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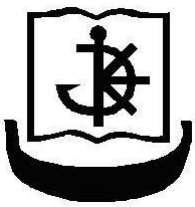

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CONTENTS

FILTERING GAS-FLUID MIXTURE INFLUX TO CYLINDRICAL DOMAIN

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Abstract
The influence of gas microbubbles on gas-fluid medium influx to cylindrical domain is studied. An expression for mass influx of gassy fluid is obtained. The results of calculations of mass influx for different values of volume content of gas depending on pressure on the boundary of domain are cited. The results of the paper permit to estimate the influence of volume content of gas on intensity of release of fluid from soil. Calculations for different values of pressure drop and gas content may be used by studying influence of gas-fluid medium on dynamics of a maritime vessel.
Keywords: *mass influx, volume content, maritime vessel, two - phase medium, state equation.*

Nomenclature

w - fluid filtration speed
$m\rho$ - fictions density of the fluid
P - Leibenson function
α_{20} - initial volumetric gas content
ρ_1^0, ρ_2^0 - real density of the carrying and dispersed phase
$\rho_1 c_1$, $\rho_2 c_2$ - heat capacity of the carrying and dispersed phase
a_0 - radius of bubbles
L - length of cylindrical domain
k - permeability of plate
h - thickness of plate
p_c, p_k - pressure on the well surface and on the removed circular external reservoir boundary
$p_н$ - saturation pressure
R_k - effective radius of draining
μ - fluid viscosity
Q_m - mass flow rate

Introduction

As is known there exist a number of hypotheses on the secrets of the Bermuda triangle, which mysterical forces effect upon the vessels. Some of them are scientifically substantiated by the scientists. There are many papers on this phenomenon but the answers to these arising questions have not been found yet.

Professor Joseph Monagahm and student David May from Melbourne (Monah University, Australia) suggested an interesting hypothesis on Bermuda triangle. They supposed that the fault of these phenomena is the methane gas in water. Gigantic bubbles filled with methane of so reduced density are formed that the motion of vessels becomes impossible and they go to bottom. True, if the vessel was between the middle and external edge of the mega bubble. This explains the cases of finding the vessels with dead people, more exactly suffocated from poisonous methane. Bubbles formation in explained by the fact that just in these places in the cracks and fractures of former volcanoes great beds of methane hydrate were found out. Thus, in this hypothesis everything in subjected to logic.

Note one more hypothesis on the existence of Bermuda triangle connected with gas hydrate accumulation in Atlantic Ocean waters. The deputy director of the Institute of Cryosphere of Earth of SB of RAS Anatoliy Nesterov reported about this fact at the press conference "Geology and oil and gas content of West-Siberian megabasin.

At the bottom of the Atlantic Ocean, in the regions of Bahama, Caliphornia and Bermuda Islands great accumulation of gas hydrate have been concentrated. When there happens advance, the gas hydrates begin to decompose and gas gives off.

According to Anatoliy Nesterov`s theory, if a vessel finds itself in this medium, then because of sharp drop of density of water surface the vessel goes into the bottom. This hypothesis has not been proved scientifically. But presence of accumulations of gas hydrate in the Atlantic Ocean waters was affirmed still in times of American program of deep water drilling in the middle eighties. In connection what has been said, it is necessary to investigate regularities of fluid filtration in porous medium.

Formation of two-phase flows is very typical in many cases of fluid flow. In such flows dissolved gas release happens. If the porous medium is saturated with fluid and gas mixture, then the gas micro bubbles substantially influence on filtration of gas-fluid medium.

On the larger part of the porous medium, the gas and fluid flow happens jointly at some time interval. Therewith, the motion of fluid in the soil in a great deal depends on the quantity of gas dissolved in it. The gas solubility in the soil is determined by pressure.

Experimental and theoretical investigations latterly conducted with gas containing fluids [5-8] show that under pre - transient conditions (i.e. in area of pressure exceeding the saturation pressure but close to it) the rheological and relaxation properties of gas-fluid systems to a large extent is determined by the existence of “micro embryos” - the smallest gas bubbles whose co-operative action becomes apparent by approaching the saturation pressure [7].

A number of experiments points to the existence of stable bubbles in pre - transient phenomena and show that the gas-fluid systems filtration in porous medium near the saturation pressure is accompanied by non equilibrium effects.

In the paper [9] a problem of gassed fluid flow in a porous medium is considered. The authors explain the periodic fluctuations of gas and fluid flow rate by the processes of sorption and desorption of gas micro embryos on the walls of porous space and their diffusion observed in experiments. The kinetic equation in which the desorption velocity is directly proportional to concentration of adsorbed micro embryos and to quality of filtration rate, and the adsorption velocity is directly proportional to the product of concentration of moving micro embryos and the concentration of free area of the pore surface is used.

In the paper [1] the results of investigations of gas-fluid solutions filtration at pressure higher than equilibrium saturation pressure are cited. It is noted that if in the fluid flow in the pipe the gas bubbles rise or fall, there appear hydrodynamic forces that speed to deflect the bubbles to the centre or to periphery of flow.By filtration from below to upwards, the bubbles are retained against the wall of pore channels. Vice-versa, when the solution flows from the top to downwards the gas is concentrated at the centre of pore channels. At horizontal filtration both characters of motion are realized simultaneously.

In the paper [7] the issues of applications of contour flooding with the use of micro embryonic technology are considered. By realization of flooding $0{,}15-0{,}36\,m^3$ air was added to each $1\,m^3$ of water injected into the layer and $1\,MPa$ layer pressure. The injection was performed at ratio of bottom-hole pressure in the input well to the bed pressure equal to 1,8:2,0. Under the indicated conditions in the layer from the well bottom to the external boundary of the perturbation zone the bubbles are situated under the pressure in 1,1:1,2 times greater than the air saturation of water.

It is indicated that increase of the layer coverage by displacement and decrease of friction resistance is explained by the existence of viscous non equilibrium properties of displacing water-air solution in pre - transient phase state, that are formed by micro embryos (micro bubbles) in water dissolved air at pressure higher than saturation pressure.

For revealing the influence of gas micro embryos on filtration processes, in [6, 7] steady state and unsteady investigation methods were used. Experiments for revealing the influence of gas micro embryos on filtration processes started with pressure exceeding the quantity of nucleation by 3 times. The experiments were conducted till the pressure in the system attained the quantity of saturation pressure.

Description of research

Let as a result of stationary filtration of gassy fluid in the porous medium, the fluid show into the open space happen. Represent this space in the form of cylindrical domain of length $2L$. Assume that the porous medium is a homogeneous isotropic soil of permeability k of thickness h and with impermeable boundaries. Let on the surface of the cylinder, the constant pressure p_c, and on the remote circular boundary of radius R_k the constant pressure p_k ($p_k > p_c$) hold up [2], [3], [4], [9], [14].

Let`s consider a plane radial flow of gassy fluid to cylindrical domain.

Write the equation of continuity at filtration of fluid into porous medium:

$$\frac{\partial m\rho}{\partial t} + div\rho\bar{w} = 0 \qquad (m = const) \qquad (1)$$

The quantity $m\rho$ is a fictions density of the fluid - the density smeared on the whole volume of the porous medium, w is the fluid filtration speed along the layer.

We assume that the Darcy low is valid:

$$\bar{w} = -\frac{k}{\mu} gradp \qquad (2)$$

We'll consider isothermal filtration flows when the density is only pressure-dependent:

$$\rho = \rho(p) \qquad (3)$$

We can transform the system of equations (1) – (3) to the form more convenient for solving the problems, when the problem is reduced to one equation with respect to one unknown function. For deriving such a function, substitute the Darcy law into the continuity equation and get

$$m\frac{\partial \rho}{\partial t} + div\left(-\rho\frac{k}{\mu} gradp\right) =$$

$$= m\frac{\partial \rho}{\partial t} - \frac{k}{\mu} div(\rho gradp) = 0$$

The further transformation is connected with introduction of the Leibenson function P:

$$P = \int \rho(p)dp, \qquad (4)$$

Introduction of the Leibenson function admits to linearize the expressions under the divergence operator:

$$gradP = \rho gradp \qquad (5)$$

Equality (4) admits to determine the explicit form of the Leibenson function at the given state equation $\rho = \rho(p)$, and substitution of the state equation into the above obtained equation admits to obtain an equation with respect to only one pressure function p.

After introducing the Leibenson function into the system of equations, we can get

$$m\frac{\partial \rho}{\partial t} - \frac{k}{\mu}\Delta P = 0$$

$$\rho\bar{w} = -\frac{k}{\mu} gradP \qquad (6)$$

$$\rho = \rho(p), \qquad P = \int \rho(p)dp$$

The system of equations (6) determines the mathematical model of theory of filtration of viscous incompressible fluid (gas) into no deformable isotropic porous medium.

Consider the steady - state filtration. By projecting equation (6) onto the cylindrical system of coordinates, we get

$$\frac{d}{dr}\left(r\frac{dP}{dr}\right) = 0, \quad \rho w = \frac{k}{\mu}\frac{dP}{dr}, \qquad (7)$$

$$P = \int \rho(p)dp$$

Draw attention to the fact that in projection of the Darcy law on the coordinate axis r the signs in the left and right sides coincide. This is stipulated by that the motion happens to the cylinder domain and the filtration rate is projected with a negative sign.

Consider the behavior of the solution near the saturation pressure $p/p_н \sim 1$, where gas is liberated from fluid. The gas bubbles formed from the solution with initial volumetric gas content α_{20}

partially clog the medium's pores, partially are filtrated through large pores and emanate from the porous sample. Therewith, the mass flow rate of gas-fluid mixture decreases.

Retrace the dependence of mass flow rate of gas - fluid mixture on volumetric gas content α_{20} and external boundary pressure.

If the volumetric content of bubbles in per unit volume of mixture $\alpha_2 \sim 1\%$, (this case is more interesting from practical point of view), then the stable bubbly structure of the medium is realized, and the latter may be considered as some homogeneous bubbly fluid [13]. The characteristic property of such a fluid under ordinary pressures when the real density of dispersed phase ρ_2^0 is significantly less than real density of the carrying phase ρ_1^0, is the higher average density of $\rho = \alpha_1\rho_1^0 + \alpha_2\rho_2^0 \approx \alpha_1\rho_1^0 = (1-\alpha_2)\rho_1^0 \approx \rho_1^0$, $(\alpha_1 + \alpha_2 = 1)$ that differs negligibly from the density of the carrying phase by virtue of $\rho_2^0 << \rho_1^0, \alpha_2 << 1$ under high (compared with pure fluid with no bubbles) compressibility.

A two - phase medium of bubbly structure differs from other two-phase media by the fact that the heat capacity of the carrying phase $\rho_1 c_1$ considerably exceeds the heat capacity of the dispersed phase $\rho_2 c_2$ by virtue of prevalent mass content of the carrying phase per a unit volume $\rho_1 c_1 >> \rho_2 c_2$, $(c_1 \sim c_2, \rho_1 / \rho_2 >> 1)$ [13].

In this connection, the fluid is a thermostat, and has a constant temperature $T_1 = const$ [10], [11].

If the bubbles are very fine (the radii of bubbles a_0 are small), and the carrying fluid is very viscous $\frac{a_0}{\mu_1}\sqrt{p\rho_1^0} << 1$, then one can neglect the radial inertia of fluid around the pulsating bubble. In this case the equalization of pressure in phases is determined by viscous forces in fluid. Such situations are realized when the bubbles are fine, the fluid is viscous and the Reynold's number is very small, $\mathrm{Re} = \sqrt{\frac{p}{\rho_1^0}}\frac{a_0\rho_1^0}{\mu_1} << 1$.

R. I. Nigmatulin the equation of state of a bubbly fluid is studied [13]. The inertial members in the Relay equation describing the law of motion of moving interface and transitional movement with respect to fluid by virtue of great viscosity of fluid and small sizes of bubbles are neglected. Furthermore, because of high velocity of sound in the liquid phase of the mixture, the compressibility of liquid phase is neglected. The capillary pressure is neglected as well. In this case in [13] it is shown that the motion of bubbly mixture is described by a model of ideal compressible barotropic medium. The equation of state of such a medium accepts the form:

$$p(\rho) = \frac{\alpha_{20} p_0}{\alpha_{10}} \frac{\rho}{\rho_{10}^0 - \rho},$$
$$\rho = \rho_{10}^0 \left(1 - \frac{\alpha_0 p_0}{\alpha_0 p_0 + p}\right), \qquad (8)$$
$$\alpha_0 = \alpha_{20} / \alpha_{10}$$

For a gas - fluid system with the equation of state (8), for $p_0 = p_k$ the Leibenson function is determined by the equality:

$$P = \rho_{10}^0 \int \left(1 - \frac{\beta_0 p_c}{\beta_0 p_c + p}\right) dp = ,$$
$$= \rho_{10}^0 \left[p - \beta_0 p_c \ln(\beta_0 p_c + p)\right] + C \qquad (9)$$
$$\beta_0 = \frac{\alpha_{20}}{\alpha_{10}} \cdot \frac{p_k}{p_c},$$

Having integrated the first equation of (7), we get

$$P = C_1 \ln r + C_0 \qquad (10)$$

Allowing for (10), equation (9) with respect to pressure takes the form:

$$\begin{aligned} &p(r) - \beta_0 p_c \ln[\beta_0 p_c + p(r)] \\ &= C' \ln r + C_0' \end{aligned} \qquad (11)$$

If we use boundary conditions $p = p_k$ for $r = R_k$ and $p = p_c$ for $r = r_c$, then the unknown constants are determined from the relations

$$\begin{aligned} C' &= \frac{p_k - p_c + \beta_0 p_c \ln \dfrac{\beta_0 p_c + p_c}{\beta_0 p_c + p_k}}{\ln R_k / r_c} \\ C_0' &= \frac{\ln R_k [p_c - \beta_0 p_c \ln(\beta_0 p_c + p_c)]}{\ln R_k / r_c} - \\ &- \frac{\ln r_c [p_k - \beta_0 p_c \ln(\beta_0 p_c + p_k)]}{\ln R_k / r_c} \end{aligned} \qquad (12)$$

The expression for mass flow rate of gas-fluid mixture is written as follows:

$$Q_m = 2\pi h \cdot r\rho \cdot w \qquad (13)$$

From the second equation of (7) we get:

$$r\rho \cdot w = \frac{k}{\mu}\left(r \frac{dP}{dr}\right) \qquad (14)$$

Having substituted is equation (14) the Leibenson function by the found value of (9), allowing for (10) and (12) we get

$$\begin{aligned} &\left(r \frac{dP}{dr}\right) = \rho_{10}^0 C' = \\ &\rho_{10}^0 \frac{p_k - p_c + \beta_0 p_c \ln \dfrac{\beta_0 p_c + p_c}{\beta_0 p_c + p_k}}{\ln R_k / r_c} \end{aligned} \qquad (15)$$

Consequently,

$$\begin{aligned} &\frac{Q_m}{2\pi h \rho_{10}^0 p_c k / \mu} = \\ &= \frac{p_{kc} - 1 + \alpha_0 p_{kc} \ln \dfrac{\alpha_0 + 1/p_{kc}}{1 + \alpha_0}}{\ln R_k / r_c}, \\ &\alpha_0 = \frac{\alpha_{20}}{\alpha_{10}}, \; p_{kc} = \frac{p_k}{p_c} \end{aligned} \qquad (16)$$

When no gas bubbles ($\alpha_0 = 0$), relation (16) coincides with Dupuy formula $\dfrac{Q_m}{2\pi h \rho_{10}^0 p_c k / \mu} = \dfrac{p_{kc} - 1}{\ln R_k / r_c}$.

Dependence of dimensionless mass flow rate of gas-fluid mixture $Q = \dfrac{Q_m \ln R_k / r_c}{2\pi h \rho_{10}^0 p_c k / \mu} = p_{kc} - 1 + \alpha_0 p_{kc} \ln \dfrac{\alpha_0 + 1/p_{kc}}{1 + \alpha_0}$ at fixed values of all parameters on p_{kc} and

different gas contents α_0 is depicted in Figure 1. The values of $\alpha_0 = 0;\ 0{,}05;\ 0;0{,}1;\ 0{,}3$ correspond to curves 1-4.

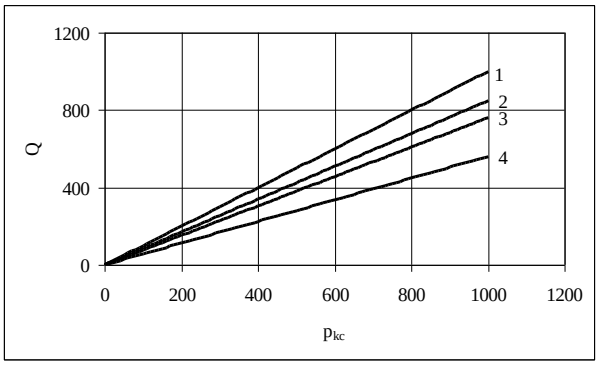

Figure 1. Dependence of mass flow rate on external boundary pressure p_k .

The calculation results show that the gas content increase reduces to decrease of mass flow rate of mixture. The flow rate drop becomes significant by increasing the external boundary pressure.

Dependence 1 on the figure that corresponds to pure fluid coincides with dependence of volumetric consumption calculated by Dupui formula. For small values of volumetric gas concentration and fixed value of p_{kc} we can get the approximation of formula (16):

$$Q = p_{kc} - 1 + \alpha_0 p_{kc} \ln \frac{\alpha_0 + 1/\, p_{kc}}{1+\alpha_0} \approx$$

$$\approx p_{kc}\left[1 + \alpha_0 \ln\left(1 + \alpha_0 p_{kc}\right)\right] - 1$$

Similarly, for $p_{kc} >> 1$ and fixed volumetric gas concentration we can get the approximation of formula (16):

$$Q = p_{kc} - 1 + \alpha_0 p_{kc} \ln \frac{\alpha_0 + 1/\, p_{kc}}{1+\alpha_0} \approx$$

$$\approx p_{kc}\left[1 + \alpha_0 \ln \alpha_0\right] - 1$$

This relation shows that the dependence $Q\left(p_{kc}\right)$ practically is linear in wide range α_0, (Figure 1).

Thus, formula (16) generalizes the known Dupuy formula for the case of gassy fluid filtration to the well.

The results show that the increase of gas content reduces the mass flow rate of the mixture. And the drop rate becomes significant with increasing pressure drop.

Conclusions

The deterministic models admit to perform calculations, make quality conclusions on fluid inflow rate to the cylinder domain. At the same time, their application is restricted by poor exactness of the results that may multiply differ from real values. This is connected with impossibility of account of large quantity of factors influencing on filtration character of fluid. However, the purpose of deterministic models is just in taking into account basic determining factors and obtaining quality picture of the process on analysis of their interaction. Therefore, for obtaining necessary accuracy of calculation on one hand it is required to have sufficient information on the other hand to use the appropriate processing methods.

The gas bubbles exert the great influence on filtration characteristics of fluid through porous medium. Therewith the volumetric gas content considerably influences on fluid inflow to the well.

At present, for estimating the production rate (inflow) at steady-state conditions of radial filtration of homogeneous fluid, the Dupuy formula is used. But, applicability of Dupuy formula is worth for small gas contents.

The hydrodynamic model suggested in the paper admits to judge on considerable influence of volumetric gas content on fluid inflow at filtration of compressible mixture of viscous fluid with gas bubbles.

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EFFECT OF CAVITATION DETERIORATION ON HERMITICITY OF COMBUSTION CHAMBER OF DIESEL ENGINES

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Abstract
The article analyzes the causes of failure of hermiticity in combustion chamber of diesel engines. As the main reason of depressurization cavitation wear and deformation of the cylinder barrels is pointed out. It is found that due to deformation cylinder barrel loses its sustainability mainly in the upper part.
Keywords: *cylinder, diesel engine, cavitation wear, deformation, hermiticity, stability.*

Introduction

Significance of improving the reliability of components of marine diesel engines with a cylinder-piston group is defined by the fact, that technical and economic, as well as energy performance, and importantly, performance life of the engine depend just on the cylinder barrel piston-ring tighten junction condition. The expenses incurred in the repair, restoration and replacement by new details of the cylinder-piston group are much higher than the costs of the repair, restoration and replacement all the other details of the engine.

The analysis shows that all the vessel engine cylinder blocks and cylinders are fabricated by the cast. The cylinder block itself is made as whole with crankcase and often is called as "block-crankcase". Block crankcase plays the role of the body frame, the different mechanisms, apparatus and separate details are attached to it. In the lower part of the block crankcase drain pan is placed, it serves as a reservoir for oil.

Discussion of the data

Block crankcase receives significant dynamic loadings creating during engine performance. It is known that the wear resistance of all the details of the crankshaft-rocker arm block mechanism of depends on rigidity of the block crankcase.

It is known that most of the vessel diesel engines have been designed in such a way that the block crankcases equipped with pull-out "wet type" barrels, that is outer surface of the barrels are covered with cooling liquid; or "washed" (Figure 1). In the case of damaging of "wet barrels" it is possible to replace them without removing engine from chassis (case, frame). Such barrels freely are placed into guides and aligning belts of the block.

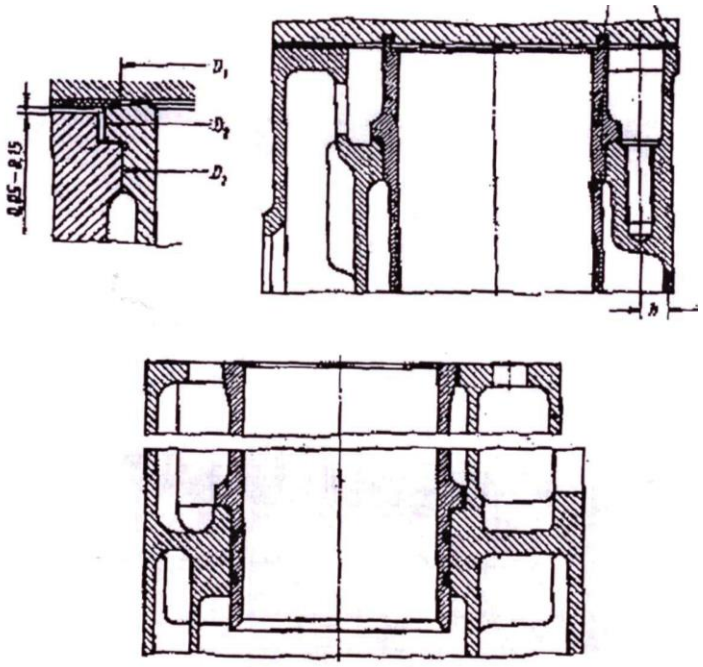
To ensure stability and to keep the geometry of the barrel two guiding straps – in the upper and lower parts – are anticipated, the lower strap has a slightly smaller diameter. Bearing plane surfaces of the "wet barrel" has been executed on ring-shaped protruding surfaces of the block, their rigidity must provide as low as possible disturbance of the geometric form of cylinder barrels during securing of fastening brackets.

To provide a reliable gas contact barrel ends should come forward slightly from the bearing plane of the block, then main part of securing forces of fastening brackets will impinge upon barrel flanges. The height of the protuberance may be different in different structures: in vessel engines it varies in the range of 0.05 .... 0.15 mm.

Consolidation of a "wet" barrel in the bottom point and the block is often reached by means of two-three rubber rings (Figure 1). Despite a variety of design features of blocks of vessel engines and distinction of installation of barrels in blocks, in any engine certain deformation is inevitable.

Practice shows that leak of gas from an interval in knot of fastening (hermetic sealing) can slightly be shown in engines operation, the start-up mode makes an exception. Leak only slightly raises temperature of a piston and a ring in a zone of an arrangement of fastening. Gas release makes distinct impact on lateral and external surfaces of the ring.

At bad consolidation of the ends with the block surrounding of the ring by hot gases leads to heating of ring and piston, drying of greasing and finally to increased deterioration of a ring, grooves of the cylinder and cylinders and at last, to them scratching.



c)

Figure 1. "Wet" barrels with upper (a), middle (b) and (c) bottom location of the bearing flanges

Infringement of the contact between the ring and cylinder sharply changes a thermal mode of the ring: the ring not only is not cooled by heat transfer on the cylinder wall, but on the contrary, heats up by hot gases passing through a cavity between a ring and the cylinder [1, 2].

At passage of hot gas through badly consolidated contact between the ring and the cylinder, oil between rubbing surfaces dries, therefore the overall picture of a friction changes dries up and considerably raises friction force of rings, the temperature of details of friction pairs grows even more. Therefore, for improvement of gas consolidation an important factor is elimination of cavity between a ring and the cylinder. At existence of such cavities pressure of gas will effect both on internal and the external cylindrical surface of the ring and will not provide pressing of the ring to a cylinder surface.

Presence of cavities between contacting surfaces of the ring and the cylinder are inadmissible as well for the reason that with acceleration of the engine resistance of the ring-cylinder pair to deterioration should be higher. Compaction of contact between a ring and the cylinder should be provided already at engine assemblage, it is not necessary to hope that compaction will be provided after work during some time. It is necessary to notice that deformations of the ring-cylinder pair of the various nature in RPQ details also have certain influence on condensing properties of pair a ring-cylinder.

It is established that at all deformations of the cylinder (change of the sizes, ovalization, et al.) round ring consolidation contact to the cylinder is lost. The exception makes a case when ring consolidation settles down in that part of the deformed cylinder where curvature is just identical with the nominal size of the round cylinder. However, and in this case, if consolidation supports one of the main axes of the oval, one of ring branches leaves from a cylinder wall.

It is established that piston rings usually are not fixed without turn and a ring can be directed in the cylinder in any kind. Therefore it is possible to consider that the biggest angle of loss of contact is connected with ovalization of the cylinder at a consolidation arrangement on the big semi-axis of the oval.

However we will notice that the tightness provided with a ring in the cylinder besides (except) an arch of a cavity also depends on width and the area of the arisen cavity. These indicators depend not only on size of deformation of the cylinder, but also and from other parameters.

It is established that other reason of loss of contact round consolidation is change of curvature of the cylinder on the consolidation location. Therefore at complicated deformations of the cylinder (simultaneous change of the size and ovalization) the cases when elementary deformations change curvature of the cylinder in one direction can be more comprehensible. In other words, it is necessary to consider a consolidation arrangement on the big axis of an oval in the cylinder with the reduced size and on a small axis of an oval in the cylinder with the increased size.

It is known that unsatisfactory operation of the cylinder-piston group is confirmed by such criteria, as reduction of sucking, increase in a burn-out of oil, increase in pressure of crankcase gases. In essence these indicators actually are a consequence of the same defect – loss of consolidating properties of piston rings. If the engine has developed overhaul period, in this case deterioration of RPQ details leads to such conclusions, that a deterioration of a mirror of the cylinder, deterioration of piston rings, loss of their elastic properties, deterioration of the piston wall occurs.

Obviously that normal and reliable operation of the engine depends on a condition of its details.

Cylinders wear out as a result of a friction on their surface pistons and rings. As a result they become conical on height, and oval on cross-section. The top part of the cylinder is subject to deterioration in a greater degree. It is explained by insufficient greasing and high temperature presence in the top part of the cylinder. Here also an important role plays hit of gases under first piston ring and pressing of the ring with a big force to a cylinder wall.

And in this case, despite carrying out of certain actions for improvement tribotechnical characteristics of adjoining surfaces, deterioration of details of the cylinder-piston group happens close to catastrophic value. For definition of deterioration degree of RPQ details indirect indicators presented in the Table 1 is used.

