reaches 45°C and then starts to drop.

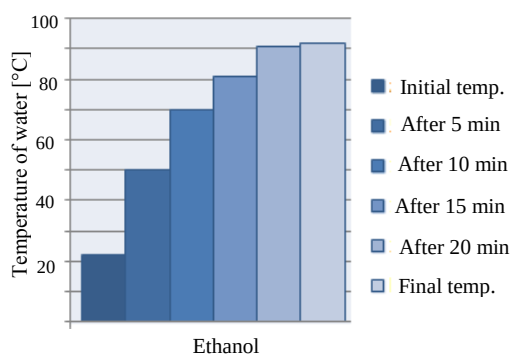


Fig. 3 Water temperature when burning ethanol

2.5.2 Residue left after the burning of solid fuels

After weighing the residue left after burning, we arrived at the following findings. (see Table 2)

Table 2: The residue after the burning of solid fuels

Fuel	Residue after the burning of solid fuels [g]
Pellets	8
Briquettes	1,2
Sawdust	4
Undried cherry stones	6,3
Dried cherry stones	6,5
Undried olive pomace	6,4
Dried olive pomace	11,6

We found that briquettes burnt down almost completely - the amount of residue left after burning this fuel is the smallest. The greatest amount of residue is left after burning dry olive pomace.

2.5.3 Burning time

The burning time of a particular fuel can be seen in the following diagram:

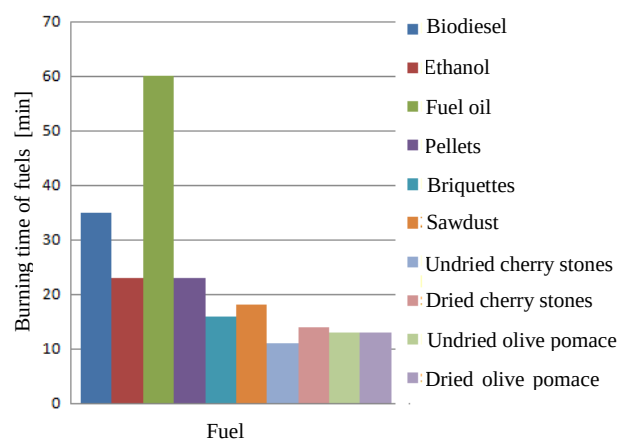


Fig. 4: Burning time of different fuels

Fuel oil burnt the longest (60 min and more), while undried cherry stones burnt for the shortest time (11 min). (see fig. 4)

3. Discussion and conclusion

The experiments done showed us the following:

- Different kinds of biofuel emit different amounts of heat during burning (for example, the final temperature with biodiesel is 42°C, while the final temperature with ethanol is 92°C), and thus we proved the first hypothesis (*Different fuels emit different amounts of heat*).

- Some substances take more time to burn, some less (for example, fuel oil burns for more than an hour, while undried cherry stones burn for eleven minutes). We thus also confirmed the second hypothesis (*Burning time varies depending on the type of fuel*).

- After the burning of all kinds of fuels we noticed a residue, even if only in the form of soot. Therefore we dropped the third hypothesis (*There is no residue left after the burning of liquid fuels, while there is some after the burning of solid ones*).

- Amongst all the samples, ethanol gave off the most heat, which is why we refuted the fourth hypothesis (*Solid fuels emit more heat during their burning than liquid ones*).

- Each of the fuels used left a residue after burning, namely different amounts of soot and ash (for example, the burning of briquettes gave us 1,2 g of residue, while dry olive pomace left 11,6 g of residue). This is how we confirmed the fifth hypothesis (*The quantity of residue left after the burning of various solid fuels varies*).

The article presents an example of making a research paper in elementary school, which is not the same as proper research work. This is especially true when it comes to the originality of hypotheses that form the basis of research and the precision with which these are tested. Students upgrade their existing knowledge with a different, research-oriented approach which includes doing experiments and forming conclusions independently. In their work, students can deploy their creativity and critical thinking skills, especially in connection to trending topics and everyday subjects of their interest.

4. References

1. Medved, S., Arkar, C., Energija in okolje: obnovljivi viri energije, Ljubljana, Zdravstvena fakulteta, 2009.
2. Novak, P., Medved, S.. Energija in okolje: Izbira virov in tehnologij za manjše obremenjevanje okolja, Ljubljana, Svet za varstvo okolja R Slovenije, 2000.
3. Činkole, Kristan, E. et al., Obnovljivi viri energije v Sloveniji: Prerez časa in prostora, Ljubljana, Borzen, 2016.
4. Eurostat Statistics Explained, available on http://ec.europa.eu/eurostat/statistics-explained/index.php/Renewable_energy_statistics
5. Directive 2009/28/EC of the European Parliament and of the Council of 23 April 2009 on the promotion of the use of energy from renewable sources and amending and subsequently repealing Directives 2001/77/EC and 2003/30/EC.
6. Zupančič M., Biogoriva, Agencija Republike Slovenije za okolje, available on <http://www.arso.gov.si/podnebne%20spremembe/poro%C4%8Dila%20in%20publikacije/>
7. Koželj, B., Vuk, D, Splošna ekologija z varstvom okolja, Maribor, Založba Obzorja, 1987.
8. Kolar, J., et al., Kako deluje?: Človekovo okolje, Ljubljana, Tehniška založba, 1981.
9. Kobal, E., Raziskovanje je odkrivanje novega znanja, Ljubljana, Državna založba Slovenije, 1989

REDUCING THE LEVEL OF THERMOELASTIC STRESSES IN THE PISTON OF A VEHICLE DIESEL ENGINE BY AFFECTING THE ENGINE CYCLE

СНИЖЕНИЕ УРОВНЯ ТЕРМОУПРУГИХ НАПРЯЖЕНИЙ ПОРШНЯ ТРАНСПОРТНОГО ДИЗЕЛЬНОГО ДВИГАТЕЛЯ ПУТЕМ ВОЗДЕЙСТВИЯ НА РАБОЧИЙ ПРОЦЕСС

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Abstract: Given are the results of a comparative design analysis of the operating cycle and thermal stressed state of a piston in diesel engine 2F10,5/12 under rated power conditions. To reduce the thermoelastic stresses in the piston, the paper suggests using the modern method of managing the operating cycle – homogeneous mixing and combustion. Such an operating cycle reduces the maximum local temperature in the combustion chamber and the temperature gradients, thereby reducing the thermal load on the piston.

KEYWORDS: DIESEL ENGINE, THERMOELASTIC STRESSES, TEMPERATURE, OPERATING PROCESS.

1. Introduction

As is known, the life of a piston engine depends, primarily, on the life of the piston. The piston operates in very rigorous conditions, and is affected by thermal and mechanical loads. Reducing the maximum temperature of the piston and the temperature gradients in the combustion chamber is one of the priority methods of improving piston operating conditions.

2. Preconditions and means for resolving the problem

Advanced program packages are used for evaluating analytically the economic, ecological and life indicators of an ICE as early as at the design stage. This enables reducing dramatically the development lead time of a new modification of an engine with superior economic and life indicators. Managing the operating cycle of a diesel engine with Homogeneous Charge Compression Ignition (HCCI) improves the engine's ecological indicators and reduces the maximum local temperatures in the combustion chamber. The burn processes in HCCI engines were investigated by such scientists as Prof. Rolf D. Reitz (U.S.A.), J. Chauvin (France) [1-7] and other researchers. In their research, these authors focused on issues related to managing the operating cycle of an HCCI engine and choosing effective adjustments of fuel injection equipment, whereas issues related to evaluating the impact of the HCCI cycle on thermal stressed state of a piston were studied insufficiently.

3. Solving the problem

Advanced design methods were used for numerical simulation of the operating cycle of diesel engine 2 F 10,5/12 (the reference design engine and HCCI). In the reference design engine, the fuel is injected over 20 degrees of crankshaft rotation (c.r.) to the top dead centre (TDC). In the HCCI variant – 4 injections: 1st – 130 deg. c.r. to TDC; 2nd – 100 deg. c.r. to TDC; 3rd – 40 deg. c.r. to TDC; 4th – 2 deg. c.r. to TDC, each with an interval of 20 deg. c.r.). This enabled filling the combustion chamber space with a virtually homogeneous air-and-fuel mixture. This, along with adding prepared exhaust gases to a fresh charge, provided appropriate conditions for self-ignition at the proper time instant.

4. Results and discussions

Fig. 1 shows the distribution of the fuel volume fraction in the combustion chamber of the Diesel cycle engine 2 F 10,5/12 and with the HCCI process at the instant of self-ignition of the air-and-fuel mixture at the crankshaft rotation angle of $\varphi = 352.5$ deg. c.r.