It is established that there are some principal causes influencing on deformation of the cylinder:

- technological causes – they are connected with infringement of the operating mode of the technological equipment and deviations of the geometrical dimensions;
- mounting causes – arise at engine assemblage;
- operational causes – they are connected with deterioration of barrels.

To all aforesaid we will add also that the barrel itself loses the spatial rigidity from influences at repair (chipping, honing, et al.), as well as because of cavitation deterioration.

Table 1. Standard values of diagnostic parameters

Parameter	Parameter value		
	nominal	admissible	limit
Quantity of the gases entering in crankcase, l/min	50	125	135
The expense of oil on a deposit, %	0.6	2,5	2.6
Pressure of gas in the end of a compression step, MPa	3.5	-	2.0

All these facts lead to the conclusion that, at all stages of the life cycle of cylinder barrels additional measures to reduce deformation should be implemented.

Gas leakage into crankcase through collar leads to negative consequences. Engine power is reduced, increases fuel and oil consumption, goes down environmental performance of the engine, carbonization of the piston collars (contamination with smut) and eventually increasing the likelihood of them breaking occurs.

Gas leakage into crankcase is of avalanche character, that is in the result of combustion motor oil solid particles are formed, and they involve into the abrasive wear process [3, 5]. These changes have irreversible nature and their results can be overcome only by extraordinary repair of the engine with replacing all of the RPQ details.

Correctly given radial pressure epure for collar with maintaining in technological process a minimum pressure in acceptable bounds, for example, can eliminate the effects of changes in barrels diameter. Worsening of the contact will occur in the event of barrels ovalization. In this case, sharp drops in pressure on the barrel wall are observed and hence during subsequent operation high wear of barrels and collars will be observed in these zones.

In addition, breakage of the link between collar and barrel may occur in the working surfaces. In this case further activities of RPQ by keeping the primary hermiticity will be impossible.

Deformations of the barrel wall alongside with mechanical wear of the inner surface of the barrel will significantly worse of RPQ hermiticity, and as a result will reduce all engine characteristics.

Therefore, experimental studies are directed to deformation of engine cylinder barrel (through engine run), to study of the effect of location and the amount of cavitation and mechanical wear zones of its internal surface.

Since the barrels in themselves are cylindrical skin, during creation loads along the axis a characteristic feature as loss of stability of the skin should be manifest necessarily. Therefore studies of external deformation was carried out for the following barrels with discrete loading starting from 2500 N to 4000 N; new barrel without running; with 7000 km running without traces of cavitation wear; with 7000 km running and strong cavitation wear in the form of separate holes to a depth of up to 3 mm; with 45000 km running and strong cavitation wear (depth of the wounds on the surface from the bottom to the upper dead point reaches a half of the barrel wall thickness).

Depending on the engine run, graph which allows to trace change on kinetics of characteristic deformation are presented in Figure 2.

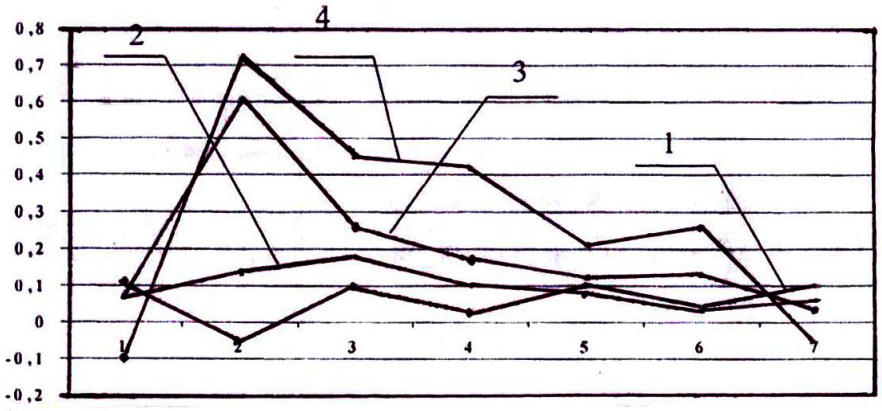


Figure 2. Graph of the barrel wall deformations:
1 - barrel without running (fresh barrel); 2 – barrel with 7000 km running without traces of cavitation wear; 3 – barrel with 7000 km running and strong cavitation wear; 4 – barrel with 45000 km running and strong cavitation wear

It was revealed that forms of deformations remains unchanged for both the new barrels and for barrels with strong cavitation wear on the outer surface. And value of deformation increase with engine run and for barrels with strong wear in outer surface deformation reaches notably higher values in comparison to ones for new barrels.

It is known results of the study on drop in pressure in receiver of the aerodynamic tube compressor during modeling of deformation of the barrel characteristic for engine block [4]. Deformations were modeled in two directions: parallel to the axis of the piston pin (low hardness zone) and perpendicular to the axis of the piston pin. Piston pin in the latter case, in fact, create additional enforcement rib.

In addition, it was determined that in the section of 85-90 mm distance from the upper flange barrel loses its stability, here maximal absolute values of deformation are observed. At the same time in this section at deformation in the end of the working stroke, that is at the lower dead point breach of the gases were investigated.

Elsewhere [4] it was shown that deformations and wearing of the barrels (working and outer surfaces) leads to a decrease sealing characteristics of SPT. This, in turn, can lead to reducing engine power and its environmental security.

In addition, it was determined that maximal permissible value for barrel deformations should be considered as not more than 30 microns; deformation characteristic for the engine block leads to decreasing of the hermiticity of SPT packing unit by at least 10%; deformations perpendicular to piston pin axis have stronger effect in reduce of the hermiticity due to lower rigidity of all unit in this direction. In view of that the piston is in position of the bottom dead point on distance of 85 mm from the barrel upper edge, hermiticity against deformations is in a critical limit.

Conclusions

The main reason of the depressurisation in combustion chamber of diesel engines is cavitation wear of cylinder barrels and considerable deformation occurred in upper part of the barrels. Admissible values of deformation of barrels have been defined.

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PROPAGATION OF LONG WAVE DISTURBANCES IN VICIOUS FLUID WITH FREE BOUNDARY

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Abstract

A mathematical model of the propagation of long-wave disturbances on the surface of a viscous fluid with a free boundary is offered. The characteristic equation for defining the propagation velocity and damping rate of the perturbations in the liquid are obtained and studied.

Key words: *long-wave disturbances, viscous liquid, decrement, phase velocity, frequency, dispersion, oscillations.*

Introduction

Stationary solutions of Navier-Stokes equations rather exactly describe the flow of viscous fluid in channels and rivers of constant discharges [5, 8].

At impulse discharge of water from water reservoirs [6] in the first approximation the fluid is considered to be ideal. The Korteweg de Vries (KdV) [1, 9] equations are obtained for this fluid from the Euler equations.

The models based on KdV don't take into account the effect of disturbance damping stipulated by the effect of fluid viscosity. For detailed study of disturbances introduced to Korteweg de Vries (KdV) equations by various properties of fluid, the direct method of theory of perturbations [1] and the method of inverse scattering problem modified for solving the disturbed Korteweg de Vries (KdV) equation are considered.

The direct method of perturbation theory is stated in [1] .

In the paper [3] for the first time an analytic expression for profile of finite amplitude periodic waves on the charged surface of deep viscous conductive fluid allowing limit passage to ideal fluid was obtained. It was shown that the state of the inner nonlinear resonance of capillary - gravitational waves is independent of viscosity and availability of surface charge. It was clarified that at resonance interaction the energy from the long capillary gravitational waves with wave number $k_* = \sqrt{\rho g / 2\gamma}$ is pumped to shorter waves with wave number $k_0 = \sqrt{2\rho g / \gamma}$.

In the paper [1] two dimensional statement a problem of definition of velocity field of the developed turbulent flow of the viscous fluid in a narrow channel is considered. The structure of velocity field components reducing to excitation of sound fields is studied . A new semi-analytic approach based on small perturbations method is offered. The instantanens field of velocities is represented in the form of the sum of the main fields of velocities and disturbances imposed on it. The main field of velocities is assumed to be time independent, and consequently doesn't reduce to onset of sound. The disturbed flow generates sound fields and is assumed to be small with respect to main one that is assumed to be known and is found by means of MKE using semi-empirical theories. As a result the conjecture on smallness of members reduces the problem to homogeneous linear partial equation whose solution allows to make assumptions on the structure of oscillations.

The mathematical model of propagation of long wave disturbances on shear flow of flow of two-layer ideal stratified fluid with free boundary was considered in [2]. The characteristic equation determining the propagation velocity of disturbances on fluid was obtained and studied. In the paper necessary hyperbolicity conditions of equations of motion for flows with a velocity profile monotone in depth were formulated and characteristical form of the system was calculated. Unlike this paper, we consider a model of disturbance propagation with regard to fluid velocity.

Problem statement

Assume that in the channel $0 \le y \le h(x,t)$ the flow of viscous incompressible fluid moves (fig.1), h is the depth of the fluid, y is the vertical coordinate of an arbitrary point in the water column. If we denote

the velocity vector components by u , v then the motion of viscous incompressible fluid over flat bottom with free boundary in the field of gravity force will be described by the system of Euler equations in the form:

$$\frac{\partial u}{\partial t}+u\frac{\partial u}{\partial x}+v\frac{\partial u}{\partial y}-\frac{\mu}{\rho}\left(\frac{\partial^2 u}{\partial x^2}+\frac{\partial^2 u}{\partial y^2}\right)+\frac{1}{\rho}\frac{\partial p}{\partial x}=0$$

$$\frac{\partial v}{\partial t}+u\frac{\partial v}{\partial x}+v\frac{\partial v}{\partial y}-\frac{\mu}{\rho}\left(\frac{\partial^2 v}{\partial x^2}+\frac{\partial^2 v}{\partial y^2}\right)+\frac{1}{\rho}\frac{\partial p}{\partial y}=-g \qquad (1)$$

$$\frac{\partial u}{\partial x}+\frac{\partial v}{\partial y}=0$$

Here ρ is the density of the fluid ; μ is the viscosity ; $p(x,y,t)$ is the hydrodynamic pressure.

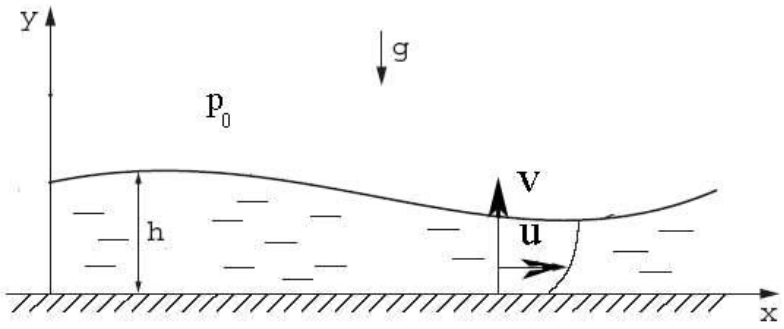

Figure.1. Schematic representation of layer of fluid of variable depth.

The boundary condition of the problem are no-slip condition and the lack of fluid flow through the channel wall

$$u(x,0,t)=0\,,\ v(x,0,t)=0\,, \qquad (2)$$

coincidence of velocity and pressure of the surface and the particles of the fluid for $y=h(x,t)$

$$\frac{\partial h}{\partial t}+u(x,h,t)\cdot\frac{\partial h}{\partial x}=v(x,h,t),\qquad p(x,h,t)=p_0 \qquad (3)$$

and no friction forces on the free surface of the channel for $y=h(x,t)$

$$\frac{\partial u(x,y,t)}{\partial y}=0 \qquad (4)$$

Write the initial conditions in the form:

$$u(x,y,0)=u_0(x,y),\quad v(x,y,0)=v_0(x,y),\quad h(x,0)=h_0(x) \qquad (5)$$

Main part

If we pass to dimensionless parameters and variables

$$U(X,Y,\tau)=u/\sqrt{gh_{00}}\ ,\ V(X,Y,\tau)=v/\left(\varepsilon\sqrt{gh_{00}}\right),$$
$$P(X,Y,\tau)=p/\rho_0 gh_{00},\ H(X,\tau)=h(x,t)/h_{00} \qquad (6)$$
$$X=x/\lambda\,,\ Y=y/h_{00},\ \tau=t\sqrt{gh_{00}}/\lambda\,,\ \varepsilon=h_{00}/\lambda$$

the system of equations (1) take the form:

$$\frac{\partial U}{\partial \tau}+U\frac{\partial U}{\partial X}+V\frac{\partial U}{\partial Y}-\frac{1}{\mathrm{Re}\cdot\varepsilon}\left(\varepsilon^2\frac{\partial^2 U}{\partial X^2}+\frac{\partial^2 U}{\partial Y^2}\right)+\frac{\partial P}{\partial X}=0$$
$$\varepsilon^2\left[\frac{\partial V}{\partial \tau}+U\frac{\partial V}{\partial X}+V\frac{\partial V}{\partial Y}\right]-\frac{\varepsilon}{\mathrm{Re}}\left(\varepsilon^2\frac{\partial^2 V}{\partial X^2}+\frac{\partial^2 V}{\partial Y^2}\right)+\frac{\partial P}{\partial Y}=-1 \qquad (7)$$
$$\frac{\partial U}{\partial X}+\frac{\partial V}{\partial Y}=0$$

The boundary conditions for $Y=0$ and $Y=0$ and $Y=H(X,\tau)$ of the problem are written as follows :

$$U(X,0,\tau)=0,\ V(X,0,\tau)=0,\ \frac{\partial H}{\partial \tau}+U(X,H,\tau)\cdot\frac{\partial H}{\partial X}=V(X,H,\tau),$$
$$P(X,H,\tau)=P_0=p_0/\rho_0 g h_{00} \qquad (8)$$
$$\frac{\partial U(X,H,\tau)}{\partial Y}=0$$

Write the initial conditions as:

$$U(X,Y,0)=U_0(X,y)=u_0(x,y)/\sqrt{gh_{00}}$$
$$V(X,Y,0)=V_0(X,Y)=v_0(x,y)/\sqrt{gh_{00}} \qquad (9)$$
$$H(X,0)=h_0(x)/h_{00}$$

Here h_{00} is the initial mean depth of the channel; λ is the length of the longitudinal wave ; ρ_0 is a parameter with size of the density, $\mathrm{Re}=\dfrac{h_{00}\cdot\sqrt{gh_{00}}}{\mu/\rho_0}$.

In approximation of long waves, when it is assumed that on the surface of the fluid there exists a long-wave of small amplitude, the dimensionless parameter $\varepsilon=h_{00}/\lambda$ is assumed to be the small. Ignoring the members of order ε^2 in equations (7) we get the following expression for the pressure distribution :

$$P=\frac{\varepsilon}{\mathrm{Re}}\left[\frac{\partial V}{\partial Y}-\left.\frac{\partial V}{\partial Y}\right|_{Y=H}\right]+P_0+H(X,\tau)-Y,\quad 0\le Y\le H(X,\tau)$$

that may be transformed to the form:

$$P=\left[\frac{\varepsilon}{\mathrm{Re}}\frac{\partial^2 V}{\partial Y^2}+1\right]\cdot\left[H(X,\tau)-Y\right]+P_0$$

Estimations (11)show that the quantity in the square bracket in approximation of long waves with high accuracy equals a unit , therefore we have :

$$P=P_0+H(X,\tau)-Y,\qquad 0\le Y\le H(X,\tau) \qquad (10)$$

We shall consider such gravitational waves in wich the speed of moving particles are so low that in the Euler equation we can reglect the member $(u\nabla)u$ in comparison with $\partial u/\partial\tau$. Such an assumption is quite justified , since in approximation of long waves , when the dimensionless parameter $\varepsilon=h_{00}/\lambda$ is assumed to be small, the amplitude of oscillations in wave is even more so small compared with the long wave. As above was shown, is this case we can ignore the convective members in equations (1) and (3). Allowing for (8) and (10) , system (7) takes the form:

$$\frac{\partial U}{\partial \tau}-\frac{1}{\mathrm{Re}\cdot\varepsilon}\frac{\partial^2 U}{\partial Y^2}+\frac{\partial H}{\partial X}=0 \qquad (11)$$

$$\frac{\partial U}{\partial X}+\frac{\partial V}{\partial Y}=0 \qquad (12)$$

$$\frac{\partial H}{\partial \tau} = V(X, H, \tau) \tag{13}$$

$$V(X,0,\tau) = 0\,,\; U(X,0,\tau) = 0\,,\; \frac{\partial U(X,H,\tau)}{\partial Y} = 0 \tag{14}$$

Lets consider flat time harmonic waves of second type when $\omega_* = \omega$ is a real positive number $(\omega > 0, \omega_{**} = 0)$ We shall look for the solution of the system(11) - (13)in the form of the real part of the following complex expressions:

$$U = U^0(Y)\exp[i(k_* X + \omega\tau)], V = V^0(Y)\exp[i(k_* X + \omega\tau)],$$
$$H = H^0 \exp[i(k_* X + \omega\tau)], \quad k_* = k + ik_{**}, \quad H^0 = H_*^0 + iH_{**}^0 \tag{15}$$

$$H = (H_*^0 + iH_{**}^0)\exp[i(kX + \omega\tau + ik_{**}X)] = [\cos(kX + \omega\tau) + i\sin(kX + \omega\tau)],$$
$$(H_*^0 + iH_{**}^0)\exp(-k_{**}X)\times$$

$$\mathrm{Re}\{H\} = A(X)\sin[\varphi + (kX + \omega\tau)],\; A(X) = \exp(-\sigma X)|H^0| \tag{16}$$

Here $|H^0| = \sqrt{H_*^{0\,2} + H_{**}^{0\,2}}$, $\varphi = arctg(-H_*^0 / H_{**}^0)$, $\sigma = k_{**}(\omega)$ is decrement of oscillations damping along the length of the wave (linear argument of oscillations damping).

The oscillation freguency ω may be an arbitrary real quantity , but the wave number k has not been determined yet. In the general case, among the numbers $k_* = k + ik_{**}$ there may be real and complex valued ones. As it follows from (16) to first of them there correspond the oscillations propagating along the flow without damping ($\sigma = k_{**}(\omega)$ equals zero) with phase speed $v_\Phi(\omega) = \omega / k(\omega)$ and with the length of the wave $\lambda(\omega) = 2\pi / k(\omega)$, to second one oscillations that are damped with distance. The case $k_{**} > 0$ corresponds to damping mode of disturbance amplitude in the direction of propagation of oscillation phase or phase velocity.

The total non-zero solution is some sum of "model" solutions of the form (15) and (16).

It is very important to calculate the logarithmic decrement of oscillations damping.

$$\Lambda = \left|\ln \frac{A(X+\lambda)}{A(X)}\right| = \left|\ln e^{-k_{**}\lambda}\right| = |k_{**}\lambda| = 2\pi\left|\frac{k_{**}}{k}\right| \tag{17}$$

characterizing the oscillation damping intensity at the distance equal the wave- length λ.

After substitution of (15), (16) in the system of equations (11), (13) and boundary conditions (14), we get:

$$i\omega \cdot U^0(Y) - \frac{1}{\mathrm{Re}\cdot\varepsilon}\cdot\frac{d^2U^0(Y)}{dY^2} + ik_* \cdot H^0 = 0 \tag{18}$$

$$ik_* \cdot U^0(Y) + \frac{dV^0(Y)}{dY} = 0 \tag{19}$$

$$i\omega \cdot H^0 = V^0(1), (Y = 1) \tag{20}$$

$$V^0(0) = 0,\; U^0(0) = 0,\; \left.\frac{dU^0}{dY}\right|_{Y=1} = 0 \tag{21}$$

In relations (20) and (21), as in [7, 10], in the case of the small oscillations, the boundary conditions on the mobile boundary are taken into account in the equal value of the boundary $h(x,t) = h_0(x)$. In this case, for simplicity the fluid surface for $t = 0$ should be flat $h_0(x) = h_{00}$.

The solution of equation (18) at boundary conditions (21) is of the form

$$U^0(Y)=\frac{k_*}{\omega}\cdot H^0\cdot\left[\frac{e^{-a}sh(aY)}{cha}+e^{-aY}-1\right],\qquad a=\sqrt{\frac{\omega\cdot \mathrm{Re}\cdot\varepsilon}{2}}(1+i) \tag{22}$$

Having integrated (18) with regard to (21) and boundary condition (20), we get the expression:

$$V^0(Y)=\frac{ik_*^2}{a\omega}\cdot H^0\cdot\left[\frac{1-ch(aY)}{e^a\cdot cha}+e^{-aY}+aY-1\right] \tag{23}$$

Relations (20) and (23) yield the sought - for dispersion equation connecting the wave member k_* and freguency ω .

$$\frac{k_*^2}{\omega^2}=\frac{a}{a-1+\dfrac{1}{e^a\cdot cha}} \tag{24}$$

Analysis of dispersion equation. Investigation of structure of pulsations.

Analyze the equation (24) in the limit case of very long waves

$a<<1$ Then $e^a\cdot cha\approx 1$ and $\omega/k_*\approx 1,\ a<<1$ for $v_\Phi\approx\sqrt{gh_0}$ (25)

Thus, the phase velocity of propagation of very long waves in viscous fluid coincides with phase velocity of waves in ideal fluid.

After distinguishing real and imaginary parts in (24) for finite values of a , we get:

$$k^2-k_*^2+i\cdot 2kk_{**}=\frac{\chi\omega^2(1+i)\cdot G_1}{G_2+i\cdot G_3}$$

$$G_1=e^{4\chi}+2e^{2\chi}\cdot\cos 2\chi+1,\ G_2=G_1\chi-e^{4\chi}+1,\ G_3=G_1\chi-2e^{2\chi}\cdot\sin 2\chi \tag{26}$$

$$\chi=\sqrt{\frac{\omega\cdot \mathrm{Re}\cdot\varepsilon}{2}}$$

Equation (26) is equivalent to the following system:

$$k^2-k_*^2=\frac{\chi\omega^2\cdot G_1}{G_2^2+G_3^2}\cdot(G_2+G_3)$$

$$2kk_{**}=\frac{\chi\omega^2\cdot G_1}{G_2^2+G_3^2}\cdot(G_2-G_3)$$

Thence we can determine the sought for roots of the disfersion equation (24)

$$k=\pm\frac{\omega}{\sqrt{2}}\sqrt{\frac{G_1\chi(G_2+G_3)}{G_2^2+G_3^2}+\sqrt{\frac{2G_1^2\chi^2}{G_2^2+G_3^2}}} \tag{27}$$

$$k_{**}=\pm\frac{\omega}{\sqrt{2}}\sqrt{-\frac{G_1\chi(G_2+G_3)}{G_2^2+G_3^2}+\sqrt{\frac{2G_1^2\chi^2}{G_2^2+G_3^2}}} \tag{28}$$

From equations (27) and (28) we can get expressions for the damping decrements

$$\sigma=k_{**},\ \Lambda=2\pi\frac{k_{**}}{k}=2\pi\sqrt{\frac{\sqrt{2(G_2^2+G_3^2)}-(G_2+G_3)}{\sqrt{2(G_2^2+G_3^2)}+(G_2+G_3)}} \tag{29}$$

and phase velocity

$$v_\Phi(\omega)=\frac{\lambda}{T}=\frac{\omega}{k(\omega)}=\frac{\sqrt{2}}{\sqrt{\dfrac{G_1\chi(G_2+G_3)}{G_2^2+G_3^2}+\sqrt{\dfrac{2G_1^2\chi^2}{G_2^2+G_3^2}}}} \tag{30}$$

Study the assumptotics of behavior of damping decrements of phase velocity for small (large) values of the parameter χ, that will correspond to small (large) values of frequencies of Reynolds numbers Re.

Let $\chi << 1$. Then $G_1 \approx 4 + 8\chi + 8\chi^2 + \frac{16}{3}\chi^3$, $G_2 \approx -\frac{8}{3}\chi^3$, $G_3 \approx \frac{8}{3}\chi^3$, $k \approx k_{**}$ and

$$\sigma \sim \sqrt{\frac{3}{2} \cdot \frac{\omega}{\mathrm{Re} \cdot \varepsilon}}\,,\ \Lambda \sim 2\pi\,,\ v_\Phi(\omega) \sim \frac{2}{\sqrt{3}}\chi \qquad (31)$$

Thus, for the high viscous fluids in the dimensional view we get the values of damping and phase velocity decrements:

$$\sigma \sim \frac{1}{h_{00}}\sqrt{\frac{3}{2} \cdot \frac{\omega\mu}{h_{00} g \rho_0}}\ ,\left(\frac{1}{m}\right),\ v_\phi \sim h_{00}\sqrt{\frac{2}{3} \cdot \frac{\omega \rho_0 g h_{00}}{\mu}}\ ,\left(\frac{m}{s}\right) \qquad (32)$$

Let $\chi >> 1$. Then, $G_1 \approx e^{4\chi}$, $G_2 \approx \chi \cdot e^{4\chi}$, $G_3 \approx \chi \cdot e^{4\chi}$, that testify the existence of the real root ($k_{**} \approx 0$ see (28)) of dispersion relation (24). Such a behavior of the equation refers to the case of incised fluid (i.e. there are no proper losses in porous medium)

$$\Lambda \sim 0,\ v_\Phi(\omega) \sim 1\ (v_\Phi(\omega) \sim \sqrt{g h_{00}}\ ,\left(\frac{m}{s}\right)) \qquad (33)$$

The solutions (29) and (30) at various values of frequency allows to distinguish the "mode" that will participate in the expression for disturbed flow.

For numerical calculation, water was taken as viscous fluid $\nu = 1.31 * 10^{-6}\, м^2/с$. The channels width $h_{00} = 0.01м$, $\varepsilon = 0{,}1$, $\mathrm{Re} = 2500$. As the length of oscillation wave can not be larger than the channel width $\varepsilon = h_{00}/\lambda << 1$ or $\lambda >> h_{00}$, then $k = 2\pi/\lambda << 600$, therefore k should be restricted from above by the value ≈ 600.

As the result, the dependences of logarithmic damping decrement Λ (fig. 2), phase velocity v_ϕ (Figure 3) and linear damping decrement $\sigma = k_{**}$ on cyclic frequency ω (fig. 4) were obtained for different values of the Reynolds parameter Re=2500, 1500, 1000.

From Figure 2 and Figure 4 it follows that because of availability of viscosity, oscillations damp along the flow. Dispersion, wave dissipation occur, the phase velocity increases, but logarithmic damping decrement decreases with increasing frequency. And the influence of viscous dissipation on linear damping decrement and phase velocity is substantial at very low frequencies. For the variant given in fig. 2-4 this corresponds to $f \le 2{,}5$ Htz. Because of availability of viscosity, a part of energy permanently dissapears at each time. Therefore, in more viscous fluid, the existence time of waves is less than in less viscous one. In low-viscous fluids the waves may propagate to considerable distance.

Conclusions

The considerable ingluence of viscosity on oscillations damping along the flow was revealed. The dispersion, wave dissipation happens,phase velocity inereases, logarithmic damping decrement decreases with frequency inereasing. The energy loss happens because of availability of viscosity.

At low frequencies the influence of viscous dissipation emerge stronger. In more viscous fluid the existence time of waves is less than in less viscous one.

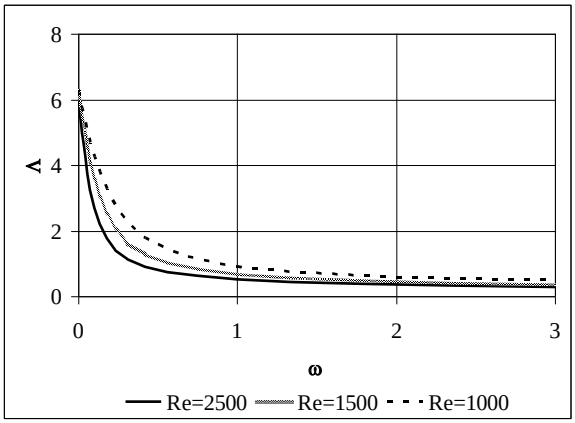

Figure 2. Dependence of logarithmic damping decrement on cyclic frequency ω.

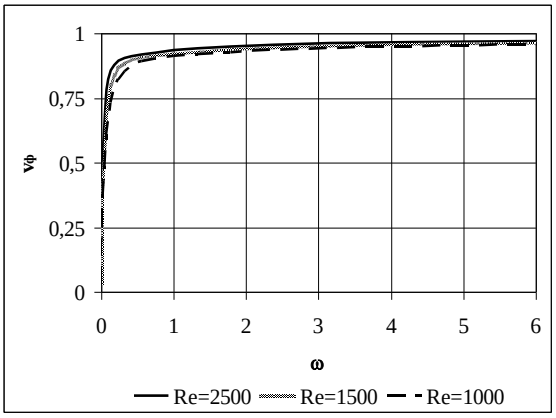

Figure 3. Dependence of phase velocity on cyclic frequency ω

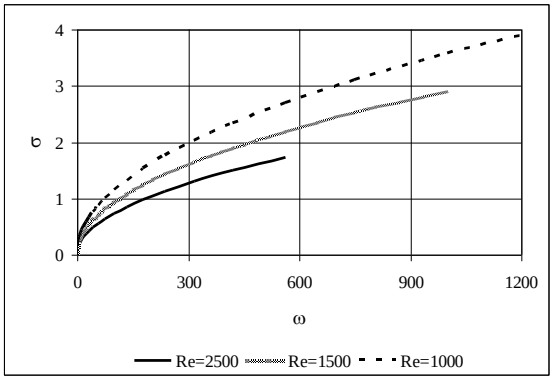

Figure 4. Dependence of linear damping decrement on cyclic frequency ω.

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WHAT KIND OF LEADERSHIP DO SEAFARERS NEED IN REGARD TO THEIR MAIN EMOTIONAL STATES CAUSED BY THE PHYSICAL AND PSYCHOSOCIAL MARITIME WORK ENVIRONMENT?

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Abstract
This paper discusses a possibility of the relationship between modern leadership theories and main seafarers' emotional states caused by physical and psychosocial maritime work environment. The research goal is a problematical discussion of leadership that seafarers need in regard to their main emotional states caused by mentioned environmental maritime factors. Relationship of leadership with the maritime monotony, seafarers' loneliness, maritime social isolation and seafarers' psycho-emotional stress is revealed. The methodology of the research is based on the International Convention on Standards of Training, Certification and Watchkeeping for Seafarers (STCW), the paradigm of the universal upbringing and existentialism. Methods such as scientific literature analysis, interpretation, heuristic and typological methods, comparison, hypothetical applying, classification, systemization and synthesis are used in the research. The methodological type of the research is theoretically descriptive, qualitative and partially quantitative in relationship to the hypothetical application of leadership theories to seafarers' main emotional states caused by the physical and psychosocial maritime work environment.
Keywords: *maritime leadership, monotony, loneliness, social isolation, psycho-emotional stress.*

Introduction

STCW Manila seafarer training amendments require the development of leadership preparing seafarers [24]. It is perceived at the level of maritime politics about changes of the maritime business, smaller crew on high-tech ships and extreme conditions that must be adequately and purposefully responded working at the sea, and instrumental using of leadership taken from psychology and management solves these problems. Researchers and professionals highlight a big problem of the maritime bureaucracy that is still growing [4]. However, the red tape shows the lack of leadership at the highest level of the maritime political management. Seafarers feel this lack and miss the integral leadership that expresses concern for the good of seafarers but not bureaucratic constraints of them.

Distributors of the leadership assign functions and features of the management often to the leadership automatically because it is trend today, for example, styles of the management are sometimes considered as styles of the leadership. This truth is not full. However, the leadership is scientifically characterized by wider conception based on the universal and integral nature of the entire personality. The leadership should not be depreciated accepting only a part of this aimed to develop the maritime leader that would be able perform his / her work in extreme conditions at the sea. A seafarer is personality but not a machine and not an experimental animal or a hostage of biological instincts only.

Researchers of the world maritime industry publish, that with the emergence of modern and high-tech ships, new forms and trends in the development of leadership become a necessity. Since leadership on board is no longer a matter of dictatorship, there is a need for officers with strong leadership skills who can empower their subordinates by giving them control over their work. Human error is no longer an excuse for maritime accidents; thus, the utilization of crew's full potentials. Stiff competition in the shipping business draws stakeholders closer to one another. This scenario poses an immense challenge on shipping companies to be more innovative by focusing, first and foremost, on employee's welfare, competence development, and positive company publicity.

The leadership should not be perceived as a new imposed unnecessary obligation. It is not just about requiring the crew to take maritime leadership courses. It is also about employing ship officers and leaders who are capable of harmonious managing competency development on board. The crew on high-tech ships long for full utilization of their competencies, as they need to be highly skilled in order to effectively and efficiently respond to emerging challenges on board. It all relates to these parts of the implementation of leadership processes: communication, information sharing, cooperation, instruction, change management, training, problem solving, corrective feedback and coaching [18].

The scope and level of the leadership culture that is applied to the American or Northern, Southern and Eastern Europe mentality, are different. However, it is very important to the maritime industry, group and personality, his / her motivation, purposeful self-expression, duty, concentration, care, joy, combining of work and rest, benefit and profit from the holistic point of view [17]. The modern leadership is not separated from the self-leadership, and includes all work-positions and all members of the crew. Initiative of crew-members is relevant. However, seafarers said, that initiative is traditionally suppressed in the fleet.

The company Green-Jakobsen conducted a global maritime survey. It was able to gather a total of 436 answers from seafarers of all rankings. One of the survey questions was: "Why did you leave your previous company?" Survey results showed, that 70-80 percent of all contract terminations was relative to the poor leadership [18]. People cannot tolerate the poor leadership psychologically experiencing excessive psycho-emotional stress and psychosomatic diseases. Of course, psycho-emotional stress and conflicts are inevitable at work but the level of them should not be too high, especially when we talk about seafarers' emotional states and psycho-physic health because of physical, biological and psychosocial maritime factors. However, the mentioned level is mostly determined by skills of the head's leadership and self-leadership. The self-leadership of employees is significant in the context of maritime and personal factors, too.

IMO conventions do not require the higher education for seafarers of the management level, and for their personal maturity that is directly related to the leadership skills. However, the good organized higher school could help future or current seafarers to develop the integral and flexible leadership with reference to important valuable attitudes that note the competence, and adequate self-esteem and creativity [8], ability to combine the strength and flexibility, to respect the situation and person, and especially to creatively orient own powers in non-standard problematical situations that are namely mostly identified working at the sea [32].

The grade of the exploration

Relevant trends of the world maritime industry related to the need of the leadership application are scientifically analyzed from the point of view of high-tech ships, smaller crew and more democracy; the manner in which the global economic competitiveness in the shipping industry is influenced by the transformational leadership; empowering of subordinates, the plight of international seafarers, responding to emerging challenges on board, recognizing of the importance of soft skills, enhancing of inter-personal relationship both on board and ashore; promotion of good safety culture on board; motivation of people to perform effectively, safely and excel in their work and duties; ability to communicate vision and strategies to the crew on behalf of the management; physical and psychosocial work factors that are related to the levels of job satisfaction and intentions to remain in the maritime industry; maritime governance, policy-making, leadership of maritime education and training institutions, and psychological evaluation of seafarers; successful occupational career and reduce health and life hazards in the maritime work environment; health promotion in the maritime work environment by the training of leaders; psycho-emotional stress, loneliness, social isolation and monotony of seafarers, cultural management and cultural differences in emotional intelligence among top officers on board merchant ships [2; 3; 9; 12; 13; 14; 15; 18; 20; 21; 22; 23; 28; 29; 31; 32].

It is important to note memoirs of seafarers with reference to the physical and psychosocial maritime affairs that in detail highlight some contents of leadership from the experienced practical point of view [4; 10; 19; 26].

There are some experimental applications of leadership to maritime affairs at the local level in Norway, Finland, Russia, USA, etc. The leadership theory is important because it highlights the real application of leadership to the practice of the world business, and makes influence on the behavior of future leaders [7]. The relevant maritime leadership that is valuably based on the practical theory could be implemented.

Goal and tasks of the research

The research goal is a problematical discussion of leadership that do seafarers need in regard to their main emotional states caused by physical and psychosocial maritime factors.

Tasks are as follows:

1. Revelation of relationship between the maritime monotony and leadership.
2. Discussion of relationship of seafarers' loneliness with leadership.

3. Characterization of relationship between the maritime social isolation and leadership.
4. Discussion of relationship of seafarers' psycho-emotional stress with leadership.

The research object is a possibility of relationship between modern leadership theories and main emotional states of seafarers caused by the physical and psychosocial maritime work environment.

Methodological attitudes and type of the research

The methodology of the research is based on the STCW convention, paradigm of the universal upbringing and existentialism.

International Convention on Standards of Training, Certification and Watchkeeping for Seafarers and requirements of Manila amendments highlight the improvement of the shipping safety developing leadership of seafarers at the level of their preparation along with other actualities. Technological training of future seafarers, and their positive world-view, creativity, understanding of the constructive philosophy and psychology for the development of own's personality, wide intellectual and cultural horizons, and the development of internal and cooperative culture influence on safety at sea. All mentioned components could help develop leadership abilities of future seafarers.

Paradigm of the universal upbringing notes the development of all powers of the personality. This holistic approach to the maritime education helps implement improvement of the self-leadership of future seafarers, especially at flexible and creative levels of the adequate reaction to nonstandard physical and psychosocial situations working at the sea. The leadership is characterized by a wide conception based on the universal and integral nature of the personality.

Existentialism refers to the human fear on land and especially at sea. Existential psychology is the cause for personality's hope. This psychology denies an attachment to life pleasures, and promotes liberation of the personality, and purification of his / her existence. The development of maritime leadership, especially of self-leadership, expands the horizon and helps people overcome the tragedy of existence, improve their emotional state and find unique comfort. Existentialism helps get a valuable basis for self-leadership and self-regulation in extreme conditions. This valuable direction is based psycho-educationally.

The methodological type of the research is theoretically descriptive, qualitative and partially quantitative related with the hypothetical application of leadership theories to seafarers' main emotional states caused by the physical and psychosocial maritime work environment.

Methods and methodological limits of the research

Methods such as scientific literature analysis, interpretation, heuristic and typological methods, comparison, hypothetical applying, classification, systemization and synthesis are used in the research.

Methodological limits of the research consist of the problem: it is impossible to unambiguously understand the leadership and implement them without creatively dynamic application of the holistic and situational approach to them because the world leadership science based on empirical researches is characterized by three different groups of leadership theories:

- The first group highlights a character of the leader, his / her personality and traits;
- The second group notes the behavior of the leader determining his / her different functions, and leadership is more related to an activity of the leader but not to his / her personal features;
- The third group highlights the leadership that depends on environmental factors but, for example, without usual features related to the leader.

The profession of seafarers is usually described as a *modus vivendi*, a cycle of inevitable separations and meetings, a transition from the home environment on the coast to the work environment at the sea, and vice versa. It is a lifestyle, which equally affects seafarers and their families [27]. Different factors - hard physical work, contingent regime of work and rest, long working hours, noise, vibration, weather change, isolation from family and friends, frequent psycho-emotional stress and irregular sexual life, the absence of normal nutrition, etc. make influence on seafarers' health and their well-being [23]. Psychological terror, maritime terrorism and piracy raise an important threat for seafarers. The result of psycho-physical and social conditions of working and life at the sea in general is fatigue, psycho-emotional stress and mental disorders symptoms. Researches showed, that the seafarers' main emotional states are monotony, loneliness, social isolation and psycho-emotional stress because of the physical and psychosocial maritime work environment [32].

The research is methodologically limited by the mentioned seafarers' emotional states of any level, and by main modern theories of leadership that are as follows:

- The great man theory (leadership is determined only by genes combination - "born to lead" but it is important to the research at the basic level of natural human health related to the leadership and self-leadership);
- The trait theory of leadership (some traits must be the best for the leader but all and various traits do leaders need from the holistic and separated point of view; the self-leadership helps develop traits of the leader but he / she must be "born to lead", too);
- The skills theory of leadership (there are technical skills, people skills and conceptual skills with a wide approach; improvement of self-leadership helps develop skills of the leader);
- The style theory of leadership (the best style does not exist because the leader must be able to concern for people and performance in the same time);
- The situational leadership theory (the leader must be flexible and able to respect the situation);
- Transactional leadership (it is characterized by rewards and punishments);
- Leader-member exchange theory (qualitative relationships between the leader and subordinates determinate better results but "lower performance - lower retention");
- Transformational leadership (not punishing non-compliance but following the leader's example is most important);
- The contingency theory (the leader is more oriented to the people or performance; it is appropriate to change the leader who is not able to flexibly lead, and whose own style does not match requirements of the environment; self-leadership helps match that);
- Servant leadership theory (the leader is ready to help subordinates with reference to the trust, cooperation, reciprocal service and higher performance; people follow out on behalf of love and gratitude rather than out of compulsion or fear) [2; 7; 30].

Results of the research can be applied theoretically and methodologically basing experimental researches of the maritime leadership, and preparing seafarers at higher maritime education from the point of view of social-humanitarian maritime studies aimed to achieve a personal improvement especially regarding to the cognitive level of the maritime leadership competence.

The relationship between the maritime monotony and leadership

A human experiences a lot of various stimuli that influence on his / her state being in different environments at normal conditions. However, seafarers begin to eventually empathize the feeling of monotony, which leads to many unusual mental states by working in closed technical systems at the sea. It is an experience similar to boredom and sleepiness that rises because of uninteresting activity, lack of information, and frequent repetition of the same stimuli. Monotony adversely affects physiological and psychological functions, causes the drowsiness and rapid fatigue. The human feels dissatisfaction by long monotonous working that narrows his / her interests and reduces creative powers. So, the leadership is particularly important to the human stabilizing his / her being.

Seafarers are beginning to feel the monotony and lack of different experiences being whole weeks in the same isolated environment. General weakness, anxiety, psychological closure and depression are rising there. The same image, monotonous sound and presence of the social isolation may finally result, that a person begins to haunt, and his / her worldview becomes deformed. In addition, there is a certain state of the slumber between the wakefulness and sleep, and an option of visual or auditory hallucinations.

Indicators by observing automatic equipment operations without the malfunction are as follows:

- Feeling of monotony eventually rises for the observer,
- Alertness begins to decrease after 3-4 hours,
- Drowsiness occurs;
- Fixed body position greatly limits the movement of the person;
- Afferentation becomes much reduced from the side of muscles [32].

Equal vestibular stimulation raises hypnotic phases and promotes a deep sleep. Operative activity requires maintaining of the intensive concentration, and preparation to quickly react to potential equipment failures. However, the human operative activity loses the effectiveness because of the monotonous environment. Self-control and self-consciousness are transformed at the hypnotic state. The human can see and perceive, what is going on, but he / she is unable to appropriately respond. Therefore a likelihood of an accident increases.

Seafarers must be able to switch psychologically, at least for a short relax, by working in extreme conditions. The human generally suffers less of monotony when a streamlining of the labor and rest regime, changing the pace of work, and increasing the size of operations manage it. When seafarers feel, that the company needs them, then it is a base of their self-regulation abilities in mentioned emotional state.

The higher level of physical training, and application of the leader-member exchange theory are relevant because of qualitative relations to the leader. Transformational leadership that helps seafarers feel being needed by the company and be not disappointed with the monotonous job, and servant leadership related to development of self-esteem, are important in this case.

Lack of new impressions and of new information is usually compensated by the psycho-physiological mechanism of clear dreams. If seafarers have opportunities, they are watching movies one after another by feeling of deep monotony [32]. Skills of self-leadership orient towards that, too. So, the visual memory comes gradually to life, imagination becomes more active, and consequences of monotony sense are compensated at some level. The human can keep his / her own mental balance working in extreme monotonous conditions in closed technical systems at the sea.

The relationship of seafarers' loneliness with leadership

Researches showed, that seafarers eventually experience loneliness working in extreme conditions. Long time of loneliness promotes transformations of their mental activity. They begin to feel the spiritual emptiness and depression. Loneliness expresses as one of main psychosocial problems of seafarers in general along with homesickness and aggressive behavior because a long stay away from home and reduced number of seafarers on board, and rapid automation of processes [27].

However, experiences of human loneliness are eased by natural recalling of clear images of his / her loved ones - family members or close friends. In addition, experiences of loneliness itself encourage a person to think abstractly, and to raise questions about the sense of his / her existence. All this promotes a relevance of self-leadership, and significance of humanitarian and social sciences, for example, personality's philosophy, anthropology and management psychology preparing maritime professionals for extreme working conditions at the sea. Future seafarers should perceive the significance of philosophical thinking to improvement of the personality, possibilities and limits of abstract thinking, and principles of the mental self-regulation in difficult situations.

It was stated, that people of a poor personality with the main concern focused to the outside, endure loneliness particularly difficult. People with self-respect, with a deep and rich spirit endure loneliness more easily. So, the seafarer who is not sad with himself / herself, who always has something to do, and who does not require the attention of others, is able to work in extreme loneliness conditions. The great man theory as a direction of the genetic nature of the seafarer, for example, with reference to the temperament when loneliness would be too unbearable for the sanguine, partially complements the application of self-leadership in this case. The situational leadership helps respect the situation. So, it is possible to creatively make decision and find a solution. The leader-member exchange theory is relevant because of good relationships to others. Servant leadership theory characterized by cooperation that eliminates loneliness, and the skills theory of leadership characterized by people skills, are important, too.

Nevertheless, if loneliness is very long, then it usually promotes personality's degradation and mental disorders because the human is social being - homo socialis - naturally. Termination of usual social relationships can stimulate shock, anxiety, depression and more poor spiritual life in general satisfying only physiological needs without higher aspirations and purposes. So, the self-leadership must be regularly developed in this case. Termination of relationship with loved ones is strongly experienced not only in loneliness conditions but also by living and working in an isolated group. Researches showed, that seafarers experience a longing for their loved ones. Seafarers rethink their relationships with them and venturing normally to communicate with loved ones in a better way. This is a development process of the seafarer's maturity for his / her leadership.

Mechanisms of compensational defensive reactions express in loneliness conditions. A lonely human is naturally inclined to personify various objects, create an imaginary partner and communicate with him / her using not only internal conversation but also an external. This conversation becomes self-command and promotes personality to manage and regulate his / her own personal behavior implementing the function of regulation of another human's behavior. The word spoken in mind is not so suggestive than expressed loudly or written.

So, the external conversation is more effective and helps manage the situation because it gets the same significance, which should get an outspoken word of another human promoting of appropriate

emotional experiences. The tendency of healthy human to think out loud and talk with oneself as a need of external self-promotion was stated not only in loneliness conditions but also by overcoming of difficulties and dangers in life in general [11].

It was highlighted the trend, that people who do not talk loudly to personified objects or imaginary partners or did not write a blog in extreme loneliness conditions, they experienced the worst mental states related to psychopathology, and acute psychosis, perceived a distorted environment and expressed delirium. It is stated, that loud conversation with oneself helps avoid neuroses in the psycho-emotional stress state. It is a defensive reaction in loneliness conditions [32]. Solving of loneliness problems cannot be perceived without implementation of self-leadership abilities.

The relationship between the maritime social isolation and leadership

Isolation of group and sense of exclusion as a socio-psychological problem is clear in the whole history of seafaring. Hard work and extreme conditions of life on board naturally promoted and still promote conflicts between seafarers. The history of seafaring shows rebellions that rised because of social isolation. Rebellions were brutally repressed in the Middle Ages. Conditions of isolation by seafaring became scientific problem in the 20th century [3]. It was stated, that less number of crew-members, more automation and longer working hours have influenced on relationships between seafarers and raised much more social isolation working at the sea [6]. So, it is relevant to apply the skills theory characterized by people skills, and the leader-member exchange theory because of good relationships development, and the contingency theory characterized by the respect of adverse circumstances.

Researches indicated, that members of smaller crews in general overcame difficulties and dangers on board of the long-term seafaring by the purposeful concentrating of their powers and altruistic caring for each other three decades ago. It was stated, that work of the crew is effective when all its members perceive their maritime activity from the point of view, that activity of each seafarer and general activity of all crew-members are significant to the whole group, and prestige of the job is determined not only by pragmatic convenience but also by vocation to maritime affairs.

However, the researches of the last years showed, that situation of crew-members' relationships is much lower. On one hand, seafarers have better conditions to more indirectly communicate with their one loved by phone and via e-mail etc. but on the other hand, smaller crew on high-tech ships and accelerating of cargoes handling note, that seafarers have fewer opportunities to go ashore and to connect with their families and the world in general. All their professional life is mostly confined on the ship [16; 23].

It is therefore understandable, that conditions of modern social isolation determine a situation, where it is much more difficult to maintain a positive psychological work climate on board. There is greater need for traditional recommendations - quietly survive internal problems alone, not spill on others, and not tamper with other mood maintaining a favorable psychological climate as much as possible. So, it is relevant servant leadership theory based on cooperation and reciprocal service, and the skills theory characterized by people skills.

However, a marginalized group for a long time is characterized by psycho-emotional stress and more often or fewer conflicts. The human who lived a long time in an isolated group is changing depending on one's concrete personality. It was stated, that isolation-working conditions have a negative impact on the personal interaction with others. It is a transformation of the personality: he / she becomes less active and of bad mood, inadequate responses in various situations, suspects others, and is constantly ready to defend himself / herself, becomes closed and self-centered. Sloth, tendency to argue, reluctance to obey orders, high sensitivity, effrontery and abusiveness may be expressed. All this is reflected in the psychological climate of the isolated group.

Conflicts in a small group can rise without a clear cause in conditions of isolation. Naturally distinctive manner of speaking or some details can encourage the member of the group to overreact. The wish to search only negative personal features of others and attack them rises. So, uncertain conflicts that are very difficult to solve rise in extreme conditions. However, the main responsibility is given to the behavior and position of the group leader. The great man theory is valid as a genetic theory of general health of the personality. The trait theory of leadership is relevant because of the ability to manage the conflict. The situational leadership theory is important, too. Leader-member exchange theory is relevant because of qualitative relationships between the leader and his / her subordinates. Transformational leadership is important because of the following the leader. The contingency theory is relevant because of flexible self-adaptation to different situations. So, it is an important problem of selection of candidates to work at the sea in mentioned conditions with reference to implementation of their self-leadership.

The human must apply self-analysis, self-reflection, and make decision about his / her ability to survive in extreme conditions of social isolation at the first maritime practice. Love to his / her job and abilities of self-management, and overcoming of difficulties in life are the most important criteria of mentioned vocational selection [32]. Good communication is characterized by altruism and empathy that determine reciprocal understanding and partial acceptance of other human's position, and help remain a dignified human. Seafarers stated, that their work requires people that are characterized by humanistic and technological competencies. So, leadership is relevant, especially the skills theory of leadership because of people skills, leader-member exchange theory because of good relationships, and servant leadership theory because of cooperation and reciprocal help.

The mentioned isolation of group determines stress in relationships among group members. So, the threat of long working in extreme conditions rises. Not only problems of the equipment performance may jeopardize but also people on mental tension and conflicts because of contempt and humiliation of some crew-members. The psychic self-regulation as a part of self-leadership is one of the most important conditions for a positive psychological climate and its support.

Another psychosocial problem is being in permanent presence of other members by working in the isolated group. Psycho-emotional stress rises not only because of individual isolation but also of permanent stare of other members of the isolated group that promotes the human to feel, that he / she is permanently observed. The theory of social roles of the personality notes, that social behavior is always limited by social norms, prohibitions and traditions. So, human becomes actor in a great scene of life performing social roles. The human behaves freely when he / she is alone, and sometimes so, how he / she would not behave in presence of others. When human is not alone, he / she make efforts to be correct, and it involves a big stress because the human knows, that others observe him / her permanently and make appropriate conclusions. This situation needs less transactional leadership that is characterized by rewards and punishments; and more transformational leadership based on following the example of the leader but not punishing non-compliance.

The human needs communication and loneliness naturally that he / she could stay with himself / herself. Permanent presence in the isolated group without of opportunity to stay sometimes alone determines conflicts that rise because of trivial details, and that are difficult to manage. The diary where experiences of the day are noted helps in such instances. It helps save the group from conflicts because the written word does not irritate members of the group. However, a short phrase that is outspoken loudly can raise the conflict but when it is written, then the positive psychological climate of the group is saved. It is related to the implementation of self-leadership.

It is especially relevant to have a loved one, whom the seafarer could trust, confide and reveal to him / her. More close relationships of seafarers arise usually when they are working together more than one trip in the same crew. Researches showed, that only a small number of seafarers reveal, that they agree perfectly with any member of the crew. Relationships are often characterized as middling. The manning strategy leads to work on various vessels in different conditions, and decreasing trend in the number of crew-members prevents of development of close friendships and social relationships [23]. Leader-member exchange theory because of good reciprocal relationships, and the skills theory of leadership characterized by people skills are important in mentioned case.

Writing of the diary psychologically stabilizes the personality, especially if he / she is living and working for a long time in conditions of social isolation. Otherwise, conditions of isolation can cause neurosis, suicidal thoughts or murder. So, member of the isolated group naturally feel hungry of any information with no free time to listen to the radio, watch television or surf the Internet, and he / she becomes a source of information for oneself in order to avoid neurosis [5]. Self-leadership determines mentioned self-implementation in conditions of social isolation.

The relationship of seafarers' psycho-emotional stress with leadership

Psycho-emotional stress is a human state that rises because of various extreme effects - stressors. Physiological stressors are a very high physical activity, too high or too low temperature, and pain. So, good genes as a start of the human health are very important at the level of the great man theory. Psychical stressors are threat, risk, abuse, overload or lack of information. Peculiar working conditions influence on the nervous system of seafarers on board all time of their presence at the sea. If stress situations are frequent or long-term, body reserves are quickly depleted; headaches become more frequent, memory is being weakened, nervousness and irritability increase, sleep is disturbed, and depression symptoms rise.

It is appropriate to different the professional factors of the maritime industry that are as follows:

- Long working hours,
- Maritime business ongoing reforms,
- Exclusion from the house,
- Constrained leisure,
- Difficult working conditions [13; 23].

So, it is relevant to regularly explain, what is going on in the maritime industry, that seafarers could understand the causal relationship of reforms. Theories of servant leadership and contingency are important because of the leader's concern for people in changing conditions. Love to work rises from the understanding. It is appropriate to differentiate a factor of information uncertainty. All machines are composed of different components and electronic equipment etc. that wears trough different time.

If the machine is more complicated, then probability, that any part of the system goes wrong and an emergency situation rises, is bigger. It is impossible to provide all variants of the emergency situation. So, the human experiences permanently the state of information uncertainty and tensed waiting. The application of the skills theory of leadership could help combine technical, people- and conceptual skills and self-leadership by strengthening oneself.

An emergency situation is an extreme event characterized by the rapid development of changeable events. While the threat of emergency is possible and can be expected at any time but it is experienced as a surprise, so, - as a new stressor in each case (in better freshness or slumber mode). Moreover, the operator does not always know the cause of the emergency nature after receiving the alarm signal "the system is in danger". So, he / she must accept the event as a task that must be creatively solved as soon as possible, and apply tools to save the system. Self-leadership and servant leadership based on the cooperation are relevant theories for application in mentioned cases. Transformational leadership is important because of the following authority in extreme conditions. The contingency theory is relevant because of adequate response in unfavorable circumstances.