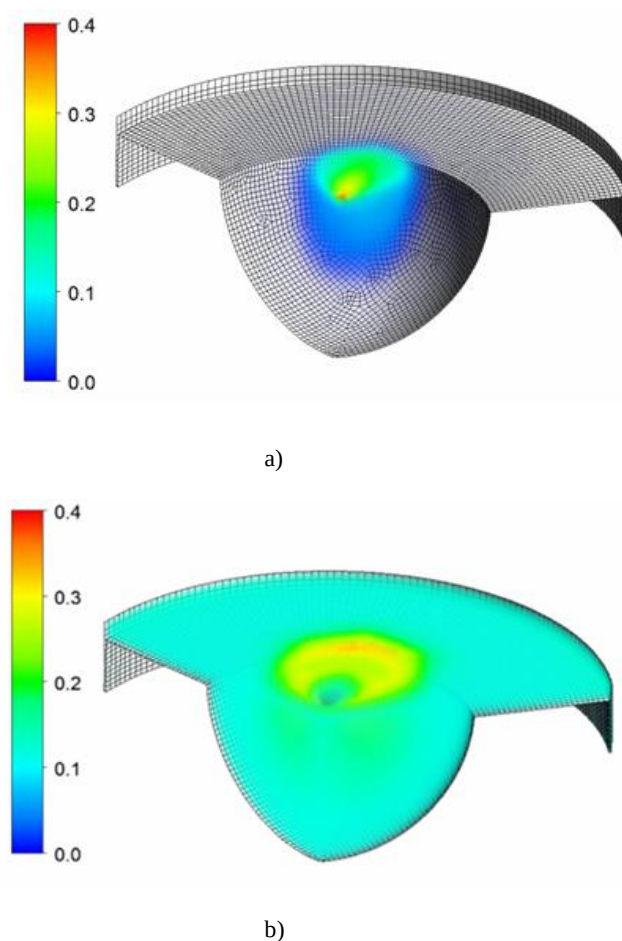


Fig. 1. Distribution of the fuel volume fraction in the combustion chamber of Diesel cycle engine 2 F 10,5/12 (a) and with the HCCI process (b)

Next are the results of numerical modelling of the operating cycle. Fig. 2 shows the distribution of local gas and flame temperatures in the combustion chamber.

The results show that the maximum flame temperature in a Diesel cycle engine reaches 2,724 K (Fig. 1 a), and in the HCCI engine, the flame temperature reaches 2,528 K (Fig. 2 b). Such a substantial local temperature drop is attributed to formation of a homogeneous air-and-fuel mixture and the presence in the fresh charge of prepared exhaust gases. However, further movement of the piston and the air-and-fuel mixture, the near-wall effects close to the

combustion chamber walls, and gas and flame turbulence localise the combustion processes.

Fig. 3 shows a comparison of indicator diagrams for engine 2 F 10,5/12.

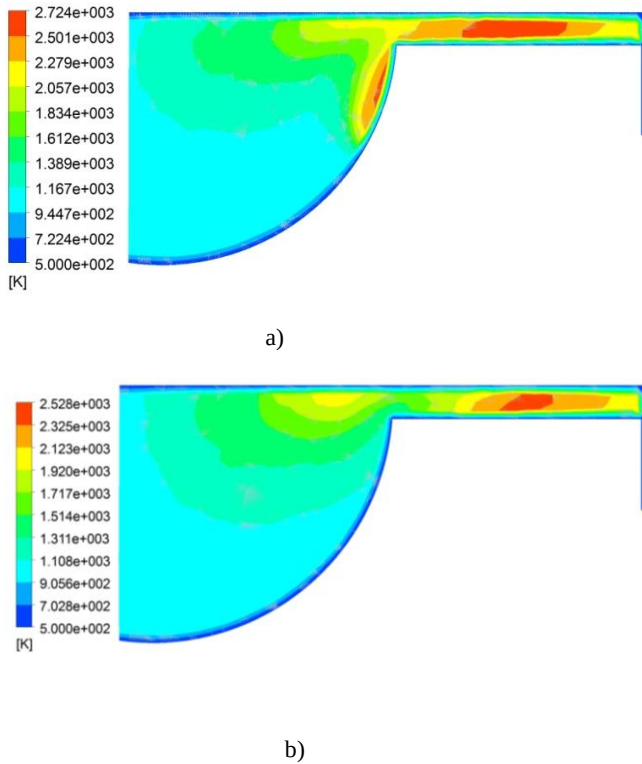


Fig. 2. Distribution of local gas and flame temperatures in the combustion chamber ($\varphi = 375$ deg. c.r.): a – Diesel cycle; b – HCCI engine

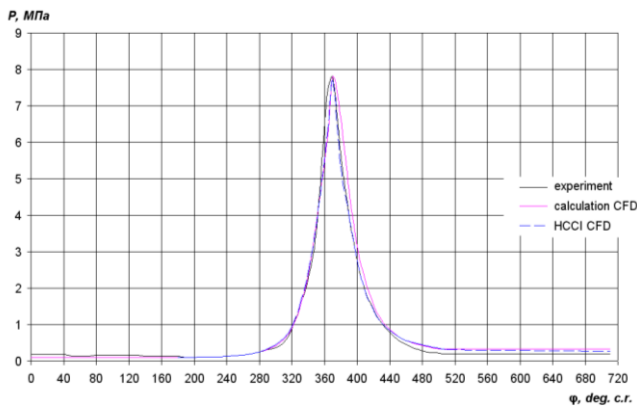


Fig. 3. Comparison of indicator diagrams of engine 2 F 10,5/12 (rated power conditions at $n = 1,800 \text{ min}^{-1}$, $N_e = 18.4 \text{ kW}$)

The results in Fig. 3 show that the design indicator diagram differs from the experimental one (averaged, with sampling of 120 cycles) in admissible limits, testifying to the correctness of the problem posed and validity of results. At rated power conditions, the maximum combustion pressure P_z (for experimental data) is 7.84 MPa, and that yielded by numerical modelling is 7.8 MPa.

The HCCI engine shows an insignificant pressure drop $P_z = 7.7 \text{ MPa}$. This is attributed to the peculiarities of the processes of combustion of a homogenised air-and-fuel mixture.

The temperature fields and the fields of thermoelastic stresses in the piston of engine 2 F 10,5/12 for design variants: a, b – standard, c, d

– HCCI engine, in the meridional section perpendicular to the piston pin axis are shown in Fig. 4.