It was stated, when a human have been working at the automate system without problems for some years, his / her health is influenced by negative factors because of the mentioned information uncertainty. The human performs nothing in the time of the watching but he / she observes and waits for any problems of the system. However, the watcher is tired in the case of "easy watching" and after the watching he / she cannot work intellectually and productively, his / her sleep becomes poor, and irritability expresses. Moreover, the human may eventually get neurosis and psychosomatic disorders. It is very relevant to maintain the psychophysical health from the point of view of the nature genes. So, the great man theory is important as the orientation to development of the self-esteem.

Scientists stated almost two decades ago, that 60 percent of seafarers experience the strong psycho-emotional stress [1]. Threat must not necessarily be an object of the self-reflection but it can influence on the human psychics. However, most of the seafarers were experiencing sthenic emotions and showed masculinity and even heroism at the sea in conditions of the high-risk from the historiographic point of view. Seafarers need these features - rapid perception and self-orienting, self-organization, self-control, prudence and resourcefulness in general [32]. The seafarer runs the risk not only for his / her own health and life but also for other crew-members in threat conditions. The experienced danger raises very high psycho-emotional stress that can be characterized on the personality long years after the threat event. So, applying of self-leadership and servant leadership theories, especially because of love to one's own work and cooperation, is relevant in the mentioned case.

Seafarers usually experience psycho-emotional stress. They are at the sea in their thoughts some days before the seafaring. However, the psycho-physiological system is so constructed aimed to surviving of the human, that the feeling of danger raises psycho-physiological mechanisms in difficult situations by activating of the human and giving a direction to the reflection in an emergency situation [25]. The great man theory can be applied as an initial psycho-physical and professional capital. The probability of an accident is very high on board ships, especially on board submarines. However, seafarers experience the feeling of safety and confidence, and that nothing goes wrong to crew-members usually only then, when the master has authority and they believe him / her. Researches showed, that crew-members give all their efforts into a creative and accurate implementation of master's orders that are accepted as right by believing in his / her authority and activity. Transformational leadership is relevant in this case because of the following the leader.

So, the direction of management of the psycho-emotional stress is using stress for creative work in extreme conditions by managing of the leader in this case. The long-term scientific observation of seafarers leads to the conclusion, that many of them need experiences of danger. It is their purpose, and they experience the highest joy in their life by responding to maritime challenges in general [32]. Self-

leadership as a permanent vocational self-improvement and self-orientation is relevant for all professions, but especially for the seafaring characterized by extreme conditions and particular emotional states.

Conclusions

The synthetic answers to the question: "What kind of leadership do seafarers need in regard to their main emotional states caused by physical and psychosocial maritime work environment?" - are as follows:

1. The mentioned emotional states mostly need servant leadership, special skills of leadership, leader-member exchange, transformational leadership and great man leadership at the level of genetic health from the *quantitative* point of view but the human is multidimensional and cannot fit into simple logical models.
2. We cannot unambiguously answer the question because any type of theories may be of practical help but not necessarily the concrete type, which is recognized by the scientific analysis of typologies or by the experimental application confirmed in one special situation but in the second situation, for example, cannot be confirmed from the *qualitative* point of view.
3. The seafarers of any level need for the competence of the self-leadership development as a permanent base of leadership from the point of view of all their emotional states in general. Creativity helps develop and apply the leadership at situations caused by physical and psychosocial factors of the maritime work environment, and is related to it and is most important. It is impossible to unambiguously understand leadership and implement it without of creatively dynamic application of the holistic and situational approach to leadership, especially in specific and nonstandard conditions that characterize the work of seafarers at the sea.

Results of the research can be applied theoretically and methodologically basing experimental researches of maritime leadership, and preparing seafarers at higher maritime education from the point of view of social-humanitarian maritime studies aimed to achieve a personal improvement especially regarding to the cognitive level of the maritime leadership competence.

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MODELING OF PASSENGERS TRANSPORTATION BY RO-PAX FERRIES PRICE FLEXIBILITY

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Abstract
Ro-Pax shipping lines itself combines two elements – cargo and passengers. This combination is the main advantage for the customers – Ro-Ro cargo carriers. On the other hand, for travelling passengers it is necessary to provide additional services. For this reason, Ro-Pax shipping lines provided passenger service is twofold and is sufficiently problematic price value. With the acceleration of trade globalization, intensive growth of freight flows, respective development of ports and new establishment of passenger and cargo terminals in ports, intensity of competition in linear shipping sector is increasing. The prices of travels reflect the differences of the ships, whose primary purpose is to carry passengers. Due to non-growing flows of passenger maritime companies seek the profit by rearranging cruise-ships into freighters that carry passengers. However, for the lack of "travelling by sea" culture, passengers often rate the provided service of ferrie mistakenly. Thus, in order to gain a competitive advantage, it is important to establish the pricing model of effective and flexible quality service and maximum profit harmoniously.
Keywords: *Ro-pax, pricing model, flexibility.*

Introduction

Passenger transportation by sea strengthens country's seaside region and port functionality. It increases mobility of population and develops sea tourism. With the increasing number of population and cities, intensive capacities of production, growth of tourism, trade, international relations and improvement of means of sea transport, the amounts of passenger transportation is growing too. Sea transport is closely related with other means of transport, because passengers or freight often continue to move further on land by other means of transport after the sea transfer. Under the activity conditions of modern transport system, when land roads are loaded heavily, it is proven, that freight or passengers are carrying faster, safer and cheaper by sea transport than by land transport. This combination is the main advantage of customer – Ro-Ro cargo carriers. On the other hand, for passengers on leisure it is necessary to provide additional services. For this reason, Ro-Pax (Roll-On/ Roll-Off/ Passenger) shipping lines provided passenger service is twofold and is sufficiently problematic price value [1, 2].

Object of research is DFDS Seaways (Lithuania) pricing of Ro-pax shipping lines passenger service. Currently DFDS Seaways (Lithuania) ferry lines connects the port of Klaipeda with Kiel (Germany) and Karlshamn (Sweden). The main *goal of research* is to model the pricing of DFDS Seaways passenger service, according to the set of customers service on board.

Main *objectives of the research* are the following:

1. Theoretical description of pricing system.
2. Analyse Ro-Pax service market in Baltic Sea region.
3. Modeling DFDS Seaways passenger service pricing according to customers service on voyage.

Research methods: analysis of scientific literature, statistical analysis, passenger service pricing modeling. Main idea of the research is to provide adequate background for effective pricing model of passenger's service according to the price flexibility. Model of passenger's transportation service rate depends on the transportation services tax, service fee, fuel charges, local purchase tax etc.

1. Theoretical Aspects of the service features and marketing

Theoretically, the service package is defined as a service that a consumer may obtain by applying to a particular service provider for a particular requirement, a set of set of items (goods, articles, material,

psychological values etc.) are presented with a single specific service name [6]. Customer service has been a widely discussed topic for decades. The end of the XX century saw a period of quality customer service, exceeding customer expectations and "moments of truth". With intensification of Systems theory impact the procedural attitude has prevailed in study of management. The extensive classic marketing theories centre is means of attracting customers and creating transactions rather than maintaining them, the majority usage of direct marketing used in the past is now gradually being used more alongside relationship marketing as its importance becomes more recognizable. The technology revolution has brought customer relationship tools and software. Technology allows business of all sizes to manage their customer relationships with profiles, trends and customer history. When analysing the topic of services it is relevant to assess differences according to the classical and consumers behaviour attitude.

Classical, procedural attitude describe servise as an activity or process of act, intangible, relations between service supplier and consumer, link with activity or property [8]. According to behavioural science service consist of the sequence of events, duration of experiences, control and choice, emotions, trust and attribution [4]. But main characteristics of service are similar: impalpability, heterogeneousness, unity of production and consumption, temporariness, contacting with client, lower standardization [4,5,9,10]. The classical theory attitude of marketing especially highlights the differences of commodities and services, and as an accent the impalpability of service is emphasized, id est. immateriality. Therefore, Dasu and Chase (2013) offer to “materialize” the service. Pricing of service is one of the methods that reflect it, and according to it, the high price of product presumes the high quality of service. Flexibility of price is assessed relating it with purposes of marketing, factors that affect marketing, stages of price determination, policy of marketing, and strategy of marketing regulation. Relationship marketing is defined as “the new marketing”, oriented towards to the fulfillment of customer needs and building of long-term relationships with customers. A company that seeks to earn the customer loyalty and maintain a competitive advantage has to be well versed in the qualitative dimensions of relationships [7].

When analyzing the flexibility of price as a rule a particular complex model is investigating, which consists of such factors as the size of price, risk of price, brand of producer, profitability, and value of consumer. Price is an important indicator not only for the enterprise that provides services, but for the consumers of service too, because it exactly determines the relations between the enterprise and market of services, and guarantees receiving of short-term or long-term profit receiving. The process of pricing due to its diversity after the abstraction could be depicted in the form of the pricing pyramid, which represents that in the formation of pricing policy the results of it depends not only on the skills of specialists, but on the organizational influence, involvement of organization into the pricing, and application of internal pricing methods too (Figure 1).

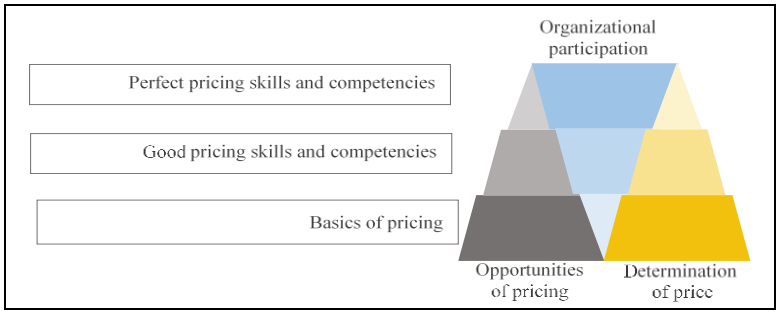


Figure 1. Effective pricing pyramid [11]

In the basic stage of pricing formation, the price is determined according to the three compound elements: assessment of pricing opportunities, calculation of price and that in significantly smaller part (25%) it is considering to the factors of organizational participation. In the higher stage all the parts of pricing pyramid are distributed in equal parts proportionally, and the generated pricing policy can guarantee the indicators of price flexibility and efficiency partly. After the proportion amplification of organizational participation in the general pricing process the best pricing decisions are achieved and determined price is marked by all of the consumer perspectives of price flexibility indicators [11]. Pricing in the service marketing is directly related to the attraction of consumers and satisfaction of their needs and requirements, therefore the classification of pricing methods is related to the main purposes of enterprise pricing – profit maximization, amplification of sales, amplification of the part of market, and aim of competitive parity.

Flexibility of service price is related to the flexibility of demand. The reaction of demand to particular price alteration. Assessment of price flexibility is the cyclic element of service pricing model existence which compels to generate alternative decisions and change execution policies of service sales when controlling change indicators and assessing dynamic indicators. Therefore, in the assessment of price flexibility one of the basic actions is the formation of price model and the basis of which will be identified the indicator of price flexibility and assessed the most sensitive parameters (Figure 2).

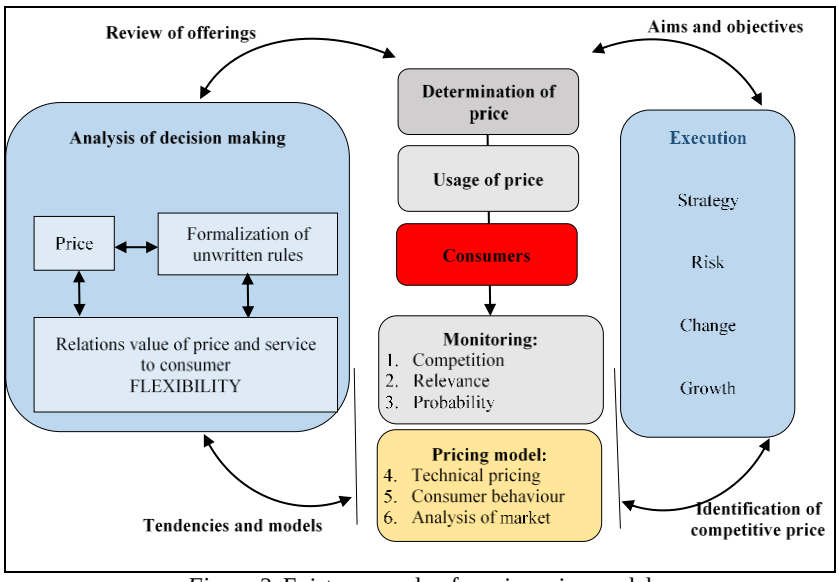


Figure 2. Existence cycle of service price model

On the all intended actions of execution rapidity that are depicted in the model depend not only the flexibility of enterprise service pricing, but also and the whole service package flexibility in the perspective of the dynamic market (Figure 2). Even on such cases when the concentration of competition is minor in the concrete service market segment, the inflexibility of pricing decreases the value of provided services in perspective of consumers, therefore, in the market often performs such alterations, which unconsciously compels the consumers to change the services supplier even on the unacceptable conditions of alterations for them.

2. Situation Analysis of Ro-Pax shipping service market in Baltic Sea Region

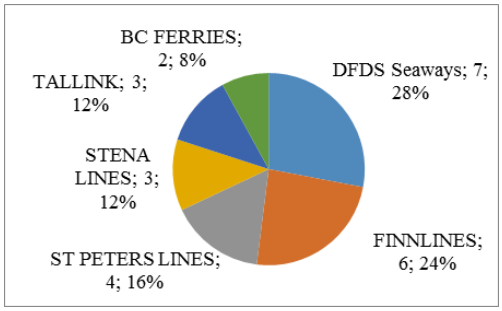
Due to the conditionally moderate distances between the ports, implementation of routing between particular sites and explicit schedules, in the Baltic Sea dominate linear shipping of feeders, which connects the most important land transport knots between the Northern and Eastern Europe countries. Linear shipping must have a clear economic reason; in this case it is a flow of passengers/freight between particular ports and may be one of the main factors in the process of development of production and tourism [2].

A practical problem of research arise because of the lack of “travelling by sea” culture – passengers often rate the provided service of ferrie mistakenly, not all of the passengers know what is the difference between Ro-Pax ships, passenger and cruise ships. Therefore, there occasionally arise various misunderstandings about the assortment of service in ships. Ferries of Ro-Pax offer fewer services than the ferries, where only the passengers are transported.The price of travel reflects the differences of the ships, whose primary purpose is to carry passengers.

Nowadays with the most powerful ferries it is possible to reach the outermost areas of the Baltic Sea countries, taking advantage of the world’s largest suppliers of marine ferry service, such as Finnlines, Tallink, Stena lines, DFDS group, ST Peters lines, BC Ferries, etc (Figure 3a). Geographical location of shipping lines in the Baltic Sea is large enough for connecting the main ports to each other. There are no fully overlapping lines between the different maritime companies, therefore those companies and their provided services compete with each other possibly, only in terms of what kind of cargo and passenger flows they can serve [3]. The member of DFDS group DFDS Seaways is the company, which operates near the Lithuanian coasts and is a leader of getting the highest revenues in the world from the services of

the global Ro-Pax shipping. This company has revenues of more than 1.3 billion EUR, and it occupies 31% of the market in terms of revenue (Figure 3b). The difference between Klaipeda city and other European ports is that there was no such terminal to serve the passengers so far. The new Klaipeda Central Terminal (KCT) was launched only in May, 2014. Its annual capacity is over 1 mln passengers, 5 mln tons of cargo and approximately 0,5 mln. tons of Ro-Ro cargo.

a)



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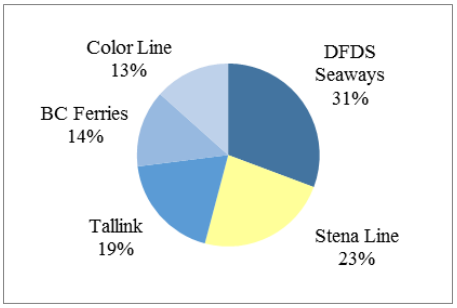

Figure 3. Ferry lines number and market occupation (a) and profit (b) in eastern and western Baltic Sea coast
Source: DFDS Seaways, Finnlines, St. Peters Lines, Stena Lines, Tallink, BC Ferries shipping lines sites; Shippax Market, 2012

The geographical analysis of shipping lines estimated that a large part of the passenger routes by sea depends on the socio-economic and political relations with neighboring countries. For example, a ferry sailing between Helsinki and St. Petersburg is designed to serve only passengers and always have a sufficient number of customers for the traditionally and historically established travels of passengers. Furthermore, in order to encourage inbound tourism, the Finnish government introduced a possibility of getting a 3 days free visa for the passengers arriving by ferries and thus increased inbound tourism indicators.

On the other hand, in regard to the geography of settled liner shipping lines, it will be complicated to insert one more additional line in this geography of lines and expect that it will be profitable. Especially to consider the fact that European Commission debates the possibility to reduce hazardous substances emissions of the ships in the Baltic Sea from 1% to 0,1%, and that would determine the absolutely inauspicious circumstances for exploitation perspectives of fuel-oil ships that are exploited nowadays. It is feared that after the establishment of this decision the circumstances of competitive activity for liner shipping in the Baltic Sea region, in comparison to other seas, would change cardinally. Whether this restriction is not valid for ships of non-EU countries, for the ships with the flags of EU countries, that are sailing in the Baltic Sea, and already to aforesaid companies, it would be necessary to arrange additional technical equipments or those companies should purchase new ships with the indicators of lower pollution.

When analyzing the competitive environment of liner shipping, it should be noted that most consumers of Ro-Pax ferries service are cargo, which are transported by the modes of land transport, and the personnel that service those cargo. Wheeled cargo is the main cargo in Ro-Pax ferries, and passengers use these lines accidently. It is commonly to travel in Ro-Pax ferries on summers or before the holidays, when travels by other modes of transport due to the various reasons are unacceptable or in the cases when it is wanted to try the unusual mode of transportation and to travel by sea.

Therefore, in order to reinforce competitive position in the market, the significant factor becomes the price of passengers' transportation and its flexibility, which is expressed through the value relation of service and price for the service's consumers, not forgetting the strategy of seeking maximum profit.

3. DFDS Seaways Passenger Transportation by Ro-Pax Ferries Service Pricing Model in Perspective of Revenue Maximization

DFDS Seaways acquires 7 Ro-Pax ferries as the tangible assets, which serves the Baltic Sea liner shipping lines (Figure 3a). The company's strategy and objectives made the preconditions for such an organizational structure to distribute material resources between the parent and subsidiary shipping companies, therefore, their transfers of cargo by sea services are provided by DFDS group, which leases ferries from DFDS Seaways. Furthermore, DFDS Seaways buys out all passenger seats in rented ferries and is responsible for the effective management of the passengers tickets fare.

Distancing from additional sources of income, it is important to investigate whether the passenger‘s ticket price is flexible enough, is firm effectively exploits passenger’s transfer by sea markets advantages and ensures maximum passenger transfer service profitability. When assessing the price flexibility, firstly it is important to analyze passenger fare model concept and to find the most sensitive factors that lead to price changes, then to establish additional parameters that would increase the value of services provided to consumers and would let to increase revenues.

In Ro-Pax ferries passenger ticket price depends on the services provided for passengers, which can be divided into main, assisted and supportive (Figure 4).

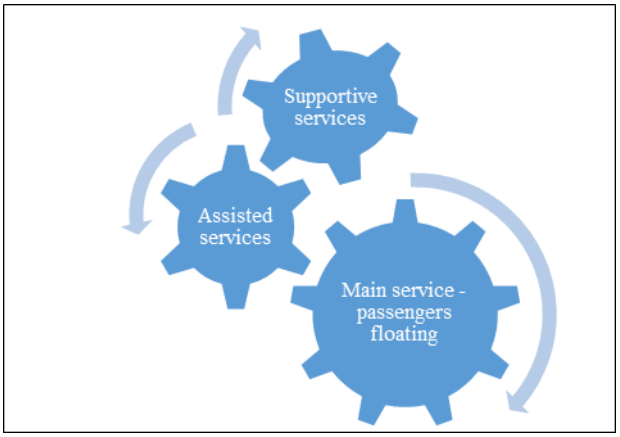

Figure 4. Marine Ferry Travel Service Package Structure

The main, core, service is the service that represents company’s activities in the market base (Fig. 4). Assisted services (online ticket booking system, the instantaneous premium, the extra costs per seat, catering services, etc.) provide the core services. Lack of these services makes it impossible to use the core service. Supportive services (shop, entertainment, IT communication, a permit to transport the animal etc.) are generally not necessary, but it distinguishes the company from its competitors.

According to Ro-Pax services for passengers structure, passenger‘s ticket price consists of the standard price for the basic service Y_s, bonuses for assisted and supportive services Y_{bon} and discounts Y_d. The income P from the sale of passenger ticket number n can be expressed as (1).

$$P = \sum_{j=1}^{n} Y_{s_j} + \sum_{j=1}^{n} Y_{bon_j} - \sum_{j=1}^{n} Y_{d_j} \quad (1)$$

DFDS Seaways model is depicted graphically, specifying the types of surcharge and discount (Figure 5).

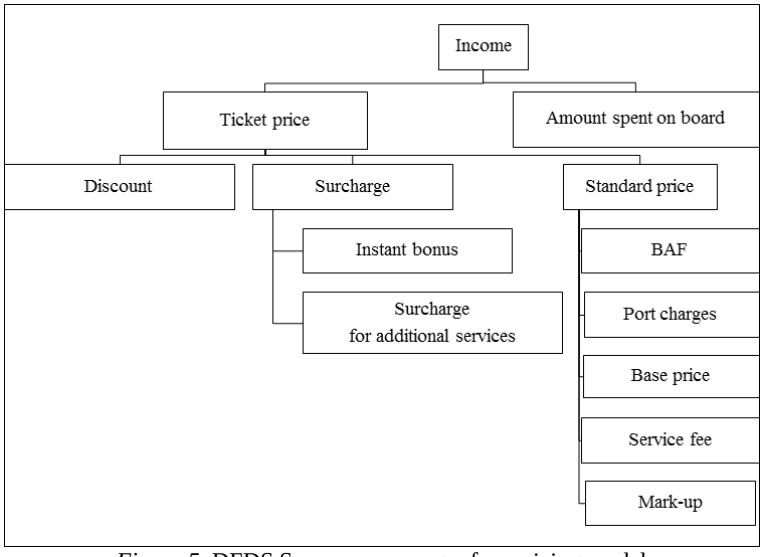

Figure 5. DFDS Seaways passenger fare pricing model

Standard passenger fare consists of a number of fairly stable over time items (Figure 5):

• Base price of one passenger space Y_b, which consists of one passenger space share in the total passenger ticket redemption sum $Y_b=Q/m$, where m – passenger seats on board, and the Q - redeemed passenger seats total monetary value, also the "$n \leq m$" restriction applies.

• BAF surcharge for fuel per passenger Y_{BAF};

• Port charges per passenger Y_{port};

• One passenger service fee $Y_{service}$, which consists of terminal fee, boat mooring, passenger's and vehicle's exportation in and out of the vessel, registration of the voyage space rental and so on;

• One passenger ticket mark-up $Y_{mark\text{-}up}$, which consists of one of the company's additional source of income, adjusted according to the legislation of LR, with the maximum limits specified, but it can be partially modeled.

Base price of the passanger ticket price share can be expressed as (2).

$$Y_s=Y_b+Y_{BAF}+Y_{port}+Y_{service}+Y_{mark\text{-}up} \quad (2)$$

In order the voyage not to be unprofitable, the following equation for expenditures must be applied (3).

$$(Y_b+Y_{BAF}+Y_{port}+Y_{service})\cdot n=Q_{sales}+Q_{fuel}+Q_{dues}+Q_{service} \quad (3)$$

Where Q_{sales} are equal to a minimum of one passenger seat cost for the company.

To receive income, the mark-up is applied, which is the same for all standard passenger ticket price, but it is necessary to comply with this restriction (4).

$$Y_s > \sum Q \quad (4)$$

Analyzing surcharges, it is necessary to distinguish between the types of surcharges, where each one depends on the time of ticket purchase, id est assessing the period until the voyge. Surcharges for passenger's tickets are applied in the following cases: mean of transport Y_{p_w}; transportation of animals Y_{p_g}; passenger's seat Y_{p_v}; food services $Y_{p_{mp}}$; surcharge of the passenger's ticket price is described (5), where j is passenger ticket.

$$Y_{p_j}=Y_{p_{w_j}}+Y_{p_{g_j}}+Y_{p_{v_j}}+Y_{p_{pm_j}} \quad (5)$$

Analyzing the size of surcharge for vehicle, it should be noted, that all contributions are determined in accordance with the pricing plan and have specific rates. By modelling these rates, the more flexible price model can be changed and predictions for the most likely outcome of the sale of tickets can be made. Income earned from the surcharge of the vehicles moved, will be calculated using the following equation system (6).

$$\begin{cases} Y_{p_w}=\sum_{t=1}^{t=9}\sum_{s=1}^{s=8} a_{ts}\cdot n_{ts}\,; \\ n=\sum_{t=1}^{t=9}\sum_{s=1}^{s=8} n_{ts}. \end{cases} \quad (6)$$

a_{ts} – price for a vehicle type;

n_{ts} –number of sellesd places for a vehicle type;

s – type of the vehicle (bicycle s=1, motorcycle s=2, car s=3, car with trailer s=4, caravan s=5, minibus s=6, bus s=7, lorry s=8);

t – period of buying the ticket for a voyage (in time of the voyage t=1, 1 day before the voyage t=2, 2 days t=3, 3-5 d. t=4, 1 week t=5, 2-3 weeks t=6, 1 month t=7, 2 months t=8, 3 months t=9.

Where passenger's ticket surcharge is defined by the following equation (7)

$$Y_{p_{w_j}}=a_{ts},\ t=1,\dots,9;\ s=1,\dots,8 \quad (7)$$

The surcharge for the place on board is calculated by analogy to the surcharge of vehicle, by keeping fixed ticket's purchase time, the surcharge of the place is modelled. Income generated from the surcharge of places will be calculated according to (8) model.

$$\begin{cases} Y_{p_v}=\sum_{t=1}^{t=9}\sum_{z=1}^{z=6} b_{tz}\cdot n_{tz}\,; \\ n=\sum_{t=1}^{t=9}\sum_{z=1}^{z=6} n_{tz}. \end{cases} \quad (8)$$

b_{tz} – price for a passenger's place;

n_{tz} –number of sold passenger's places;

z – type of the passenger's place (reclining seat z=1, place in the cabin without window z=2, place in the cabin with window z=3, cabin without window z=4, cabin with window z=5, LUX cabin z=6);

t – period of buying the ticket for a voyage (in time of the voyage t=1, 1 day before the voyage t=2, 2 days t=3, 3-5 d. t=4, 1 week t=5, 2-3 weeks t=6, 1 month t=7, 2 months t=8, 3 months t=9.

Surcharge of the passenger's ticket is defined (9).

$$Y_{p_{v_j}}=b_{tz},\ t=1,\dots,9;\ z=1,\dots,6 \quad (9)$$

Then the surcharge of the passenger‘s ticket is calculated as (10).

$$Y_{p_{s_j}} = c_t,\ t=1,\ldots,9 \tag{10}$$

Income generated from the surcharge of animals transportation will be calculated by (11) system.

$$\begin{cases} Y_{p_s} = \sum_{t=1}^{9} c_t \cdot n_t ; \\ n = \sum_{t=1}^{9} n_t . \end{cases} \tag{11}$$

c_t – surcharge for a passenger‘s place during transporting animals';

n_t – number of sold passenger‘s with animals places;

t – period of buying the ticket for a voyage (in time of the voyage t=1, 1 day before the voyage t=2, 2 days t=3, 3-5 d. t=4, 1 week t=5, 2-3 weeks t=6, 1 month t=7, 2 months t=8, 3 months t=9.

When buying a ticket for the ferry, it can be food service and food coupons pre-ordered in advance, as the addition for the ticket. There is an oppurtunity to buy complex catering services. However, the sensitivity of the parameters is uncertain, as there is no difference for the passengers to buy services on board or in advance, because these services cost the same. In order to analyze the sensitivity of this parameter by adapting differentiatied pricing over time, the table of surcharge of food service is made. Passenger‘s ticket surcharge of food service is described (12) in model.

$$Y_{p_{mp_j}} = d_{th},\ t=1,\ldots,9;\ h=1,\ldots,6 \tag{12}$$

Income from the surcharge of food services are calculated using (13) equation system.

$$\begin{cases} Y_{p_{pm}} = \sum_{h=1}^{h=6} \sum_{t=1}^{t=9} d_{th} \cdot n_{th} ; \\ n = \sum_{h=1}^{h=6} \sum_{t=1}^{t=9} n_{th} . \end{cases} \tag{13}$$

d_{th} – price for a food service;

n_{th} – number of sold passenger‘s places with a food service;

h – type of the food services (breakfast h=1, lunch h=2, dinner h=3, lunch and dinner h=4, breakfast and dinner h=5, breakfast, lunch and dinner h=6);

t – period of buying the ticket for a voyage (in time of the voyage t=1, 1 day before the voyage t=2, 2 days t=3, 3-5 d. t=4, 1 week t=5, 2-3 weeks t=6, 1 month t=7, 2 months t=8, 3 months t=9.

Therefore, the expression of the passenger‘s ticket, after the assesment of size of the surcharge of additional services, can be expressed as model (14).

$$Y_{p_j} = Y_{p_{w_j}} + Y_{p_{s_j}} + Y_{p_{v_j}} + Y_{p_{pm_j}} = a_{st} + b_{zt} + c_t + d_{th} \tag{14}$$

In equation:
s=1,..., 8; z, h=1,..., 6; t=1, ..., 9

Income from the surcharge are assessed according to (16) equation system.5

$$Y_p = \sum_{s=1}^{s=8} \sum_{t=1}^{t=9} a_{ts} \cdot n_{ts} + \sum_{z=1}^{z=6} \sum_{t=1}^{t=9} b_{tz} \cdot n_{tz} + \sum_{t=1}^{9} c_t \cdot n_t + \sum_{h=1}^{h=6} \sum_{t=1}^{t=9} d_{th} \cdot n_{th} \tag{15}$$

Discount system is applied according to the type of the passenger (Figure 6). The application of loyalty system is implemented only calculating the amount of discount of the surcharge to the standard passenger fare. The most important group is the constantly traveling business clients. Less significant group is the casual business customers. This significance has been identified in accordance with the enterprise‘s service sales strategy providing the guidance for sales to business clients, in accordance with the ever-expanding flows of cargo transporting trucks.

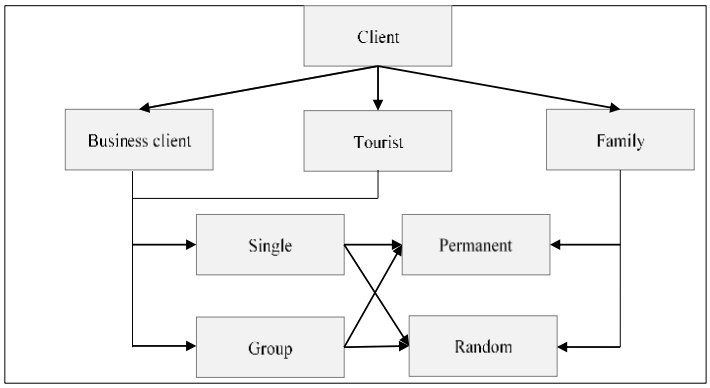

Figure 6. Customer loyalty classification by groups

There may be 10 types of discounts applied to specific cases, therefore the table of discount value parameters can be made, which can be assessed by sensitivity to discounts on the price flexibility model.

Values are set out in order of significance: 1 – the smallest significance, 5 – the highest significance, provided in the company's pricing strategy. According to the table of parameters the last pricing model component can be made, which is in passenger's ticket (16).

$$Y_{n_j}=e_{wq},\ w=1,2;\ q=1,\ldots,5. \tag{16}$$

Sum expression of discounts, loyalty costs, are calculated in accordance with (17) model.

$$\begin{cases} Y_n = \sum_{h=1}^{t=9} \sum_{q=1}^{h=6} e_{wq} \cdot n_{qw}\ ; \\ n = \sum_{h=1}^{t=9} \sum_{q=1}^{h=6} n_{qw}\ . \end{cases} \tag{17}$$

e_{wq} – amount of the discount;
n_{wq} – number of discount;
w – type of the discount, permanent w=1, random w=2;
q – business client (group) q=1, business client (single) q=2, family q=3, tourist (group) q=4, tourist (Single) q=5.

In summary DFDS Seaways passenger fare model is presented (18).

$$\begin{cases} P=(Y_b+Y_{BAF}+Y_{port}+Y_{service})\cdot n+\sum_{s=1}^{t=9} \sum_{t=1}^{s=8} a_{ts}\cdot n_{ts} + \sum_{z=1}^{t=9} \sum_{t=1}^{z=6} b_{tz}\cdot n_{tz} + \sum_{t=1}^{9} c_t\cdot n_t + \sum_{h=1}^{t=9} \sum_{t=1}^{h=6} d_{th}\cdot n_{th} - \sum_{h=1}^{t=9} \sum_{q=1}^{h=6} e_{wq}\cdot n_{qw}; \\ (Y_b+Y_{BAF}+Y_{port}+Y_{service})\cdot n=Q_{sales}+Q_{fuel}+Q_{dues}+Q_{service}; \\ Y_s>\sum Q; \\ \sum_{h=1}^{t=9} \sum_{q=1}^{h=6} n_{qw}=\sum_{h=1}^{t=9} \sum_{t=1}^{h=6} n_{th}=\sum_{t=1}^{9} n_t=\sum_{z=1}^{t=9} \sum_{t=1}^{z=6} n_{tz}=\sum_{s=1}^{t=9} \sum_{t=1}^{s=8} n_{ts}=n; \\ \sum_{s=1}^{t=9} \sum_{t=1}^{s=8} a_{ts}\cdot n_{ts} + \sum_{z=1}^{t=9} \sum_{t=1}^{z=6} b_{tz}\cdot n_{tz} + \sum_{t=1}^{9} c_t\cdot n_t + \sum_{h=1}^{t=9} \sum_{t=1}^{h=6} d_{th}\cdot n_{th} - \sum_{h=1}^{t=9} \sum_{q=1}^{h=6} e_{wq}\cdot n_{qw} \geq \sum Q_{service\,establ.} \end{cases} \tag{18}$$

DFDS Seaways empirical model of the customer's price applied in the present time is presented by (19) equation system.

$$P^{emp}=Y_b+Y_{BAF}+Y_r+Y_{service}+Y_{mark\text{-}up}+a_{ts}+b_{tz}+c_t+d_{th}-e_{wq} \tag{19}$$

According to the consumers behavior of management approach, assessing the service economic benefit and cost ratio, user's point of view is taken into account and the following term is used – user desired price $P^{desired}$. Then the company's price flexibility F is determined and is defined by the ratio of (20).

$$F=\frac{P^{desired}}{P^{emp}} \tag{20}$$

The passenger's ticket price flexibility can be evaluated:

- If F>1, then the flexibility of the price is too high and there is a risk that the price is unprofitable;
- If F=1, then the flexibility of the price is enough;
- If F<1, then there is a possibility of increasing the flexibility of the price.

Passenger's ticket price model's goal and task can be formulated using (21) equation system.

$$\begin{cases} P \to \max; \\ F \to 1; \\ P^{emp} \to \min \end{cases} \tag{21}$$

Summing up the price model and assessing the conditions of price flexibility, it can be concluded, that in order to achieve an optimal passenger's ticket price model, it is necessary to evaluate the parameters of price flexibility and their values of alternative perspectives of the company's general income model, subject to its maximum criterion.

The introduction of an additional component – passenger's expenses on board – price model reveals the connection between the attain of the highest income and price flexibility. The model becomes more complex, however, the additional expenses, needed to achieve the ideal passenger's ticket price flexibility index, can be compensated by additional income from supportive services on board, that are focused on increasing the comfort, as well as access to services and diversification.

4. Ticket price flexibility modeling based on price model

Analyzed price model of DFDS Seaways line Klaipeda (Lithuania)-Kiel (Germany) by sea ferry "Regina Seaways" (414 seats in cabins, 118 seats, data from AB DFDS Seaways annual financial report). Using a created price model, variations between the lowest and the highest passenger's ticket prices can be compared. In order to calculate a standard price the base rates of December, 2013 are defined (Table 1).

Table 1. Ro-Pax ferry "Regina Seaways" passenger's ticket price

Base price	$Y_b = 70$ Lt
Surcharges (fuel, port charges, terminal charges)	$Y_{BAF} = 17$ Lt; $Y_{port} = 52$ Lt; $Y_{service} = 35$ Lt
Number of places	m=414+118=532
Mark-up 20% for one passenger seat	$Y_{mark-up} = (Y_b+Y_{BAF}+Y_{port}+Y_{service}) \cdot 20\% = 35$ Lt
Standard price (2)	$Y_s = 70 + 17 + 52 + 35 + 35 = 209$ Lt
Company's expenditures (3)	$Q = (70 + 17 + 52 + 35) \cdot 532 = 92568$ Lt
Total mark-up (4)	$Y_{mark-up}=(Y_b+Y_{BAF}+Y_{port}+Y_{service})\cdot 20\%\cdot 532=18514$ Lt
Surcharge (5)	$Y_{p_1} = 0 + 0 + 95 + 0 = 95$ Lt
Voyage ticket price (19)	$P_j^{emp} = 209$ Lt $+ 95$ Lt $= 304$ Lt

In the start of selling tickets, through the surcharge of time, service provider tries to cover Q sum, according to standard price, as fast as possible. Therefore, in the case when the number n<m of sold tickets are such that covers sum base passenger line Q and service provider costs, ticket price can be modeled flexibly. Additional assumptions can be made when analyzing surcharges. When calculating a minimal price of passenger's ticket, assumption can be made that passenger purchases ticket 3 months in advance; he is a casual single consumer, who doesn't belong to any loyalty programs. He travels without a vehicle and takes no animals, buys a seat in the ferry without acquiring additional food service in advance. Surcharge is calculated using equation (5). When j=1 (the first passenger who buys a ticket), then $Y_{p_{w_j}}=0$ Lt, $Y_{p_{g_j}}=0$ Lt, $Y_{p_{v_j}}=95$ Lt, $Y_{p_{pm_j}}=0$, $Y_{n_j}=0$.

Analyzing parameters in Table 8, using equation (19), a minimal empirical ticket price is about 304 Lt. The resulted price flexibility ratio is quite low (22).

$$F = \frac{P^{desired}}{P^{emp}} = \frac{36}{304} = 0,12 \quad (22)$$

The research has represented that those passengers, who travel on board with the cheapest tickets, though at the minimum, but enter into the expenditure. On average, costs per passenger per trip aims to 107 Lt. After the evaluation of mark-up expenditures, this price can be modeled again. At this time, price flexibility rate is on index of 0,61. For example, applying a 10% discount on catering services, when buying a ticket, would increase ticket's price and would reach 304+63*0,9=361 Lt. Ticket's price flexibility would decrease to 0,10 (7%). However, food catering service flexibility would increase by 10% (55/63*0,9=0,96). Therefore, the service flexibility index and the minimum price of the voyage could be increased in the economic value of the user's point of view. It doesn't mean that consumer after assessment of service and quality of serving during a voyage will give up buying dinner on board for the additional fee. Analogous steps can be carried out with other services in order to increase the flexibility of price. Assuming that it is a single casual passenger, loyalty program does not apply to him. However, an introduction of advanced flexible catering surcharge may improve the situation.

When calculating average price passenger's ticket, assumption can be made that passenger purchases ticket in medium urgency terms, approximately 1 week in advance till voyage. He is a casual single consumer, who doesn't apply to any loyalty programs; travels alone, with a vehicle, carries a pet and he has to redeem the whole cabin and the consumer's income is attributable to higher income group (Table 2).

Table 2. Model of ticket price to travel with an animal

Elements of price	Meanings
Instantaneous surcharge for passenger	$Y_{p_{cr_1}} = 200$ Lt
Surcharge of animal	$Y_{p_{g_1}} = 138$ Lt
Surcharge of place	$Y_{p_{v_1}} = 2 * 500 = 1000$ Lt
Surcharge of food service	$Y_{p_{pm_1}} = 0$ Lt
Discounts	$Y_{n_1} = 0$ Lt
Total surcharge	$Y_{p_1} = 107 + 138 + 1000 + 0 = 1245$ Lt
Ticket price of average voyage	$P_j^{emp} = 209$ Lt $+ 1245$ Lt $= 1454$ Lt

Traveler is travelling with pet, thus the surcharge of animal is applied. Furthermore, under the existing rules, he must travel in a separate double cabin; therefore both places have to be redeemed. Also,

the surcharge of animal is quite high. Passenger doesn‘t sign up for the additional catering service, therefore surcharge of food service is not applied. Because he is a casual and more likely travelling in transit through Lithuania to Germany, loyalty programs doesn‘t apply to him. To sum up, the surcharge for such passenger will be high enough and that would increase the whole price of the ticket (Table 2).

According to the accomplished survey results, such ticket price flexibility 0,33, is 3 times higher than (23) minimal-cost travel case (23).

$$F = \frac{P^{desired}}{P^{emp}} = \frac{478}{1454} = 0{,}33 \quad (23)$$

Each additional service provides more flexibility for the passenger‘s ticket price and it is valuable for consumer. For example, comparing only one, carrying an animal service price flexibility, it was found that flexibility index is 0,40 (21% increase). Separate vehicle transportation service fee flexibility is 0,29 (13% decrease in flexibility). Therefore, complex service fee flexibility is somewhat lower than the average of price flexibility of individual services (0,35), which is not unsatisfactory (it should be higher).

If the original ticket‘s calculation assumptions would be modified and passenger would apply to the certain loyalty group (which currently does not exist), holding 10 % discount for surcharge of the ticket, then the passenger‘s ticket price would be calculated (24) and flexibility (25).

$$P^{emp}_{i\_disc} = 1454 - 10\% = 1308 \text{ Lt} \quad (24)$$

$$F = \frac{P^{desired}}{P^{emp}} = \frac{478}{1308} = 0{,}37 \quad (25)$$

Such price flexibility of the complex voyage would be enough for the specific case analyzed (0,37>0,33), because in this case the flexibility could be increased on average by 0,04 point. Of course, modeling of a real situation requires constant monitor of the parametric restrictions that increase in price flexibility would not become unprofitable for the company.

Using analysed price model, various situations can be evaluated and using optimization problem algorithm to generate alternative solutions for increasing price flexibility, and to accept the optimal ones.

Conclusions

1. Service pricing is understood as a complex integrated process involving not only services numerical evaluation setting, but also requires to evaluate the risk of customer’s and supplier’s price and to assess the consumer’s perceived value of the service. The final price and ability to persuade consumers to buy the service for a maximum price possible – is pricing decision effectiveness index. These objectives are presented by the user-oriented pricing, which main purpose is to comply with the price flexibility and the value of consumer’s services perception principles. In order to achieve the effective marketing, direct and constant communication with the customer and maintenance of consumption value is the key of complimentary services and price flexibility influencing factors.

2. For Ro-Pax shipping specificity for passenger transport, maritime transport system is superior to the others with the current lower rates, increased capacity and productivity. For sufficiently isolated environmental impact of passengers on board it is difficult to evaluate the flexibility of services provided, as the value of customer service is determined not only by common factors, but also by the increased sense of security, trust of staff and other psychosocial factors. The main advantage in the passengers’ service area is the sufficient amount of space on board, which allows creating the larger package of services.

3. Goal of created price model is to maximize the income from sales of travel tickets, creating flexible price service package, maintaining the adequate price and services level of the qualitative and quantitative perspective from a customer’s point of view. DFDS Seaways services price flexibility depends on the following factors (in ascending order): extra cost of ticket, extra cost of vehicles transportation, catering services, additional store services, entertainment services, internet connection and loyalty program. Applying the price model it was established that it is possible to increase the low flexibility – the proposal is to create the complex service packages.

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INVESTIGATION OF ELECTRO-MAGNETIC PROCESSES IN A TRANSFORMER BASED AC PULSE MODULATION SYSTEM

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Abstract
In the paper some results regarding electro-magnetic processes investigation in the single-phase transformer based AC pulse modulation mode regulated system of network voltage stabilization are presented. The main attention is paid to the mathematical description of switching electro-magnetic processes of transformer windings, which influence output parameters of device. Switching processes are regarded to application of transistor switches with proper snubbering circuits. Computer simulation of the processes above mentioned as well experimental investigation of a model are done and its outcomes are presented.
Keywords: *transformer, switch, snubber, inductance, position*

Introduction

A problem for developing of fast-operating simple and reliable AC single-phase voltage stabilizer is really actual one. It is connected with Internationally accepted standards which allow variations of AC supply voltage in range +/-10% from the rated value (230V for the single-phase) of voltage level [1] and in electric system of a ship it can change from +6% to -10% [2]. Thus electrical equipment is stressed by the higher meanings of voltage at the same time applying of higher voltages foster in many applications rise of consumed power and decrease of efficiency. Therefore stabilization of the single phase AC voltage for customers is of high authority. Such stabilization devices must comply to a some requirements – to provide simplicity, cheapness, bi-directionality, to be reliable. Power ratings of stabilizers couldn't be above some kW.

Information of such stabilizers in ship electric systems has not been fount.

Such stabilizers can be developed on base of power electronic solutions – for instance it's possible to realize double-stage conversion – rectifying with succeeding invertation on necessary output voltage shape and parameters. But devices of such type shouldn't comply with requirements. It's proposed to use direct PWM controlled converting [3, 4, 7] realizing bi-directional BUCK_BOOST operation on base of IGBT transistor application at application of the fast-operating sensors of the secondary voltage [5,6]. But anyway this solution is rather complex and asks for application of filtering devices [8] which rise as complexity as well cost of application.

In the last period have been proposed to apply systems where transformer is combined with semiconductor modulation tools [10, 11, 12]. Especially interesting is application of auto-transformers like devices which are characterizing with property when in case of small voltage variation range it's possible to gain-through load power which can be much larger as transformer rated power [9, 10, 11]. For instance in [10] it's shown that at 15% output voltage variation power of load could tenfold to be above one of an autotransformer's. Supplementing such device with controllable electronic switches it's possible to achieve stepwise change in small range a load voltage wave. At that simplest solution should be at application of only one secondary winding calculated for full load current and for BUCK case – contrary introduced regard to the separated by current ways the primary winding [10, 11].

For better understanding of operation properties it's of special significance to provide an investigation of switching processes in such complex system which essentially influences as reliability as well output parameters of the device. This is the task of the presented paper.

I. Scheme and principle of operation

Let's observe voltage regulation circuit which includes 2-winding transformer and 2 regulation transistors (Fig.1). Circuit is meant to compensate small range (up to 10%) voltage deviations in network on constant impedance load which consists from resistor R and inductance L.

System works in following way: when load voltage is higher than needed, switch S2 is turned on and it connects the load to secondary winding w_2 , which is connected in respect to primary winding w_1 in opposite phase. Primary winding w_1 is constantly connected to circuit supply voltage.

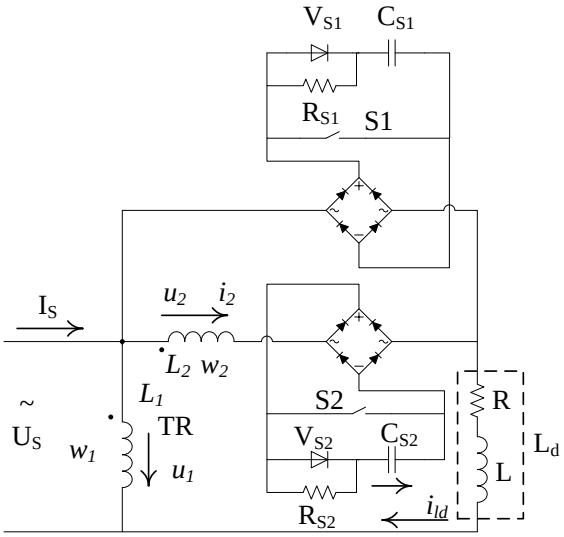

Figure 1. Scheme of modulated by transistors single-phase transformer

Effective voltage of winding w_2 is $U_2=U_s w_2/w_1=U_s/N$ and transformation ratio N is approximately 10, which would ensure compensation of U_S rise on the load.

When voltage on the load is lower than needed, switch S2 is turned off and switch S1 is turned on. Switching process is implemented with constant and high enough frequency f_m, as well is controlled a switching duty ratio of switches S1 and S2 in constant switching cycle T_m to achieve necessary output RMS voltage. If on-duty cycle for switch S1 is $D=t_1 \cdot f_m$, than simplified load voltage and network current can be shown in Fig.2.

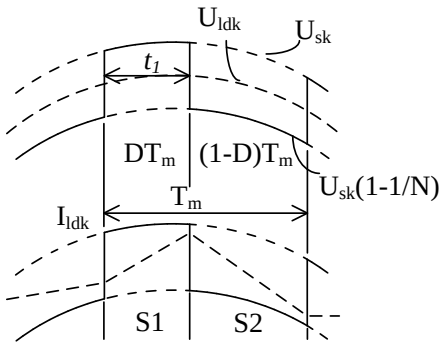

Figure 2. Simplified diagrams of load voltage and supply current in one (*k*) switching cycle

Simplified average voltage of the load at k-th interval is:

$$U_{ldk} = U_{sk}D + (1-D)\left(U_{sk} - \frac{U_{tk}}{N}\right) = U_{Sk}\left(\frac{N-1+D}{N}\right). \quad (1)$$

Simplified source current value in k-th interval is:

$$I_{sk} = I_{ldk} D + I_{ldk}\left(1-\frac{1}{N}\right)(1-D) = I_{ldk}\left(\frac{N-1+D}{N}\right) \cdot \quad (2)$$

II. Commutation processes and its influence on the output parameters

1. Commutation processes at gating of switch S1

Let's consider switching process from the on-position of the switch S2 to the on-position of the switch S1. At the moment when the switch S1 is turned-on and the switch S2 – turned-off, the transient process starts in duration of which through the snubber capacitor C_{s2} of the switch S2 current i_2 of the winding w_2 of transformer passes and instantaneous meanings of current through the S1 in the very-short k-interval of supply voltage (modulation interval) wave can be find as

$$i_{1k} = i_{ldk} - i_{2k} = I_{ldk} - i_{2k} \ , \quad (3)$$

where it's accepted that in the commutation interval load current is constant one, i.e., $i_{ldk}=I_{ldk}$.

At very beginning of the process current of the switch $i_{1k0}=0$, but process itself characterizes with differential equation

$$-U_{2k} = L_{2TR}\frac{di_{2k}}{dt} + \frac{1}{C_{s2}}\int i_{2k}dt \quad (4)$$

solution of which at the initial in the k-interval current $i_{2k0}=I_{ldk}$ can be expressed as

$$i_{2k} = -\frac{U_{2k}}{\omega_k L_{2TR}}\sin\omega_k t + I_{ldk}\cos\omega_k t \ , \quad (5)$$

and

$$i_{1k} = \frac{U_{2k}}{\omega_k L_{2TR}}\sin\omega_k t + I_{ldk}(1-\cos\omega_k t). \quad (6)$$

Here U_{2k} is voltage of the secondary winding of the transformer in k-interval (accepted as constant one), L_{2TR} is a total leakage inductance of transformer reduced to the secondary winding w_2 ,

$\omega_k = (L_{2TR}C_s)^{-0.5}$ - the angular speed of the process.

Current i_{2k} reaches its zero value in time interval

$$t_k = \frac{1}{\omega_k} arctg\frac{I_{ldk}\omega_k L_{2TR}}{U_{2k}} \ . \quad (7)$$

Voltage of the snubber capacitor C_{S2} in the process increases from the initial zero value in accordance with equation

$$u_{2k} = \frac{1}{C_s}\int i_{2k}dt + A = U_{2k}(\cos\omega_k t - 1) + I_{ldk}\rho_k \sin\omega_k t \, , \quad (8)$$

succeeding its end value

$$U_{C2km} = U_{2k}\left[\cos(arctg\frac{I_{ldk}\rho_k}{U_{2k}}) - 1\right] + I_{ldk}\rho_k \sin(arctg\frac{I_{ldk}\rho_k}{U_{2k}}) =$$

$$= \frac{U_{2k}^2 - U_{2k}\sqrt{U_{2k}^2 + I_{ldk}^2\rho_k^2} + I_{ldk}^2\rho_k^2}{\sqrt{U_{2k}^2 + I_{ldk}^2\rho_k^2}} \ , \quad (9)$$

where $\rho_k = (L_{2TR}/C_s)^{0.5}$ - is wave impedance.

Processes in the scheme at transients are presented in Figure 3.

2. Commutation processes at gating of switch S2

When the switch S2 is turned-on but S1 – turned-off, then rise of current through switch S2 and current i_{2k} of transformer's winding w_2 starts but in the way of transient a balance of currents, similar as in the first case (3), is in force.

Rise speed of current of the secondary winding in the transient interval depends on variations of voltage of the snubber capacitor C_{S1} of the switch S1 which should be described as

$$L_{2TR}\frac{di_{2k}}{dt}=\frac{1}{C_s}\int i_{1k}dt \quad , \tag{10}$$

where it's accepted that the both capacitors of snubbers have same volume.

Taking into account balance of currents it can be written that

$$L_{2TR}\frac{di_{1k}}{dt}+\frac{1}{C_s}\int i_{1k}dt=0 \quad . \tag{11}$$

Solution of differential equation, taking into account, that at initial instant t=0 current $i_{1k}=I_{ldk}$ can be presented as

$$i_{1k}=I_{ldk}\cos\omega_k t \tag{12}$$

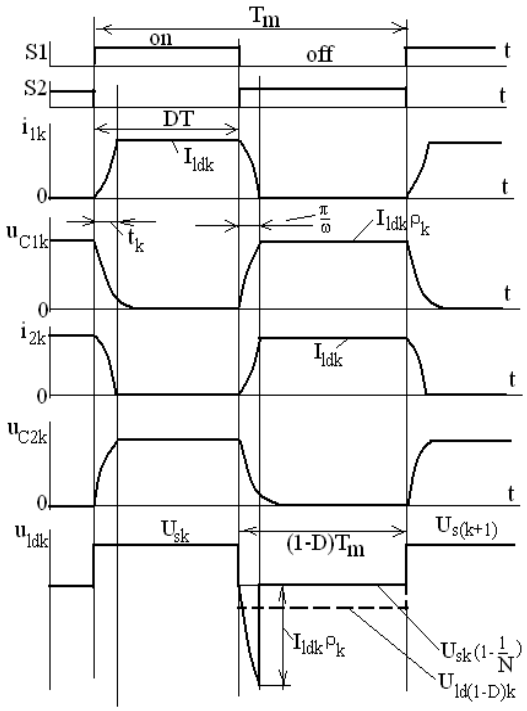

Figure 3. Diagrams of signals in the k-interval of network voltage wave

As it can be seen current in the circuit of winding w_2 is rising as

$$i_{2k}=I_{ldk}(1-\cos\omega_k t) \tag{13}$$

but voltage of capacitor C_{s1} is rising as

$$U_{C1k}=\frac{1}{C_s}\int I_{ldk}\cos\omega_k t=I_{ldk}\rho_k\sin\omega_k t \quad , \tag{14}$$

reaching its maximum value $I_{ldk}\rho_k$ at time instant $\omega_k t=\pi/2$ when current $i_{1k}=0$ but current i_{2k} reaches its maximum value I_{ldk} .