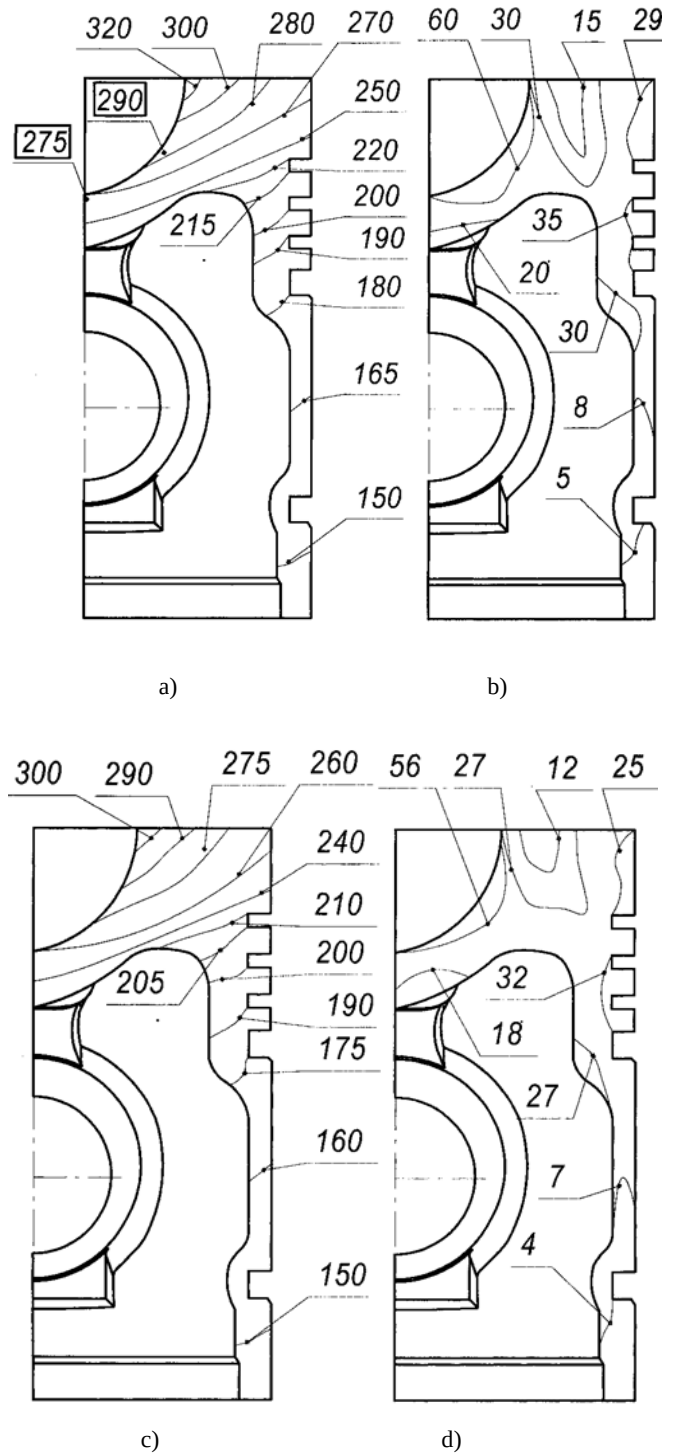


Fig. 4. Temperature fields (a – standard, c – HCCI engine), $^{\circ}\text{C}$ and fields of thermoelastic stresses (b – standard, d – HCCI engine), MPa in the piston of engine 2 F 10,5/12

The rectangles show the results of thermal measurements in piston reference points. The results (Fig. 4 a) show that the piston temperature field of the piston was recreated with adequate accuracy. For the standard variant, the maximum piston temperature is 330°C near the combustion chamber edge in the piston (not shown in Fig.). Near the annular groove for the first compression ring, the temperature is within 220°C . Over the piston height, the temperature changes from 200°C to 150°C (Fig. 4 a). The thermoelastic stresses are 60 MPa in the piston combustion chamber, and over the piston height they change from 35 MPa to 5 MPa. An HCCI engine demonstrates an average piston

temperature drop of 15-20 °C (Fig. 4 c), with a positive effect on the level of thermoelastic stresses, which decrease by 3-5% (Fig. 4 d). Reducing the temperatures and thermoelastic stresses in the piston of an HCCI engine will facilitate piston operating conditions and have a positive effect on engine running as a whole.

5. Conclusions

The research conducted has demonstrated that the HCCI cycle offers the following benefits:

- Reduces the maximum local temperatures in the combustion chamber and the temperature gradients, on the average, by 15-20%;
- Reduces the maximum piston temperature in the fireside by 20 °C;
- Reduces thermoelastic stresses in the piston, on the average, by 5-7%. This increases the diesel engine boosting level without degrading the piston life indicators.

6. Literature

1. Perini F., Zha K., Busch S. and Reitz R. Comparison of Linear, Non-Linear and Generalized RNG-Based k-epsilon Models for

Turbulent Diesel Engine Flows. *SAE Technical Paper*, 2017-01-0561.

2. Wickman D., Yun H. and Reitz R. Optimized Split-Spray Piston Geometry for HSDI Diesel Engine Combustion. *SAE paper*, 2003-01-0348, *SAE Transactions*, Volume 112, Section 3, Journal of Engines, 2003, 488-507.

3. Munnannur A., Abani N. and Reitz R.. Use of a Pressure Reactive Piston to Control Diesel PCCI Operation - A Modeling Study. *SAE Paper*, 2006-01-0921. *SAE Transactions*, Vol. 115, Section 3, Journal of Engines, 2006, 542-555.

4. Ra Y., Reitz R., Jarrett M. and Shyu T. Effect of Piston Crevice Flows and Lubricant Oil Vaporization on Diesel Engine Deposits. *SAE Paper*, 2006, 2006-01-1149

5. Genzale C., Reitz R. and Musculus M. Effects of Piston Bowl Geometry on Mixture Development and Late-Injection Low-Temperature Combustion in a Heavy-Duty Diesel Engine. *SAE paper*, 2008-01-1330, Special Publication, SP-2185, Compression Ignition Combustion Processes, *SAE Int. J. Engines*, Vol. 1(1), 2009, 913-937.

6. J. Chauvin, G. Corde, and N. Petit. Transient control of a Diesel engine airpath. InnAmerican Control Conference, 2007.

7. J. Chauvin, G. Corde, and N. Petit. Constrained motion planning for the airpath of a Diesel HCCI engine. In Conference on Decision and Control, 2006.