Rise of current in the winding w_2 at turn-on of the switch S2 is connected with self-inductance voltage generation in the inductance L_{2TR} . As result load voltage is decreasing in way of the transient process and this process can be described with equation

$$u_{ldk}=U_{sk}(1-\frac{1}{N})-L_{2TR}\frac{di_{2k}}{dt}=U_{sk}(1-\frac{1}{N})-\rho_k I_{ldk}\sin\omega_k t\,, \tag{15}$$

where time interval is from 0 to π/ω_k . At that largest instantaneous decrease of voltage is at instant,

when $\omega_k t = 0.5\pi$ (see Figure 3). As result really realized load voltage in the time interval (1-D)T is less as $U_{sk}(1-\frac{1}{N})$ and should be considered with expression

$$u_{ld(1-D)k} = U_{sk}(1-\frac{1}{N}) - I_{ldk}\rho_k \frac{\pi \cdot f_m}{2\omega_k(1-D)} \quad . \tag{16}$$

Taking into account decreasing of voltage in the intervals (1-D)T and as well phase shift of the fundamental harmonic of load current $\varphi = arctg\frac{\omega_s L_{ld}}{R_{ld}}$ in respect to the load voltage wave, where R_{ld} and L_{ld} are respectively resistance and inductance of load, a wave of the fundamental of load voltage can be described with expression

$$u_{ld(1)} = U_{sm}(\frac{N-1+D}{N})\left[\sin\omega_s t - \frac{\rho_k \pi f_m}{z_{ld}\,2\omega_k}\sin(\omega_s t - \varphi)\right], \tag{17}$$

where U_{sm} is the amplitude of supply voltage, ω_S is an angular speed for supply voltage wave, z_{ld} is an impedance of the load.

As it can be seen a wave of load voltage is performed by two rotating phasors shifted by angle φ and the common phasor of load voltage can be obtained using subtraction of the second phasor dependant on the load current from the main phasor performed by modulation. At such approach the modulus of the common load voltage phasor is

$$U_{ld(1)m} = U_{sm}(1-\frac{1}{N})\sqrt{1-\frac{\rho_k \pi f_m}{z_{ld}\omega_k} + \left(\frac{\rho_k \pi f_m}{2z_{ld}\omega_k}\right)^2} \quad , \tag{18}$$

and angle δ by which the fundamental of load voltage leads regard to the supply one – as

$$\delta = arctg\left(\frac{\rho_k \pi f_m \sin\varphi}{(2z_{ld}\omega_k - \rho_k \pi f_m \cos\varphi)}\right). \tag{19}$$

III. Verification of theoretical solutions

For verification of processes a computer modelling have been done applying transformer of 50VA, winding's ratio w_1/w_2=8.33, reduced to the secondary winding leakage inductance $L_2=L_1{}^1$=2.16mH, resistance of windings $R_2=R_1{}^!$=0.137 Ω, magnetizing inductance L_m=30H with load as R=100Ω, L=50mH and transistor pulse modulator operating with modulation frequency f_m=1kHz at different duty ratios. In the table 1 some calculation results of process parameters for U_{sm}=340V, 50Hz at applied duty ratio D=0.7 of modulator with RDC snubbers comprising C_s=1 μF and R_s=50 Ω as well obtained ones from computer modelling are presented.

Table 1. Comparison of calculated and simulated operating parameters of the investigated scheme

Name of the operating parameter	Calculated value	Simulated value	Applied expression
RMS voltage of the load	229.4 V	226.0 V	(18)
Amplitude of load current	3.21 A	3.09 A	(18)
RMS of load current	2.26 A	2.2 A	(18)
RMS of supply current		2.14 A	
Load voltage drop at turn-on of S2	96.1 V	97.5 V	(14)
Angular speed for snubber circuits	$1.52.10^4$ 1/s		$\omega_k = (L_{2TR}C_s)^{-0.5}$
Turn-on transient interval of S1	9.10^{-5} s	$8.8\cdot10^{-5}$ s	(7)
S1 snubber capacitor maximal voltage	166 V	154.9 V	(9)
S2 turn-on transient interval	$1.03\ .10^{-4}$ s	$1.04\ .10^{-4}$ s	(13)
S2 snubber capacitor maximal voltage	203.0 V	245.8 V	(14)

As it can be seen an accordance of the calculated and simulated parameters is rather good. Simulated diagrams of currents of switches and voltages of snubber capacitors at above mentioned parameters are presented in Figure 4.

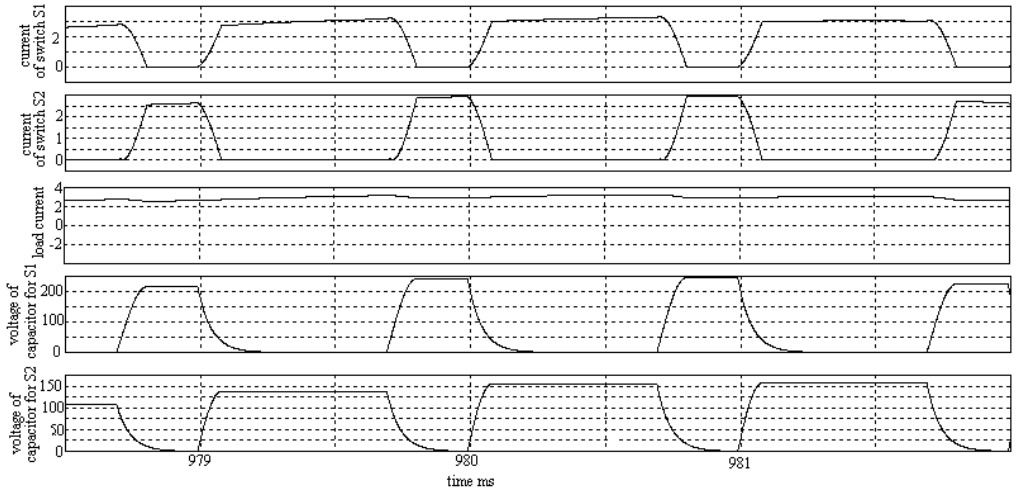

Figure 4. Simulated diagrams of currents of the switches and voltages of snubbers

Conclusions

Presented system of AC voltage regulation with modulated by transistor switches transformer windings can provide proper regulation of load voltage at small range deviations of AC supply voltage, which has not been done in electric systems of ships before. Processes in circuits of switches depend on snubber circuits applied for restriction of voltage spikes across the transistors of switches. But character of the processes influence output meanings and waves as of load voltage as well of its current. Obtained expressions for accounting of switching transient processes influence and its parameters are obtained and they provide rather good for engineering approach complying ones with really processes.

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GREEN LOGISTIC CONCEPTION IMPLEMENTATION THROUGH MODERNIZATION OF POLYETHYLENE WASTE MANAGEMENT IN MARITIME LOGISTIC PROCESSES

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Abstract
Authors analyse a problem which consist of maritime transport and port business companies and the amount of polyethylene waste's concentration after cargo repacking. Technology of waste utilization in these companies is inefficient and it does not fit the principles of green logistics. The main idea of paper is to analyse principles of green logistic and evaluate benefits of waste management modernization in maritime logistic processes. Main results show that the payback period of implemented waste modernization project in maritime logistic company is 9 years, but the results are more tangible in the case of minimised financial risks of fines for environmental pollution. It is important to say, that involving of each logistic company to take part in implementation of green logistic concept can help to minimize the pollution of environment, including urbanized places near the seaport areas.
Keywords: *marine, seaport business, green logistic, sustainable development, waste management*

Introduction

Logistics is the term now widely used to describe the transport, storage and handling of products as they move from raw material source, through the production system to their final point of sale or consumption [1]. Maritime logistics is the part of whole logistic chain, especially from the viewpoint of warehousing services and transforming from sea to land transport systems [9]. It can be stated that maritime logistics is a very complex process that combines in himself the smaller local and regional significance processes and integrates them into the global trading system of the logistical chain. The general concept of the logistics process including maritime logistics in the contemporary international trade complements the waste disposal logistics, which is inevitably linked to social responsibility and sustainable development concept, even authorized and updated to ISO 9001 and ISO 14001 standards, forthcoming next year. Therefore, it can be said that it is aimed not only for sustainable development goals, but also for development of alternative logistical activities in any maritime logistics enterprise and in any logistical processes by enabling development of disposal processes and it is important not only from the environmental security viewpoint, but also from the viewpoint of limited territorial resources [14].

Green logistics - one of logistics' types, which economically serve the environment, which is consistent with social responsibility principles and has influence for sustainable development [7]. Green logistics most realistically is displayed by statistics on the quantity of accumulated, recycled, and disposed waste in the country and it is important to say that Klaipeda state seaport cargo flows are more than 30% of all cargo turnover in all Lithuanian transport market.

One of the most harmful substances is polyethylene. This is a very acute issue for seaport companies providing not only transport but also warehousing, repackaging services such as containerized cargo repacking [5]. Polyethylene waste disposal in the traditional way is implemented by utilization it as household waste material at big part of seaport companies. It has strong negative impact to environment and it shows the importance to solve the problem of polyethylene waste management not only in maritime logistic companies, but in whole logistics' business sector. The modernization of the maritime logistics' companies' waste management system every year by improving legislation adds additional financial costs, an additional social responsibility, but it is not efficient [10]. So it is important to find alternative solutions: it is possible to implement regional policy of waste management and different financial programs through involving of maritime logistic objects into waste management system's modernization activities. It is relevant to analyse the costs and what economic effect would be reached by the

modernization of the maritime logistics company's waste management system. On the other hand, partial implementation of the green logistics concept to maritime logistics business processes can lead to renewed compliance with ISO quality standard, while the same business can contribute to sustainable regional development and social responsibility. So the *object of research* is polyethylene waste management in maritime transport and port business companies and the *aim of the research* – is to evaluate the polyethylene waste management systems' modernization benefits in marine logistics business.

Objectives of the research:

- to describe the concept of green of logistics;
- to identify the sources of polyethylene waste in maritime logistics processes;
- to describe the plastic waste management problem in Lithuania and EU countries;
- to assess the benefits of polyethylene waste modernization project of maritime logistics company.

Research methods. Scientific sources and a literature review allow identifying the importance of research, to explain selected methods. Research application permits to define and describe the essential features of the object, SWOT analysis allows to identify environmental factors, linear trend prognosis allows to evaluate tendencies.

1. The conception of green logistics

Sustainable development idea was started to develop from the early seventies and was presented as non-destructive development, later – as options for the world, as the future, emphasizing on the role of the market in the development process and poverty, overpopulation impact on natural resources for present and future generations of people's quality of life [3]. The literature analysis showed that sustainable logistics concept is often collated with the term "green logistics" and it is the background of this study and allows maritime logistics sector to be integrated into a coherent developing seaport logistics system [14].

Green logistics term covers actions of the organization in order to create energy-efficient and environment-friendly universal coherent logistics [8]. The main target of green logistics is to save resources, to dispose waste safely, to improve competitiveness and processes efficiency by reducing the organization's negative impact upon the environment [6]. It is important from maritime logistic business viewpoint, because a big part of seaports are located near the urbanized areas, or they are located in the areas of intensive shipping and increasing of pollution have a strong impact for surrounded areas. According to the scientific literature analysis, the green logistics is the logistical process oriented to continuous assessment and reducing the impact for the environment based on measurable indicators [20]. Green logistics can also be defined as an environmentally-oriented feedback logistics process which balances the logistical resources, and reduces environmental pollution by using modern logistics technologies in the design and implementation of freight, handling, storage, and packing [19].

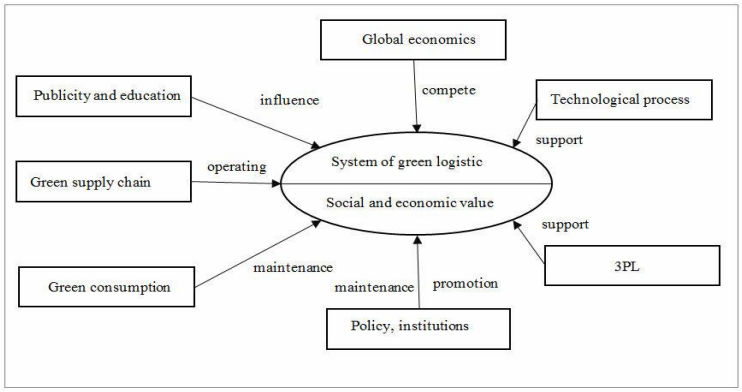


Figure 1. Model of green logistics' principles [20]

The main aim of the green logistic is to pursue the development of sustainable logistics system through the basic logistic technology and innovative activities, thus the efficiency of logistics processes are increasing and the negative impact on the environment is gradually reducing [2]. This has to become the main goal of the traditionally perceived maritime logistics processes, whose main objective is to achieve a high level of cargo operation's processes, taking just over a financial perspective but not over to

the negative impact on the environment. Participants of the green logistic processes are not only logistic companies, located in seaports or other areas, but also industrial, retail and recycling sites, participating in logistical chains, having both positive and negative processes in the direction of production movement, therefore in green logistic context, it is possible to analyse these companies integration, with a view of optimizing of resources usage reducing inefficient allocation of resources (figure 1). From other viewpoint the seaports have possibilities to become special centres where all sites of green logistical chain will be integrated in the implementation of green logistics' principles and the last argue is based on the functional conception of seaports: they are the main connection between different types of transport systems that are used for supporting of whole logistic chain's functionality. Meanwhile, maritime logistics chain stakeholders are maritime logistic service companies by the viewpoint of traditional logistic processes' concept so it is difficult to optimize the shared resources and to integrate the manufacturers and processors in the whole logistic chain [11]. So, the inefficiency of waste management systems in modern maritime logistical systems is the result of conceptual differences and that situation describes the problematic of green logistics principles implementation into traditional maritime logistics processes.

The analysis of green logistics' concept is necessary because it is important to note that the logistical processes are formed in a green circulation, which includes not only green technologies, but also to form an alternative direction of logistical processes in waste disposal logistics, so it is possible to state that an additional niche are formed in the maritime logistics market [4]. Another factor for green logistic implementation into maritime logistics business is technological progress. Clearly can be stated that green logistics concept is impossible without the development of innovative and high-tech applications traditionally formed in logistics [15]. It is the same as the development of technological capacities in cargo handling processes: high technological supporting is one of the main factors of effectiveness. If the maritime logistics company fails to assess changing environment and takes into account logistical processes transformation and orientation to the environment through innovative technologies, it will not define its potential in maritime logistics industry and will not be kept in the original "high-tech" installation level, so the interests and technology of maritime logistics company have to be controlled targets by regional legislation and promotion [22]. This suggests that cooperation of government, educational institutions, and research institutions is inevitable for sustainable development of green logistics concept in maritime logistics sector (Figure 1).

In summary, it can be said that the concept of a common green logistics system is framed by the concept of environmental protection. Green logistics includes not only environmental pollution reduction measures, but also define and form waste disposal logistical processes. As shown by the green logistics concept description, the ideas of green logistics implementation are addressed at the highest level, not only by favourable or unfavourable political decisions, but by requiring maritime logistics companies to ensure not only the targeted supply logistics, but also by implementation of waste disposal logistics processes as well. The economic, social and environmental benefit in the entire country, the region, the global economy should be a result of successful green logistic principles' implementation into traditional logistic system.

2. Identification of polyethylene waste's sources in maritime logistics processes

In most cases any cargo logistic chain is made up of several units, depending on the geographical distance that exists between the sender and the recipient [6]. The greater the distance, the more intermediate links are formed in the same logistical chain, which means that accumulates greater variety of packaging waste, in the number of different elements of the logistic chain [21]. Generally, cargo logistic chain can be read as follows: there are a few key points where the cargo may be repackaged or to be transferred to another vehicle during transportation of goods from the sender to the recipient in logistical chain (figure 2).

Such logistic chain points are freight terminals and logistic distribution centres. If geographical distance between the senders and recipients is not great, there will be only the one link, but as the geographical distance is greater, the number of intermediate links in the cargo logistical chain will be bigger especially in cases where the goods are travelling by combined method and maritime business becomes the main factor of cargo transportation's effectiveness [1]. In that way, the logistical chain forms the multilevel logistic system consisting of n units, and each of all handling processes forms additional handling process which generates a variety of packaging waste: paper, wood, plastic and so on. The waste removal processes construct another logistical direction, which has reversible nature of the logistical

processes and on the base of reverse process it can be stated that the green logistics principles should be implemented [17].

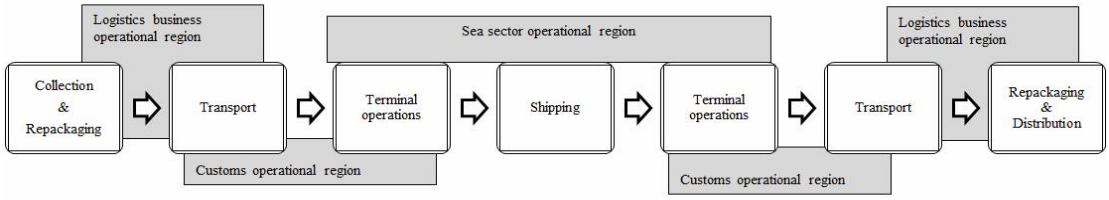


Figure 2. Cargo travel points through basic marine logistical chain [17]

It can be stated that maritime sector can join to logistical chain at any stage of cargo transportation depending on the whole cargo logistical chain, excluding the stage of transportation to the end user, so the principles of waste managing are actual in the same level of importance as they are actual in the land transportation sector. In order for cargo to travel by sea it must be prepared and packed by ISO international standards. As annual transport rates are increasing quantity of packages are growing too. The main points of waste generation in the whole logistic chain of shipping are cargo repacking points: marine logistics warehouses, customs points where some of the cargo are inspected and terminals where cargo is split for more specific distribution or damaged units are repacked (Figure 2). The main concern comes when sender and receiver are the same maritime logistics companies, the units are often packed more than needed in order to secure the cargo more than needed resulting in further more waste generation, this is most notable in big port enterprises (Figure 2).

Analysing of maritime logistics' business' processes and taking into consideration the fact that general logistic system is requirements of the end user for goods delivering and consignment, it can be seen that each logistical processes produces a certain amount of waste. But the waste recovery processes are different in different logistic processes [20]. The main difference is that the supply logistics chain generates plastic waste outside of the assembly stage and wastes can be recycled directly, while packaged goods dominate at the distribution logistics and part of the polyethylene wastes are transmitted in the form of packages to consumers, thereby fall into the second use. The last type of polyethylene waste's transformation dominates in maritime logistics but in larger amounts comparing with end users' sector.

When the polyethylene waste accumulates it becomes the management problem for many maritime logistical companies especially for warehousing services providers. If the plastic waste is disposed using conventional waste containers, port companies will face high costs of waste disposal. It is important to say, that plastic waste requires a lot of space, the containers fill up quickly, and waste services' companies are increasing waste disposal service fees. So the costs of waste disposal are increasing in maritime logistic companies too. Direct secondary usage of polyethylene packaging is practically impossible due to the fact that the package is violated during repackaging and distribution process, resulting company's waste management becomes more difficult as the cargo flow growing [8].

In summary it can be said that polythene waste on the specifics of practice is not directly used to re-occupy enough space in an unprocessed form, is harmful to the environment, and maritime logistics companies form a demand in the waste management modernization, which can be done in various ways through additional investment in innovative technologies and activities.

3. The plastic waste management problems in maritime logistic market

The importance of polyethylene waste management and green logistic conception implementation can be analysed through analysis of waste generation trends in all sectors of waste generation because research found out that it depends on import and export rates. The export's dynamics has two periods in Lithuania. The first period is from recovery of independence until Lithuania joined the Europe Union and second – from the time when Lithuania joined the Europe Union until now. From 1995 to 2004 Baltic States' export dynamic's indicators were positive, although the growing was slow comparing with second period. After 2004 when the Baltic States joined the European Union (EU) dynamic of export became more intensive: the fastest growing of export indicators of all Baltic States was fixed in Lithuania, averagely annual absolute change seeks 1427.6 million EUR (Figure 3).

According to forecasts, export will grow in Lithuania and averagely annual absolute change will be significantly above than Estonia's export – 1.9 times more, Latvia's – 2.1 times more on next year. One of the most important export growing's factors is increased intensity of freight's and logistics' processes,

and the result of these processes is increasing number of packaging and plastic waste's generation points, because import's dynamics has similar trend during all period.

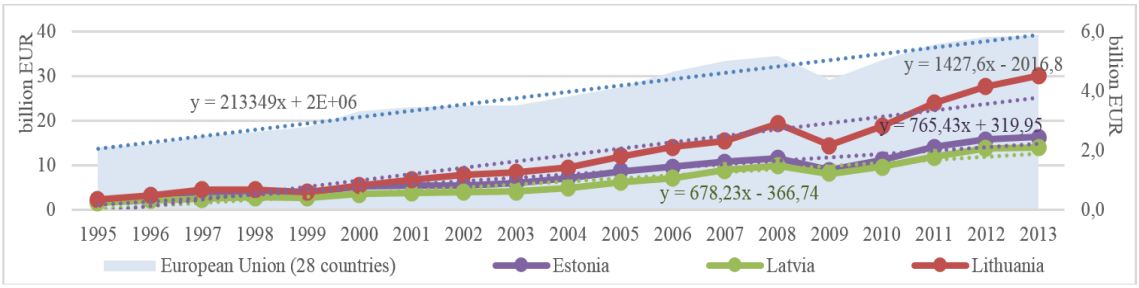
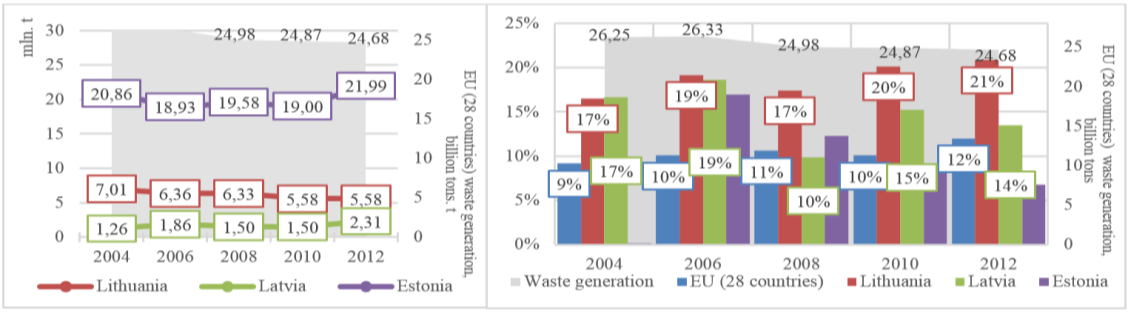


Figure 3. Export dynamics [Eurostat statistical database]

According to statistics, 28 EU countries' index of averagely amount of waste decreased 0.6% from 2008 to 2012 (Figure 4a). Index showed that the annual amount of waste in European Union countries decreased by 5 million tons (Figure 4a) each year. A similar trend prevails in Lithuania where the annual amount of waste decreased by 363.22 thousand tons. Comparing Lithuania with other Baltic countries, the best total waste's generation trend was fixed in Lithuania, because every year in Latvia averagely the amount of waste is increasing by 174.44 thousand tons each year and in Estonia averagely the total amount of waste is increasing by 233.06 thousand tons each year (Figure 4a).

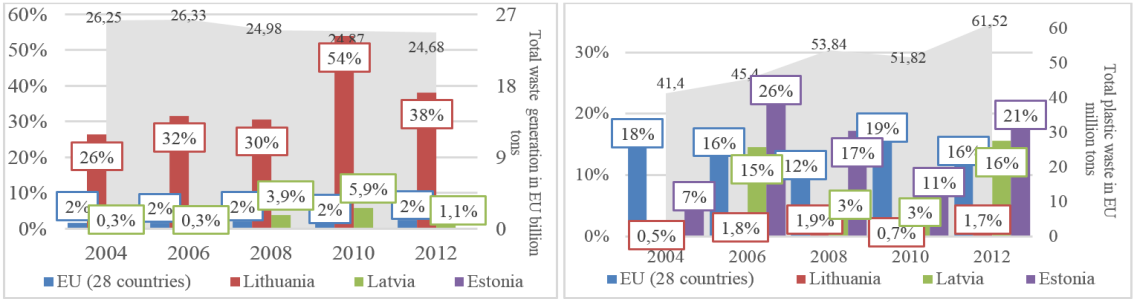
Data analysis showed, that the percentage of recyclable waste in the generated waste's stream averagely increased in European Union by 28 countries index. Within 2004 - 2012 averagely amount of recyclable waste formed 10.4% of the waste stream in the European Union countries. In Lithuania the amount of recyclable waste growth by 4%. That trend shows that Lithuania takes strategic measures for waste's recycling and utilization, however those measures will not be sufficient according to average indicator of the European Union (Figure 4b).



a) b)

Figure 4. Waste generation: a) total waste generation; b) the part of recyclable waste [Eurostat statistical database]

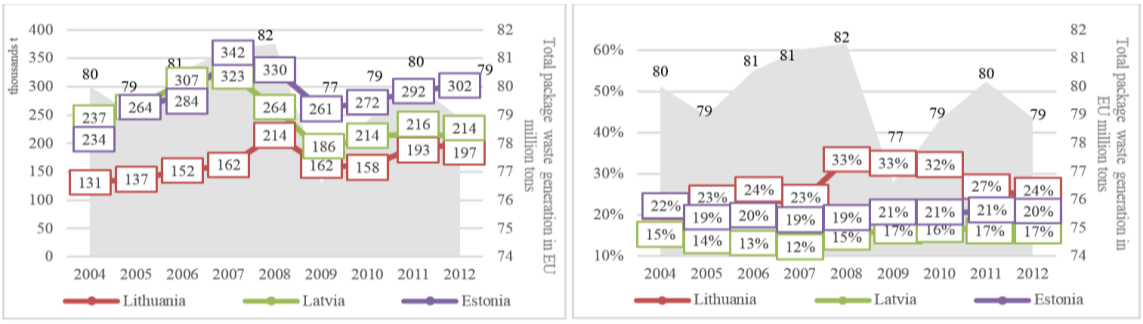
These results gave possibility to argue, that positive dynamics of import and export indicators influenced increasing of recyclable waste ($r=0,75$; $t_r=2,68>t_{stj}=2,36$) and it means that increasing of intensiveness in whole logistic chain where maritime logistics is very important connection influenced the importance of applying of green logistics' principles and make waste management in logistics more effective. And such trend was fixed in all Baltic States, but in Lithuanian market it was stronger, so it is important to analyse the structure of waste and identify amounts of polyethylene waste and its trends.



a) b)

Figure 5. Plastic waste generation: a) total plastic waste; b) treatment of plastic waste [Eurostat statistical database]

Considering properties of plastic, one of them has high level of chemical inertness, that means the plastic and his products can be very successfully used as a secondary raw material. Although plastic is very useful mostly everywhere, its processing level is remain low.



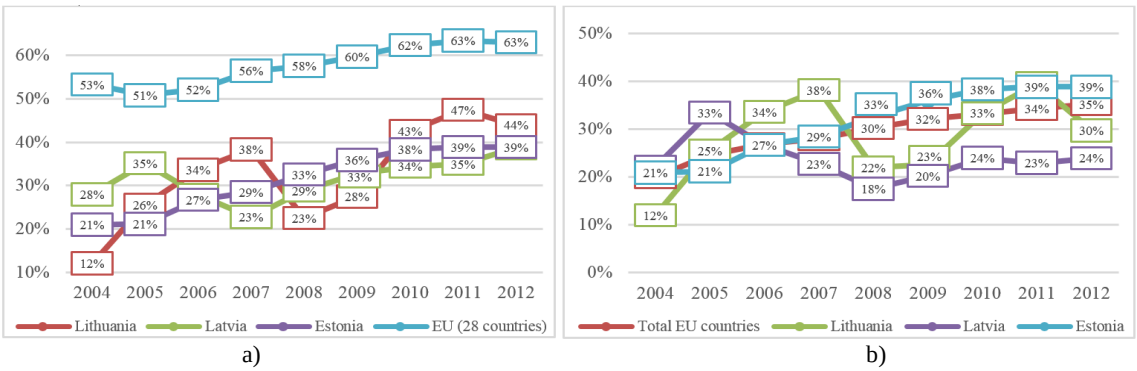
a) b)

Figure 6. Packaging waste generation: a) total; b) plastic packaging waste [Eurostat statistical database]

During the years in Lithuania a large part of the accumulated waste consisted of plastic and plastic product wastes: if in 2004 they formed 26% of the total waste, so at the end of 2012- 38 %, but in 2010 plastic waste peaked at the 54% in the overall waste stream (Figure 5a). Meanwhile the average rate of plastic waste in the European Union countries during all period did not exceed 2 % and although in Baltic countries it was higher comparing to European Union countries rate, but did not exceed 6 % (Figure 5a). Research results established that strong relation exists between increasing of import and export indicators and plastic waste generation and it can be stated that waste management is problematic not only in maritime logistics but in whole logistic chain, because only 1,7% of all recyclable plastic waste was reated in 2012 in Lithuania (Figure 5b).

Increasing cargo import and export flows in Lithuanian logistic market together with increasing of plastic waste influenced that amount of packages increased too. It means, that packages waste increasing in logistical business activities. As statistical indicators show, packaging waste accounts large proportion of waste. According to statistics department data during 2004 – 2012, Latvia's packaging waste will be decreased, over the year it is going to be averagely decreased by 9.3 thousand tons (Figure 6a). The opposite situation observed in Estonia and Lithuania: in Estonia averagely annual increasing by 4.3 thousand tons, in Lithuania - 7.4 thousand tons (Figure 6a). So it can be stated, that packaging waste management is not effective in Lithuania including and maritime logistics area, because waste management in Klaipeda seaport is oriented to solve problems of liquid waste management, but all other waste types, including polyethylene are managed in the simplest way redirecting all cargo flows to dumps and all responsibility are going to port business companies.

Plastic packaging is one of the most currently used types of packaging. Plastic and polyethylene packaging is very popular in maritime logistics processes, so it is important to analyse main plastic waste indicators. From the growth of the total amount of packaging waste also grow the amount of plastic packaging.



a) b)

Figure 7. Packaging plastic waste treatment: a) recovery; b) recycling [Eurostat statistical database]

Comparing Baltic countries with the European Union countries the average plastic packaging waste and dynamics changes are quite similar. However year of 2005 was the start of Lithuanian intensive export flow growth and of course that was one of the main year when generation of plastic packaging waste started to grow (Figure 6a), but the recovering indicators were increased too (Figure 7a). In the

period of 2008 – 2010 when the economy of mostly all countries was constrained by the financial crisis, the plastic packaging average amount was more when 30% in Lithuania. But from the year of 2010 the legal regulation of package waste was developed in Lithuania, so amount plastic packaging waste was reduced to 24% of the total packaging waste stream, but even these conditions didn't stop plastic waste generation and plastic package waste generation was most intensive between Baltic States (Figure 6a). Analysis of indicators for plastic packaging recycling and secondary recovery (Figure 7) showed that in the European Union countries more than 60% of plastic packaging was used as second raw (Figure 7a) and 35% was recycled (Figure 7b), while in Lithuania and other Baltic countries those indicators were low.

Main statistical analysis of waste generation found out that, increasing cargo import and export indicators in Lithuania influenced waste amount increasing, where biggest part of them were polyethylene waste in whole package amount. Therefore, it is important to say, that in Lithuanian biggest part of polyethylene waste were recyclable, but less than 2% of them was treated. And the practice of waste management at Klaipeda seaport showed that waste management policy are oriented to liquid waste management, and all other kinds of waste are redirected to dumps, and it means that all responsibility and implementation of environmental law were going to private ports companies including maritime logistics companies. On the base of made waste sector trends it is important to evaluate the results of experience of one Klaipeda state port's logistic company, which implemented waste management and felt economic benefits of polyethylene waste management system's modernization.

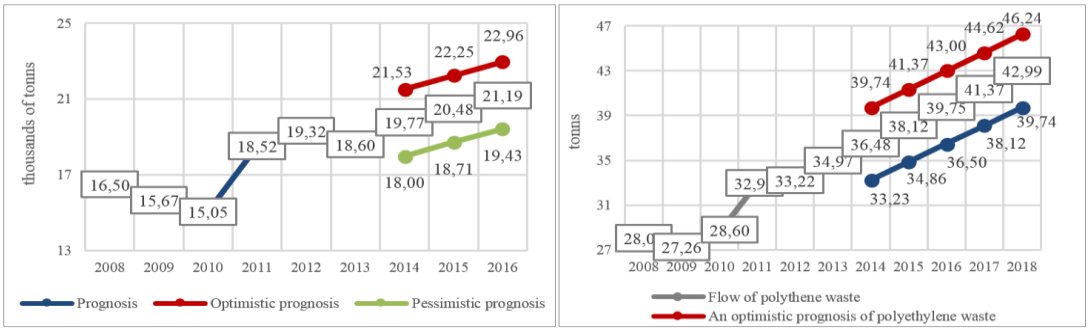
4. Economic benefits' evaluation of polyethylene waste management modernization in the maritime business logistic company

In order to demonstrate the application of the principles of green logistics by modernizing the management of polyethylene waste was analysed a medium-sized maritime business logistics company located in Klaipeda seaport which offering logistics services i.e. sea and land transport, warehousing and distribution, and integrated supply chain management, packaging, repackaging, also company is a member of international logistics organizations, having enough partners and a group peer network. Prognosis of partial and small cargo's flows growing has revealed that one of the companies weakest both financially and economically areas is management of polyethylene waste. In today's industry, one of the most popular packages is polyethylene package, which is used for a large part of cargo packaging. It's difficult to use polyethylene for a second time, unlike wood pallets or cardboard, therefore many logistics companies give polyethylene waste to secondary raw material collection points, what constitutes a sufficiently appreciable cost increase. In addition, non-sweeping of polyethylene packaging creates additional environmental pollution and the associated risk of financial loss, associated with environmental pollution penalties under the existing Lithuanian Republic legislations.

Waste disposal issues in Lithuania is regulated by waste management and packaging laws, legislations that require logistics companies to utilize used packages or transfer them into secondary raw material collection points at their own expense [13]. At the moment a new Lithuanian national strategic waste management plan [16] is being prepared, it is the waste management law, packaging management law, national waste management plan, which is prepared for the 2014-2020 period. It is more focused on the organization of waste management process, the distribution of responsibilities, aiming to promote sorting of waste. Penalties for infraction of these rules are anticipated. Under the current laws of the Lithuanian Republic, the waste can be kept no longer than 6 months, otherwise an authorization of the Ministry of Environment for secondary raw materials storage activities is required, therefore it is common to store waste for no longer than 6 months [12]. Some maritime business logistics companies during this period accumulate so much of the waste mentioned above, that they lack storage facilities for waste accumulation. Then they have to use the company's additional funds and also dispose the waste more frequently. The solution should be the modernization, through which the company's inventory should be updated, and modern facilities (waste compactors) should be implemented.

Maritime logistics company, which is taken as a typical and extra storage services providing company, has a large area, the structure of which is not used effectively, since even as 40% of the territory is vacant and can be used for waste storage installation. The analysis of the dynamics of cargo during 2008-2013 shows that full freight shipment has rapid growth, averagely 516.35 tons per year. As shown by the prognosis, the averagely growth rate will not be very intense and small and partial cargo flows will grow averagely by 3.5 % every year and in 2016 will be 21.19 thousands of tons (Figure 8a). Predicting the growing of small's and partial's cargo flows, together are predicting and polyethylene package's growth in warehouses, even now the company has problems with these package's disposal,

especially in the context of green logistics conception. The largest side of all package's in partial and small cargo's flow processes are consisted of polyethylene, due to their technical characteristics it's probably hard to store them for a long time because polyethylene takes up a lot of space in warehouses. The indicators which were made by statistics show that the average polyethylene wastes growth averagely 5% per year, that's why there is prognosis that plastics wastes growth already in 2016 will almost be 40 tons per year (Figure 8b).



a) b)

Figure 8. Trend line of cargo and polyethylene waste flows in maritime logistics processes: a) linear prognosis of cargo flows; b) linear prognosis of polyethylene wastes.

In conclusion it can be said that the higher polyethylene proportion in part of total cargo flows encourage faster accumulation of plastic wastes in logistics processes, considering to the fact that increasing the number of polyethylene packages. As the green logistics conception's studies show in theoretical part, polyethylene takes 75% of the total packaging market. According these prognoses, modernization of polyethylene waste management in the logistic business company is really needed. The justification of modernization can be performed through a situation analysis.

In analysed maritime logistics company polythene waste is not sorted and it does not have a special indoor (according to environmental requirements) storage of the said waste. Because polyethylene waste is not designed for repeated use, so the company is storing polyethylene waste in containers for. The company has one 5 m^3 container which they use not only for polyethylene, but also for paper (cardboard) waste. In order to avoid polyethylene release to the environment they have been combined with heavier cardboard packaging in the same container. Statistically, the exploitation's of one household waste container for polyethylene waste efficiency seeks 65%. The averagely per month in 2008- 2013 was accumulated over 2570.07 kg of polyethylene waste and in 2013 – 2914 kg. Within a month averagely is filled 1.5 containers, what shows that averagely per year are filled 18 containers, excluding carton packaging. Disposal price of one container in Klaipeda city is 150.69 EUR, so per year for polyethylene waste utilization company pays 2712.41 EUR. Assessing one container's 65% efficiency rate, inefficient waste fees are 949.34 EUR per year.

An alternative situation disposes polyethylene waste to recycler points. But the problem was found, polyethylene waste's delivering costs are related to the additional financial costs for logistic company. In the special sites of the Klaipeda city there is carried out polyethylene collect activities. Klaipeda city has the specific lots where polyethylene waste is collected, however, this requires additional transportation costs. If there is just a small quantity of plastic waste (up to 5000 kg) per month, there is the need for additional transportation costs and special very roomy transportation. The processing companies purchase polyethylene waste and price of the secondary raw materials in Lithuania is 0.14 EUR per 10 kg of polyethylene waste. So per month it would be 40.51 EUR of income. According to the averagely costs of waste transportation to take such a quantity of polyethylene to collection point would cost 63.72 EUR per month**,** excluding the costs of additional work organization and employees' salaries. Such calculations show that monthly costs of polyethylene waste's delivering to processors would be unprofitable and seek -23.21 EUR per month. According to the additional labour costs for staff, the annual increase in the cost of waste treatment would grow to 471.50 EUR. Alternative situation is more favourable, but these costs would increase in consideration that waste would grow averagely by 5% per year.

The world practice of polyethylene waste shows that many countries using special pressing equipment, which can be different sizes and can have different functionality which is selected depending on the quantities of polyethylene waste (Table 1):

- the small machine is perfect for both small cardboard boxes and loose plastic packaging;

- other model of bigger machine is ideal for businesses with medium to large volumes of cardboard and/or plastic packaging waste;
- large machine is the ideal solution for effectively dealing with large volumes of cardboard and/or plastic, particularly when storage space is vital.

Table 1. Waste management modernization SWOT analysis.

Strengths	**Weaknesses**
– Effective plastic waste management in maritime logistics – Transformation principles into actions – Sustainable development – New competencies and skills – Green logistics dispersion into social environment	– Lack of competence for facility maintenance – It is difficult to find external sources of funding – Substantial investment costs – Increasing of new warehouse operational expenses – Long economic payback period (9 years)
Opportunities	**Threats**
– To provide alternative services - polyethylene waste's operations at seaport territory – To have alternative activities – New business niche – Innovative technological process	– Without a government strategy and promotion many port companies might not upgrade waste management – Reduced purchase prices can increase the payback period – Increasing of electricity rates – Not enough appropriate policy decisions

Economic evaluation of waste management advantage is a key indicator that an extruded polyethylene takes five times less space while maintaining the same weight, therefore, it can be said that the annual waste polyethylene waste could occupy five times less space, which means that the average logistics company using 5 m^3 containers could reduce to four containers per year. Next advantage - if the establishment of recyclable waste accumulates more than 5000 kg, the purchasers could collect the said waste from their locations and the holders free of transportation charge.

Complying with the waste storage warehouses law and to the concept of green logistics principles, medium-sized maritime logistics company should to remove waste 2 – 4 times a year, and it shouldn't to lead to significant costs of the company. This medium-sized marine company would save about 2693.47 EUR per year. Baling equipment for moderate production processes is priced at 7282.50 EUR. In accordance with warehouse building services and additional expenses, the company aims to enforce waste management modernization and with the required storage space, the project payback period would be significantly shorter (on average, 3 times). Implemented waste management modernization project in logistic company expects a 9-year payback period (the required warehouse construction, the company's territory infrastructure alignment). However, the 9 years payback period is shorter than that provided by the manufacturer warranty maintenance for optional plastic balling machine (warranty services are ensured for 10 years). So, it can be concluded that for a medium-sized logistics company this plastic waste management modernization would still provide benefits from 10^{th} year.

The Table 1 provides SWOT analysis of renewed waste management system: these are the strength, opportunities, weaknesses and threats. It can be argued that one of the strengths of this modernization project is implementation period. According to the modernization project's implementation scopes on average implementation takes about 18 months in the medium-sized logistic company. This term is convenient in the sense that in most cases small project's funding period is not very high and amounts to an average of 1-2 years.

However, such a polyethylene waste management modernization project in any logistical company will have indirect benefits to the public because of significant direct environmental pollution risk reduction that can be seen not only in reducing the risk of contamination with polyethylene, but the carbon dioxide indicators. If during the year 18 pieces of 5 m^3 bins must be removed and it needs to run transport 18 times, on average, in both directions the distance seeks 35 km, so the total annual distance seeks 630 km per year. After upgrading the same mode of transport should to drive only 140 km, which is almost 4 times less comparing with today's situation. Considering that one truck's emission into the atmosphere is more than 250 g of carbon dioxide, it could be argued that at least 122 500 g carbon dioxide will not emit to the atmosphere from one truck. Green logistic concept would be achieved with the double indirect effect: not only more efficient plastic waste reduction systems and increasing its reuse, but at the same time to achieve the carbon dioxide in the atmosphere in urban areas reduction. But all of these impacts will not be able to implement without a government strategy and promotion program in the sector of waste management (Table 1), many port companies might not upgrade waste management, because modernization project is based on additional investments and payback period's efficiency depends on not local factors such as electricity rates, reduced purchase prices etc.

Conclusions

1) Green logistics defines formed logistic processes resulting from the logistical disposal processes. Green logistic implementation ideas are addressed by making policy decisions; requiring maritime logistic companies to ensure and to be not only the targeted to supply logistic, but also the implementation of disposal logistics processes. In this way, green logistic objectives are to achieve economic, social and environmental benefits of inclusive for the whole country and the region and the global economy, preserving the environment.

2) The main amount of polythene waste is generated in maritime logistical repacking points: maritime logistics warehouses, customs points where some of the cargo are inspected and terminals where cargo is split for more specific distribution or damaged units are repacked. Polythene waste on the specifics of practice is not directly used repeatedly in maritime logistic company and it holds enough space in unprocessed form, is harmful to the environment. As a result, most of maritime logistics companies initialize the need to modernize waste management, which can be carried out as part of investment to innovative modernization projects.

3) Plastic waste increasing each year in whole waste flows and in Lithuania polyethylene waste is problem: only 1.7 % of plastic waste was treated in Lithuania. Other problem is the increasing packaging waste in maritime logistic sector. About 44% of plastic waste is recovered and 35% of plastic wastes are recycled in Lithuania, but these indicators are low comparing them with averagely indicators of EU countries. That situation shows that more than 21% of plastic packaging wastes are going to dump and on the level of legislation government has to decrease that indicator. On the base of statistical data Klaipeda seaport cargo flows are more than 30% of all cargo turnover in all transport systems of Lithuania, ant these results show that effective waste management in port companies are very important from whole logistic chain viewpoint. In accordance to growing tendencies of maritime logistics market especially to growing containerized cargo it is reliable to forecast that plastic waste will increase in the maritime logistic market, so it is important to modernize waste management systems in maritime logistic sector, because supply and recovering logistic is the main element of green logistic system.

4) Implementation of polyethylene waste management project for the modernization in foreign maritime logistics company 9-year payback period would be achieved, including the current incurred inefficient polyethylene disposal costs, environmental risks fines and so on. Economic payback period of assessment has taken into account only in the polyethylene packaging growth, but on the increase in employees' competencies, assessment of new forms of work organization emergence the benefits would be visible when the maritime logistics company implemented the project of modernization and acquired an additional opportunity to develop alternative activities, implementing the basic principles of green logistics in logistical processes. Results of the project have a significant dependence on such factors as changes in electricity prices, polyethylene buying price changes, changes of legislation of environment protection framework and etc. In addition, such project could help the company meet the requirements of the international ISO not only in the environment but also the quality of management sector: to promote the principles of sustainable development and be a socially responsible company. To the implementation of green logistics concepts not only in reducing the risk of contamination of the environment polythene waste, but the implementation of projects of this kind can lead to significant CO2 reductions in urbanized areas.

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EVALUATION OF TECHNOLOGICAL IMPACT FOR CHANGES OF GRAIN HANDLING TURNOVER IN KLAIPEDA SEAPORT

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Abstract
The main bulk cargo handling seaports on East Baltic are Klaipeda, Riga, Tallinn, Ventspils, Liepaja and St. Petersburg. All of these ports compete for grain handling volumes, because a big part of handled grain are grains grown in Lithuania's, Latvia's or Estonia's agriculture farms and less part of handled grain are transit grain freight with grains grown in East Europe and Asian countries. The idea of this paper is to evaluate how improvement of port infrastructure and superstructure can influence the changes in grain freight flows.
Keywords: *grain handling, railways and maritime transport interaction, technological impact.*

Introduction

Each grain handling port must have special terminals for bulk cargo loading and storage to accommodate bulk handling, transshipment and storage facilities. Port infrastructure parameters like quay length, berthing depth alongside quays and port channel depth are essential for bulk turnover volumes. On the other hand, to enable large bulk carriers loading with grain, bulk terminals must be capable to promptly and efficiently receive bulk grains therefore a well-developed road transport infrastructure is a must to each such terminal to enable efficient accommodation of sufficient amount of grains with minimum delays and ensuring the safety and qualitative properties of the commodity [4]. As seen from the Lithuanian and Latvian transit cargo flows, the greater part of them is transported by rail. However in terms of grain exports, a crucial role is played by the interaction of rail and maritime transport systems whose operational efficiency directly influences the dynamics of grain handling at ports; and its technological impact assessment is based on a common terminal equipment and transport systems throughput interaction in handling dry cargo vessels at ports.

Subject of research: the grain handling changes.

The aim: to identify the ports' technological change impacts on grain handling trends in Liepaja and Klaipeda ports.

Objectives of the study:

– to describe grain logistic chain specificity in view of cost minimization;
– to describe the grain handling trends on the East Baltic;
– to assess the impact of new technological solutions on grain handling trends in KSS.

The research method: article uses scientific and research literature review method which allows investigating the grain logistic chain's identities formed by ports infrastructural and superstructural factors that affect grain handling. SWOT and PEST analysis is used to define grain handling internal and external environment and the impact of major grain handling, to identify the main technological factors. Statistical methods are used for data processing, and the results further used in grain handling trends research.

Logistic chain of grain transportation

Grain handling logistic chain begins with the farms (holdings). The harvested grain undergo processing with various agricultural machinery and the processed grain is delivered to grain storage, barns and agricultural warehouses, where they are kept for a very short period of time in order to retain brand and nutritional properties (Figure 1). The farm is the starting point to grain transport logistic chain – and is involved in logistical chain as long as the grain reaches the storage location and is sold [13]. Later on the transport chain is activated by other factors: the buyer, the developer/collector and other, whose

whereabouts, along with grain cargo destination in today's global market is not strictly defined and limited: practically grain cargo destination point can be anywhere in the world [8].

In the next stage, the theoretical model presents four alternative directions of grain logistics chains, which are conveyed by land transport alone [14]:

– grains transported to the mill, where they are partially processed and then continue the way within logistical chain already as processed grain product, usually transported in bags;

– grains transported to a special elevator (grain towers);

– grains transported to inland waterways terminals;

– grains travel through special land based transshipment terminals (Figure 1).

It can be noted that logistical chain requires special terminals (hubs) in those places where the transport systems are interchanged. Hub is a complex functional element to an overall transport system for interfacing different types of transport [9]. Transport hub operates using common technology, and there exists a complex of technical measures applied to guarantee this technology. Despite their diversity, hubs can be divided into two types [2]:

– multimodal hub which involves two or more transport modes with the interaction of these schemes (in addition to pipeline transport):

– maritime transport and rail transport (road transport, river transport);

– rail and road transport (river transport);

– single mode transport hub (sea, rail, river, road) which interacts with private internal transport units.

For cargo handling and transportation terminals normally use: vehicles, loaders and loading equipment, storage facilities and equipment, cargo transporters and packaging containers, and all these tools help to quickly and safely transfer bulk grains from one vehicle to another [1]. It is notable that most complex technologies and equipment are used in maritime and railway terminals.

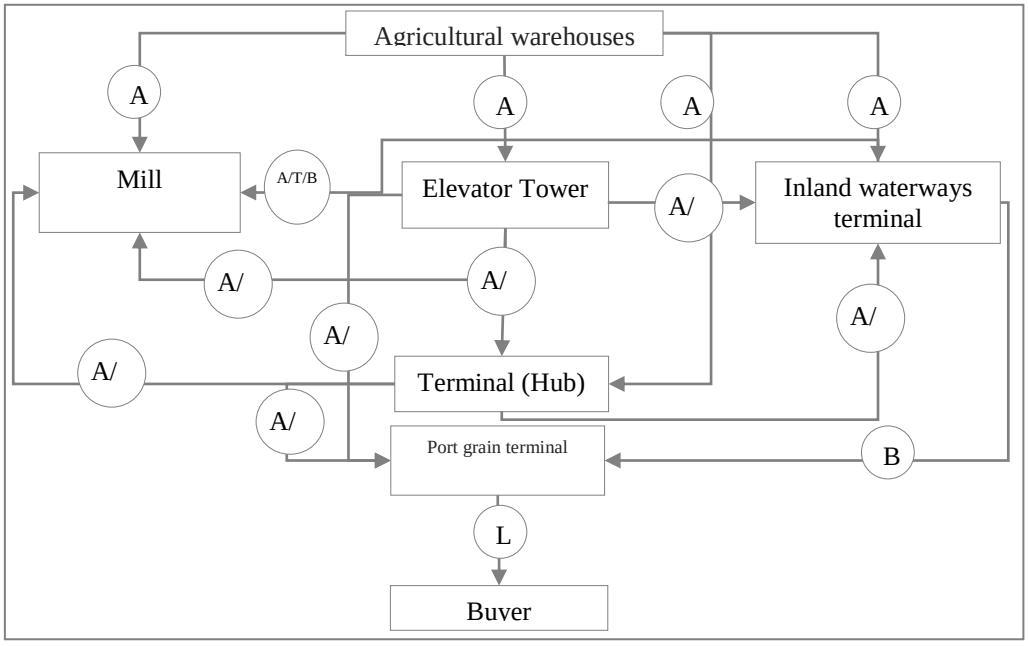


Figure 1. Grain exports logistic chain (Designation: A vehicles; T train, B barge, L ships) [8]

After the grains are deposited in grain elevators or silo towers, onward transportation is carried out by road vehicles or railway. These vehicles are used for grain transportation to [8]:

– the mill, whereby grain completes the logistical chain as unprocessed product;

– inland cargo terminals;

– transshipment terminals within land transport systems (e.g. to nearest railway station with grain towers);

– port bulk terminals (Figure 1).

Once the grain on the secondary level of logistic chain gets delivered to inland terminals, they are further transported to the port by means of water transport – using mainly inland barges.

Moving on to the next level of the supply chain, the land transport cargo terminals, grain may be transported to the mill from there by road or rail, whereby completing participation in the logistical chain as grains. Land transportation can also be employed for transits to the inland terminal, or likewise by land transport may reach port bulk terminals (Figure 1) and their grain storage facilities [7].

Significant impact toward grain handling characteristics may be related to physical properties of grain, such as density, moisture, dustability etc., as grains refer as bulk cargo type, therefore on their physical properties depend the overall bulk grain handling, storage and transportation technology and efficiency [12]. In addition, taking into account the logistical chain of grain we need to highlight the fact that most small countries with developed agriculture are incapable to consume total grain harvested in the country due to much too low demand, so a large part of cereals is exported [14]. When it comes to the exports of grain we must emphasize the importance of the port within grain logistic chain.

Port terminals are using gantries with grapples for grain handling and transshipment. If the terminals have no specialized bulk warehouses, ambient sensitive goods are loaded directly: ex wagon to ship, ex ship to wagon. Whereas ambient resistant and insensitive goods may be stored in temporary warehouses, storage sites [9]. Large-scale grain storage facilities feature as very high-impact factor in the handling of grain, allowing to retain all the qualitative characteristics of grains [13].

The analysis of different transport systems, terminals and their interaction within grain logistical chain, depending on the grain transportation chain complexity it is necessary to evaluate the different transport systems, hubs and transportation costs [6]. Given the fact that the study analyses surplus grain yield exports, it is clear that port terminals will be used for grain loading from land vehicles to dry-cargo bulker vessels [11]. Given the fact that the eastern Baltic countries provide a fairly well-developed road infrastructure, the existing railway network is convenient in terms of routes due to overall coverage throughout the entire republic [3]. Another reason is that railway system offers technologically well-equipped cargo terminals and grain towers, where railway wagons can be loaded with grain fast enough and not too complicated, whereas road transport terminals are technologically rather intended for another type of cargo [10]. That is why in grain handling and supply logistics chain there is obvious port bulk terminal and rail system interface.

Evaluation of grain handling characteristics of the East Baltic

The analysis of the eastern Baltic seaports grain handling characteristics reveals a tendency that highest grain handling concentration is dominated by Liepaja and Klaipeda ports. After Liepaja and Klaipeda seaports, the third-largest grain handling is Ventspils seaport, featuring more or less stable handling dynamics. Joint Tallinn Grain port shows annually decreasing bulk grains handling levels. Yet as of 2009 St. Petersburg seaport grain handling rates grown rapidly, and by end of 2012, compared with 2009, cereals handling change rated 222%, which indicates that in 2012 St. Petersburg seaport handled more than 2 times more grain crops, and by general output indicators almost reached Ventspils port handling rates, although back in 2008 St. Petersburg seaport handled almost twice (1.98) less bulk grains than Ventspils Port (Figure 2).

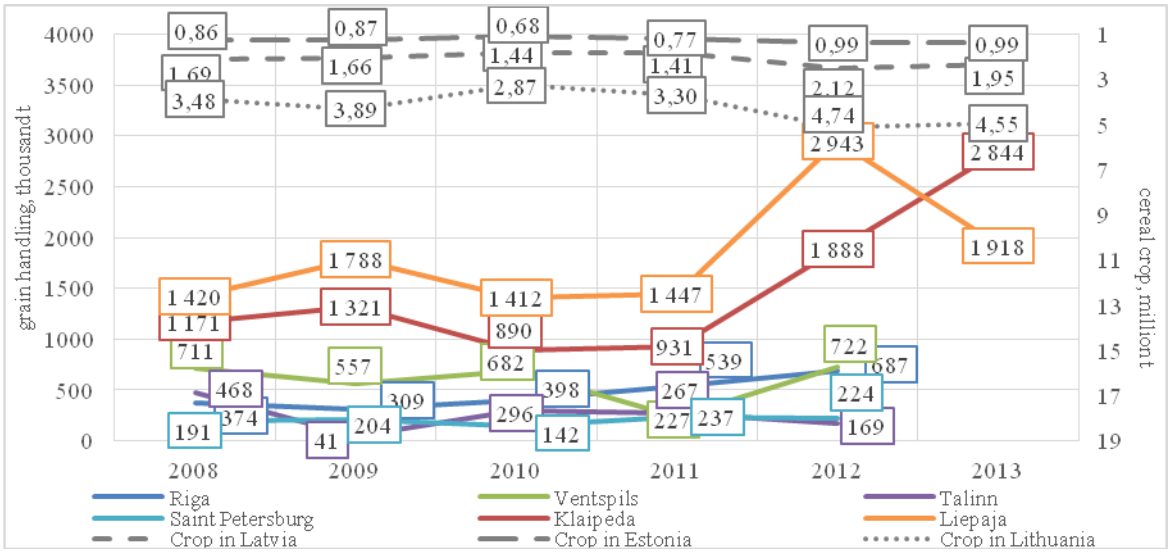


Figure 2. Grain handling and grain crops in Eastern Baltic Seaports 2008-2012

Grain handling accounts for largest part of Liepaja port handling turnover, mounting to almost 40 percent [5]. This suggests port of Liepaja is one of the most specialized grain ports on the eastern Baltic. Although the port of Klaipeda stands out as port majoring in fertilizer handling, petroleum products and ro-ro cargo, investments were made to grant adequate material resources for grain handling; since the grain terminal output capacity accounts for ca up to 17 percent of total port handling turnover, and considering that agrobulk commodities in Lithuania are a positive trend, for these reasons stevedoring companies over recent five-year term launched to orientate toward bulk cereals handling (Figure 2). It should be noted that Lithuanian grain yield in comparison with Latvia and Estonia is the highest, and taking into account that about 70% of the crop grown in Lithuania is exported, it can be seen that the crop grown in Lithuania has not been exported to full extent through Klaipeda port, thus considerable part of Lithuanian agro bulk exports is handled via port of Liepaja (Figure 2).

In order to demonstrate the port grain handling capacity growth tendencies, along with changes in grain handling terms and conditions, linear trend charts as of 2012 were presented (Fig. 3a) when capacity was not to increase, and as of 2013 (Figure 3b) when Klaipeda Seaport grain handling turnover mounted owing to renewal and modernization of one of the major grain bulk terminals' production plant. As shown in Klaipeda and Liepaja ports' grain handling dynamics charts, the trend is positive and intensely progressing (Figure 3a and 3b).

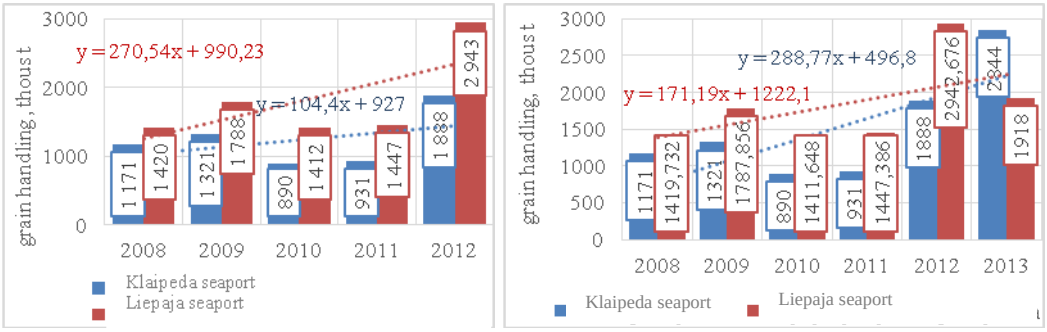


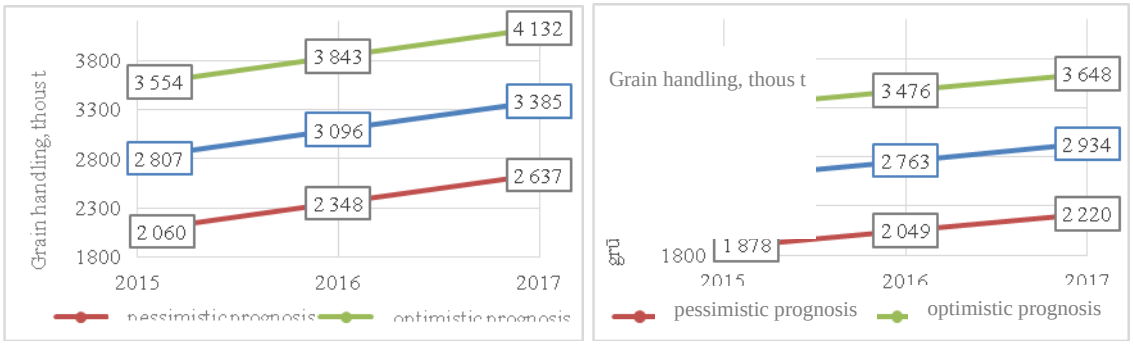
Figure 3. Grain handling dynamics in Liepaja and Klaipeda Seaports: a) period of 2008-2012; b) period of 2008-2013
Source: Klaipeda and Liepaja Seaports' annual activity reports

The competitive analysis of the KSS and Liepaja sea ports reveals that by 2012 intensive growth was observed in the port of Liepaja, with annual grain handling increase rated averagely of 270.54 thousand tons by end 2012, which accounted for 15% of mean annual turnover (Figure 3a). Klaipeda Seaport grain handling dynamics also showed positive, yet by 2012 somewhat less intense than that of Liepaja; and the annual turnover change averaged 104.4 thousand tons, to account for 8 percent of the average annual output (Figure 3a). However, since 2013 a renewed and upgraded major agricultural bulk terminal of Klaipeda port allows to monitor different situation (Figure 3b), and signs of considerable growth trends become visible in both ports. KSS created adequate conditions to promote higher quantities of exports, thus average annual growth more than doubled (Figure 3b). Respectively, turnover of agro bulks decreased significantly in port of Liepaja (Figure 3b): average annual growth dropped by almost 100 thousand tons per year.

Predicting changes in grain handling in 2015-2017, after 2012 modernization of one of the main agricultural terminals, it can be observed that by year 2017 Klaipeda State Seaport agro bulk handling rates will come closer to the maximum throughput of grain in the port, whereas the figures projected in the port of Liepaja to be slightly higher than 2015 forecast of Klaipeda State Seaport handling rates (Figure 4).

The set grain handling dynamics trend of two leading ports in grain handling on the eastern Baltic is determined by the technological progress factor (terminal modernization, implementation of additional functionality in respect of agricultural producers etc.), which is the incentive component of maritime ports competitiveness. However there are certain parallel risks such as sufficient grain yield, adequate port terminal grain handling capacity, but also to other transport systems, actually, railway throughput in particular, which indicate the grain handling dynamics trends to be quite strictly determined by certain complex factors set consisting of infrastructural and suprastructural port changes, adjustments to the grain

exports demand on the global market. And another major change implies the balance between railway capacity and agricultural products handling port terminal.

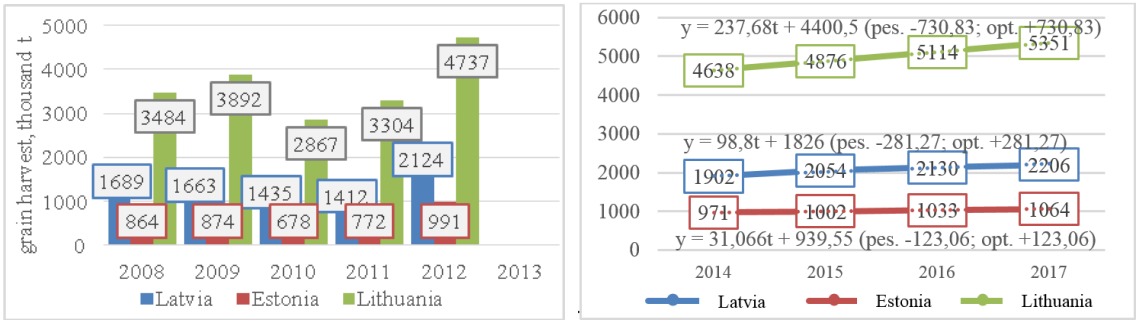


a) b)

Figure 4. Grain handling projections in 2014-2016 a) Port of Klaipėda (σ=747,35); b) Port of Liepaja, thousands t (σ=713,50)

Identification of factors affecting the grain handling at seaports

One of the reasons of agricultural products handling growth in Eastern Baltic ports is intensive farming which produce high-yield crops (Figure 5b), which is one of the external environmental factors attributed to *natural factors*. For example, according to statistics, in Lithuania average absolute change of annual crop amounted to 191.62 thousand tons and is the highest compared with Latvia and Estonia, however not the whole of the crops yield is exported by farmers and developers thru Klaipeda State Seaport, whose bulk turnover in 2012 was 4.5 million t, not only due to lack of technological grain handling capacity of the terminal, but also due to the fact that Lithuanian farmers do not have elevators, so try to stock the grain in own barns or warehouses, or trying to sell the stock at the moment, whilst majority of the developers (collectors) try to export large part of total crops (ca 70%). The upgrade of one of the largest agricultural terminals of Klaipeda port enabled the farmers to store grain and even dry out in terminal's warehouses, which allowed farmers to conveniently drop off the grain at the collection point and cut the costs related to grain storage and drying yet retaining the quality properties of the crops. The projections indicate that already in 2017, KSS should be handling not only grain yield grown in Lithuania (Figure 4a and Figure 5b), but also crop grown on farms of neighboring countries, emphasizing here the importance of railways and their routes and rates acceptability for neighboring farmers in grain transportation.



a) b)

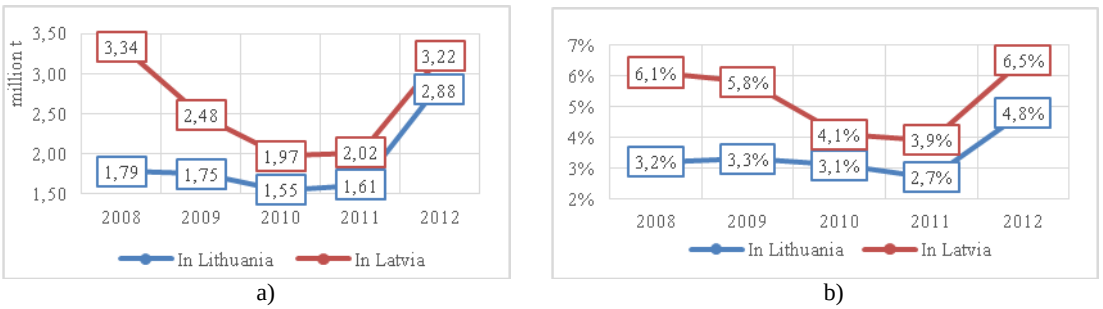
Figure 5. Grain harvest index dynamics in Lithuania, Latvia and Estonia for 2008-2012: a) empirical indicators; b) predictive indicators

Source: Data of Lithuanian Department of Statistics

The analysis of changes in the grain harvest and their processing prior to start of export procedures in Lithuania, Latvia and Estonia, showed that by end of 2012, at harvesting season in full swing, farmers would encounter problems to rent cars or rental price was higher, so farmers and developers had to transport grain by vehicles which automatically elevated transportation cost. In addition, the Klaipeda State Seaport had not sufficient storage and drying facilities suitable for grain storage, drying, sufficient

to receive and accommodate the yield to be exported in situ during the process of buying: e.g. in 2012 grain yield was over 4 million t, while the storage facilities at the port could house less than 1 million t of grain storage. Therefore, due to favorable geographical location and rail infrastructure, majority of farmers directed their grain exports flow through the port of Liepaja, which clearly shows in Liepaja and Klaipeda seaports grain handling comparison. Therefore just as another *economic factor* can be identified rail service tariffs dynamics as since 2012 *AB Lithuanian Railways* changed their pricing of services, what lead to decreased grain freight by rail in Lithuania. Comparing Lithuanian grain transportation rates with Latvian grain rail freight rates, it can be noted that Latvia maintains higher intensity of grain flows by rail (Figure 6).

With regard to railway system analysis, we can say that Lithuania featuring more rail freight what suggests that rail transport is better developed (Figure 6a). The analysis of agricultural rail freight flows (Fig. 6b) indicates intensive rail transported agricultural flow in the Lithuanian territory. However, rail transported agricultural products, including grain, in Lithuania directly depend on exports or transit cargoes ($r=0,879$; $k_r=3,19>t_{stj}=3,18$), but the strongest dependency relates to grain shipments within the country ($r=0,931$; $k_r=4,45>t_{stj}=3,18$), this confirms the hypothesis that a large part of Lithuania's grain yields grown for exports are transported by rail to seaports. Meanwhile, Latvian railways freight dynamics and the interface correlation suggests that Latvia transported by rail a larger share of exported grain ($r=0,952$; $k_r=5,56>t_{stj}=3,18$), which confirms the previously made assumption that a part of Lithuania's crop is handled at the port of Liepaja.

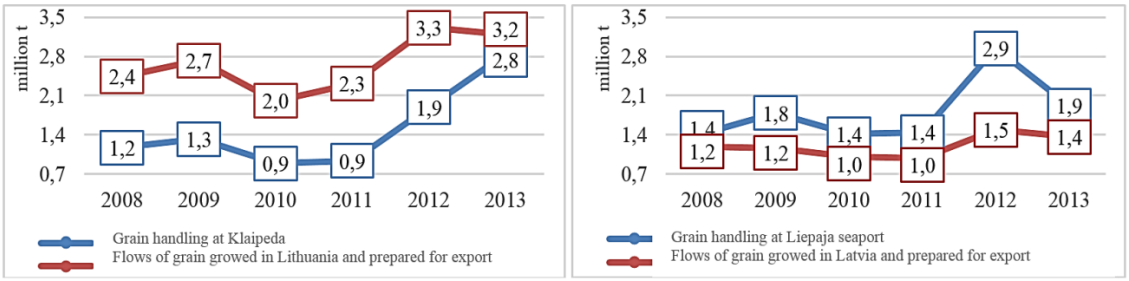


a) b)

Figure 6. Dynamics of agricultural rail freight in Lithuania and Latvia in 2008-2012: a) turnover; b) a share in the total flow of rail freight

Source: Latvian and Lithuanian Departments of Statistics

The study based on information of statistical databases considered the maximum grain exports limit up to 70 percent of the country's total grain yield. Such a limit was required in the research in order to establish a link between the grain handling capacity of the terminal and the farmers' grains grown for export. The study findings (Figure 7) verify the hypothesis as formulated: in the period of 2008-2011 the difference between total grain production, exports and the amount of grain handled in Klaipeda was significant, which indicates that part of Lithuania-grown grain exports was handled in the port of Liepaja (Figure 7).

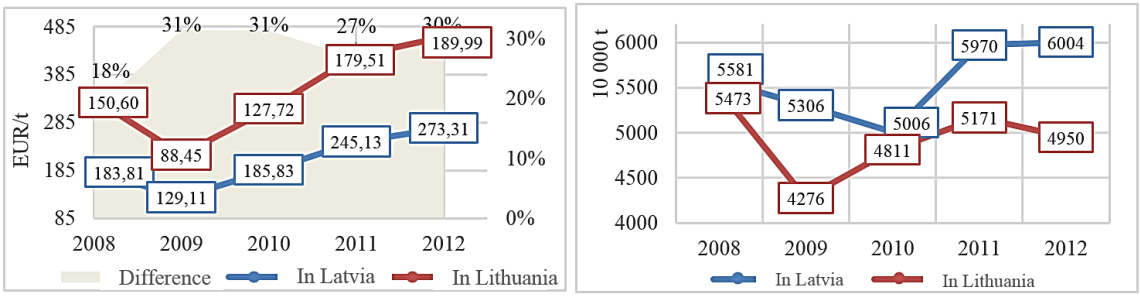


a) b)

Figure 7. Dynamics of difference in quantities of country's total crop and exports vs cereals handled at the port for export during 2008-2013: a) in Klaipeda State Seaport; b) the port of Liepaja.

Another external environment factor attributed to *economic factors* are grain purchase prices which prompt agricultural producers to look for a most efficient grain supply chain. As shown by grain purchase price dynamics in Latvia and Lithuania, grains through the whole period of 2008-2012 were purchased at higher rates in Latvia and the average grain purchase difference in the countries amounted to an average

of 27.4 percent (Figure 8a): in 2008, the price difference was 18 percent (Latvia € 183.8 / t, Lithuania € 150.6 / t.); in 2009 purchase price was affected by the global crisis and prices dropped remarkably; after 2010 monitored Latvian grain purchase price is growing steadily and significantly ahead of Lithuanian farmers bids.



a) b)

Figure 8. Dynamics of the economic factors to impact grain handling: grain purchase price difference in Lithuania and Latvia (a) rail freight flow dynamics in Latvia and Lithuania

Source: Latvian and Lithuanian Departments of Statistics

The stable prices helped to maintain stable handling index in the port of Liepaja and attract larger quantities of agricultural commodities. As shown by the correlation analysis, grain purchase prices in the countries affect grain handling and transshipment to/from wagons, yet quite insignificantly. Lithuania shows more intensive reliance on grain purchase prices ($r=0,728$; $k_r=3,21>t_{stj}=3,18$) than Latvia, where grain purchase prices are higher ($r=0,686$; $k_r=3,19>t_{stj}=3,18$), but the dependence ranges at ca 53 percent only, so we can assume that grain flow formation are impacted by the economic and technological factors, such as transport services prices, transport system deployment etc.

Based on the results of the study, external conditions of agro bulk handling in seaports can be viewed through political, social, economic and technological factors. Predominant globalization worldwide can be attributed as one of the most important political factors affecting the efficient operation of seaport cargo terminals. Increasing amounts of freight flows allow for the development of ports, technological modernization of terminals, enhanced infrastructure capacity. Therefore very important is geographical position of a port and transport corridors that pass through the port, along with transport systems integration to port infrastructure (Table 1). Of course, equally important is the nation's foreign policy, developing partnerships, existing contractual obligations, which promote establishing strong networks and form the basis for networking foreign policy.

Another factor to affect seaport cargo terminals is a growing competition for attraction of the same type freight to the port. Presumably competition can be a strong positive factor for the seaports to impact the development of ports, because under intense competition in the market a seaport's technological progress may have a strong impact on the formation of freight traffic, what means that owing to technological progress cargo flows can be attracted to a port (Table 1).

Table 1. PEST analysis of grain handling in Lithuanian and Latvian maritime sectors

Political	Social
Predominant globalization process worldwide Increasing competition between the eastern Baltic ports International policy Customs and tax policy changes	Social situation of agricultural companies and private farmers. Social responsibility and sustainable development measures of agricultural products handling terminal (port) Sustainable development and servicing of related industries
Economical	**Technological**
Agricultural sector development program and the subsidy strategy Grain purchase prices High transportation tariffs of land transport Port charges and tariffs	Adequate land transport infrastructure in the country Railway and branch lines (marshalling yards) throughput at the port Grain storage and drying equipment. Bulk handling equipment capacity (terminal throughput)

As regards the economic factors, one of the greatest influencing factors, in addition to developing rail and road transport systems and the country's integration into international transport corridor, but also very important factors are rail and car rates. Seaport is just a transport hub, which hosts stevedoring, yet the largest share of agricultural products here are shipped by rail or road means (Table 1). Besides, these economic factors are associated with technological factors and the port's technological progress in servicing of agricultural freight flows. As an example is Klaipeda State Seaport, which introduced a

modernized agro bulk handling terminal, equipped with grain drying and storage technology elements, the handling processes that caused remarkable increase in grain handling at Klaipeda State Seaport (Table 1). Equally important is the agricultural sector development program and the subsidy strategy, grain purchase price and other economic factors (Table 1).

In summary, grain cargo flows in Latvia and Lithuania and their port handling indexes and trends, the following key factors can be identified that have effect on grain handling: firstly, it is the grain harvest in the country and the exported part of crop; secondly, it is grain handling terminal throughput and functionality; thirdly, it is technological interface of port and rail infrastructure throughput, which is an essential factor in grain exports.

An external analysis has shown that there are certain internal and external factors that may precondition the ports' competitive situation in the region, so it is important to distinguish and compare such factors. Since the two largest grain handling maritime ports in the eastern Baltic are located in one region and have very similar navigation conditions, the analysis of the ports' strengths, weaknesses, threats and opportunities (see Table 2) has found a similar set of factors that are essential in order to demonstrate the advantages and weaknesses of the seaports in terms of competitiveness that were arranged in parallel in the table. The internal study of seaports identified the main seaport strengths determining factors, such as Liepaja and Klaipeda seaport geographical location, allowing ports' operability all year round (Table 2). Another important factor characteristic of the compared seaports are technologically advanced, specialized grain handling terminals and constantly increased rail lines permeability in them. The analysis of Liepaja and Klaipeda seaport strengths established fundamental differences that affect the grain flow distribution: main advantage of Klaipeda seaport is that most of the grain exports are grown in Lithuania's agricultural sector. However the port of Liepaja as its main advantage has a well-developed specialization of grain handling and sufficient number of specially designed grain terminals. Another considerable competitive advantage of Klaipeda port can Klaipeda seaport capability to accommodate post-Panamax vessels with greater draft. This makes it sufficient ground for the formation of grain flows and also promotes the technological progress of Klaipeda port grain handling terminals, and the rail lines at the port. Both compared seaports' weaknesses are the same, because of very similar political and economic situation, transport systems deployment in Latvia and Lithuania, therefore as key weakness of the two seaports in terms of grain exports can be mentioned underdeveloped inland waterway transport, which could well contribute to further minimization of grain transportation to ports costs and encourage rail infrastructure managers to adopt a more flexible pricing (Table 2).

Table 2. SWOT analysis of grain handling in Klaipeda and Liepaja seaports

<table>
<tr><td colspan="2">Strengths</td><td colspan="2">Weaknesses</td></tr>
<tr><td>Klaipeda</td><td>Liepaja</td><td>Klaipeda</td><td>Liepaja</td></tr>
<tr><td colspan="2">Good geographical position for grain freight flows
The ice-free port
Freight can be shipped to the port by rail or road transport</td><td></td><td>Available less depth alongside berths than in port of Klaipeda</td></tr>
<tr><td>Can accommodate Post Panamax vessels, with draft of 12,5 m</td><td>Specialized grain terminals</td><td colspan="2">Underdeveloped inland transport that would enable transportation of part of the grain flow by inland waterways</td></tr>
<tr><td colspan="2">Opportunities</td><td colspan="2">Threats</td></tr>
<tr><td>Klaipeda</td><td>Liepaja</td><td>Klaipeda</td><td>Liepaja</td></tr>
<tr><td colspan="2" rowspan="2">A large market in the East preconditions increase in transit grain flows in the direction of the East and the West;
There is a possibility to expand the storage capacity
Possibility to increase the freight flows, by means of modernizing the terminals, enhancing their functionality within grain logistics chain in view of agricultural focus</td><td colspan="2">Unbalanced development of international transport corridors and individual modes of transport
Shifting of freight to other ports
Change of the country's economic and political relations with other states</td></tr>
<tr><td>Disagreement over the freight rates between Klaipeda port companies and the railway operator and carrier, AB Lithuanian Railways</td><td></td></tr>
</table>

The study found that main possibilities for Liepaja and Klaipeda seaport to promote the flow of grain freight are preconditioned by factors such as the modernization of grain handling terminals, storage sites and increasing storage space, which allows create technologically attractive environment for the agricultural sector and attract grain transit flows. However in the context of opportunities, there are highlighted main threats to the compared seaports (Table 2), which derive from the unbalanced development of different modes of transport on Lithuanian and Latvian international highways, the

countries' economic and political situation in the regional agricultural sector, and changes in relations with other states that have an impact on grain freight flow formation.

Conclusions

Research of the grain transportation logistics chain has found that Lithuanian market is dominated by rail and sea transport interaction, especially noticeable in grain crop exports. This interface is linked to the fact that transportation of grain as a bulk type requires special handling equipment installed in railway freight stations (grain towers) and bulk terminals, allowing the grain handling without depositing in warehouses in order to retain all of their qualitative and nutritional properties, a developed rail network to minimize grain freight costs, and elimination of additional terminals. The specifics of grain logistics chain facilitates rail and sea transport interaction, which can be analyzed for assessment of rail and port terminals operability in grain handling and output capacity, loading terminals technological progress indicators, as well as evaluating the external and internal environmental factors that have impact on this interaction.

The identification of key factors to cause changes in grain handling at seaports, found the national and international transport axes' sustainable development, the country's agricultural economic development measures, subsidy measures plan to have an immense impact. Slightly less potent factors include grain yield, purchase price, but amongst the biggest impact factors are advanced terminal technology and functionality in regard to the agricultural sector. Comparing the different ports' indicators has established that the port of Liepaja features majority of agricultural products, including grain freight flows, to be transported by rail, but Lithuania shows higher quantities of agricultural freight that are transported by rail, while major flows of domestic and transit cargo transported in Lithuania include grain freight. Meanwhile, Latvia has higher exports transported by rail, including the Lithuanian grain crop. Grain yield of Lithuania has a direct, statistically strong impact on Klaipeda Seaport grain handling indexes, whereas different grain purchase prices in Lithuania and Latvia, grain yield in neighboring countries has no significant effect on grain export flows changes, it is thus concluded that the grain flow changes in bulk grain terminal depend on the transport system service prices and technological capability to handle the amount of traffic..

Modernization of one of grain terminals in Klaipeda State Seaport hugely increased grain handling output thus forming adequate reason for changes in terms of seaports' competitiveness on the eastern Baltic: grain handling in Liepaja seaport stabilized and lost intense growth dynamics, meantime situation of Klaipeda port has changed to the contrary, with grain handling to intensify in terms of positive dynamics. A reason for this can be the increased grain handling terminals and rail lines capacities in the port, and port's functional adaptation to meet the farmer's needs: purchase of grain, drying and storage, which suggests that technological progress of grain handling ports strongly positively correlates to the increased grain handling indices of the seaport.

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